**Department of Transport and Regional Development**

**Bureau of Air Safety Investigation**

INVESTIGATION REPORT
9300484

# Mikoyan & Gurevich MiG 15UTI, VH-LSN Canberra, ACT 13 March 1993

BASI
Bureau of Air Safety Investigation

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## FOREWORD

Having received additional factual information at the coronial inquest (Canberra, July 1995) into the deaths of the pilot and passenger of VH-LSN, and following representation by interested parties, the Bureau of Air Safety Investigation re-opened the investigation of this accident. As a result, the original investigation report (published July 1994) is withdrawn and is superseded by this present report.

## CONTENTS

## GLOSSARY OF TERMS AND ABBREVIATIONS

| | |
|---|---|
| AGL | above ground level |
| AMSL | above mean sea level |
| ATC | air traffic control |
| ATIS | Automatic Terminal Information Service |
| ATPL | Airline Transport Pilot Licence |
| AWI | Airworthiness Instructions |
| BPC | barometric pressure controller |
| CAA | Civil Aviation Authority |
| CAO | Civil Aviation Orders |
| CAR | Civil Aviation Regulations |
| cm | centimetres |
| EST | Eastern Standard Time |
| FOI | Flying Operations Instructions |
| HP | high pressure |
| IAS | indicated airspeed |
| ICAO | International Civil Aviation Organisation |
| j.p.t. | jet pipe temperature |
| NGV | nozzle guide vane(s) |
| NSW | New South Wales |
| psi | pounds per square inch |
| RPM | revolutions per minute |
| RFFS | rescue fire fighting service |
| SEM | Scanning Electron Microscope |
| SN | Serial Number |
| TSI | time since last inspection |
| TTIS | total time in service |
| °C | degrees Celsius |
| Blade creep | Plastic deformation of a blade under prolonged load, greatly accelerated by high temperatures. |
| QNH | The altimeter sub-scale setting in hectopascals which when set on the altimeter, provides the pilot a reference in height as related to mean sea level. |

All times are Eastern Standard Time (Co-ordinated Universal Time plus 10 hours) unless specifically stated.

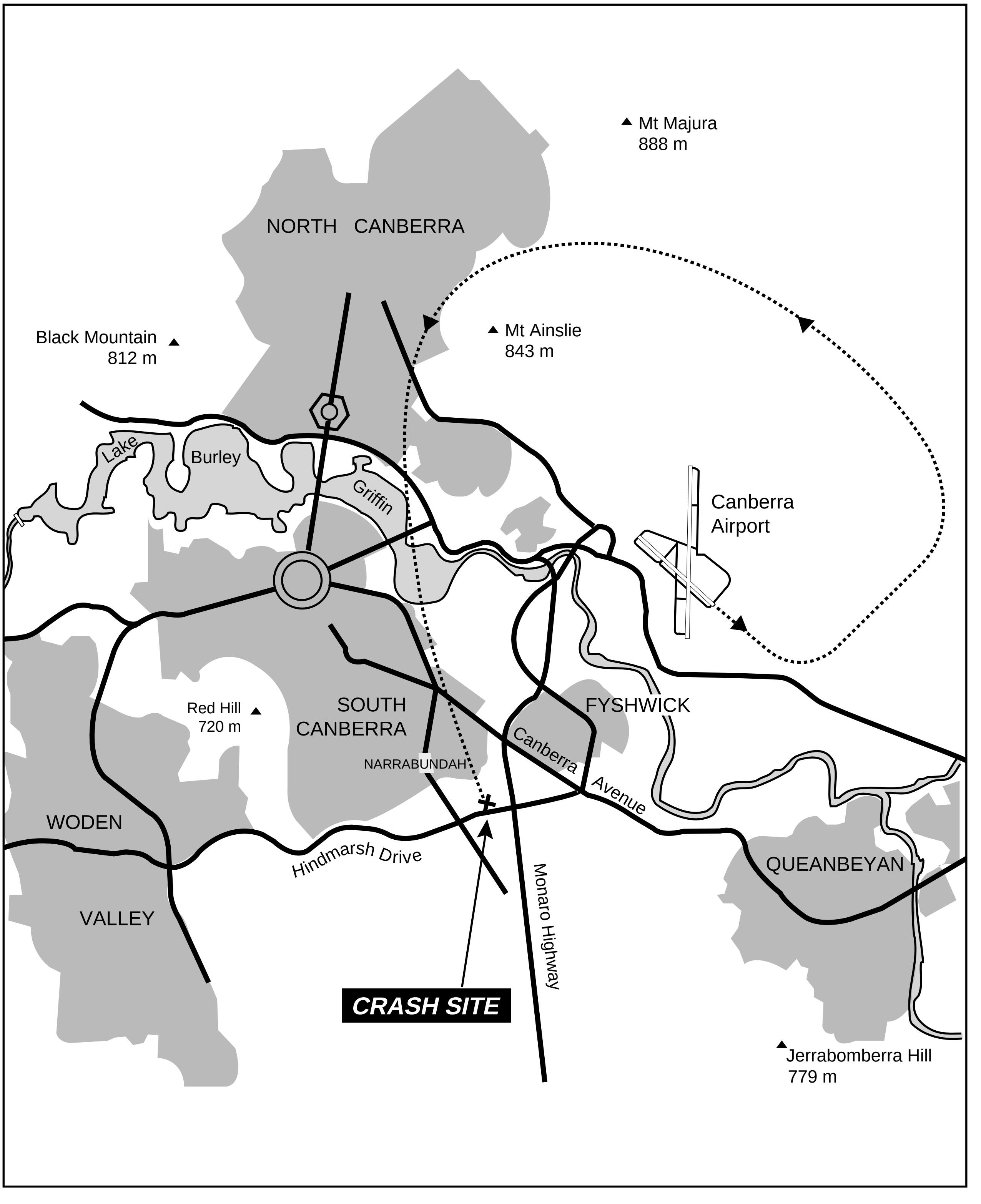


**Figure 1**. Approximate flight path and impact location of VH-LSN

**SYNOPSIS**

The MiG 15UTI, VH-LSN, took off from runway 12 at Canberra Airport with the pilot and one passenger on board. After becoming airborne, the aircraft entered a climbing left turn and levelled at about 1,200 ft above ground level. The pilot advised the tower controller that he was having a minor technical problem and requested a landing. After a short discussion, the aircraft was cleared to land on runway 35. When the aircraft was about 4 km from the threshold of runway 35, it was seen to enter a steep nose-down attitude. The aircraft subsequently impacted the ground and the pilot and passenger were killed.

The Bureau of Air Safety Investigation's analysis determined that an in-flight fire, fuelled by an unknown source of combustible material, melted and burned the rudder and elevator control tubes located in the fuselage aft of frame 21. As a result of the damage to these items, control of the aircraft was lost. The area where the fire occurred was not monitored by over-heat or fire detection devices. The pilot was probably not aware of the fire and was therefore unable to take emergency action.


# 1. FACTUAL INFORMATION

## 1.1 History of the flight

On 13 March 1993, the MiG 15UTI VH-LSN with the pilot and one passenger on board took off from Canberra Airport for a city sight-seeing tour and a flight to one of the local training areas. Prior to receiving taxi clearance, the pilot was given ATIS information and was cleared for a standard city route at 4,000 ft. The aircraft then taxied for runway 12 at 1605:30 EST.

After receiving a take-off clearance, the aircraft was observed to enter runway 12 and commence the take-off roll. No abnormalities were observed by eye witnesses. After becoming airborne, the aircraft levelled briefly at about 15 ft AGL and the landing gear was retracted. The aircraft then entered a left climbing turn and levelled again at about 1,200 ft AGL.

At 1611:25 the pilot reported that he was downwind for runway 12 and requested a clearance to land due to a minor unserviceability. The pilot then reported that he was at 3,000 ft AMSL and requested minimum delay. He was advised of a B737 on left base for runway 35 and was asked to report sighting the aircraft. At 1612:25 the pilot stated that he would take runway 12 and when he was advised by the aerodrome controller that he would be number two, he stated that he had the B737 in sight and that he would land on runway 35. At 1613:55 the pilot requested a wind check. No further transmissions from the pilot were recorded. During the latter part of the flight the aircraft was in a shallow descent and had descended to about 500 ft AGL when it was observed to enter a nose-down attitude of about 30°.

A diagram depicting the approximate flight path and impact location of VH-LSN is at figure 1.

Shortly afterwards a fire and smoke plume were observed by tower personnel and the crash alarm was activated. Two units of the Canberra Airport rescue fire fighting service were dispatched to the scene.

Impact occurred about 2 minutes and 30 seconds after the pilot advised that he had a problem.

Two witnesses who had observed the aircraft during its downwind leg, saw what they believed were fuel vapours or smoke trailing behind the aircraft prior to the nose dropping. Both also stated that they saw flames coming from the vicinity of the aircraft speed brakes. An amateur video tape recording taken of the aircraft during the accident flight also shows a short smoke trail behind the aircraft about 20 seconds before the nose-down pitch occurred.

The crash site was located 300 m west and 200 m north of the intersection of the Monaro Highway and Hindmarsh Drive about 4 km south-west of Canberra Airport. The pilot and passenger were fatally injured and the aircraft was destroyed by impact, explosion and fire.

The accident occurred at 1614 EST during the hours of daylight at latitude 35°22' south and longitude 149°09' east.

## 1.2 Injuries to persons

| Injuries | Fatal | Serious | Minor | None | Total |
|---|---|---|---|---|---|
| Crew | 1 | 0 | 0 | 0 | 1 |
| Passengers | 1 | 0 | 0 | 0 | 1 |
| Total | 2 | 0 | 0 | 0 | 2 |

## 1.3 Damage to aircraft

The aircraft was destroyed.

## 1.4 Other damage

A paddock fence and several trees were damaged by impact and fire.

## 1.5 Personnel information

| | |
|---|---|
| Licence category | Aeroplane |
| Licence type | ATPL 1st Class |
| Total flying time | 7,027 hours |
| Total on type | 16 hours |
| Total last 90 days | 141 hours |
| Total on type last 90 days | 0.5 hours |
| Total last 24 hours | 0.5 hours |

The pilot had attained 4,289 hours of experience on a variety of military single engine jet aircraft. Of these, about 1,095 hours were flown in de Havilland Vampire aircraft which had an engine fuel system very similar to that of the MiG 15UTI.

On the day prior to the accident, the pilot had completed a standby period as second officer for an airline company in Sydney. He was not recalled to duty during that time and had not flown since 3 March 1993.

On the night prior to the accident the pilot had about eight hours sleep at his Canberra residence. He awoke in the early morning and drove to Nowra NSW where he carried out a pre-flight check of the aircraft and then flew the aircraft to Canberra. The flight duration was approximately 25 minutes. He then drove to his home, returning to the airport in the early afternoon with the expectation of carrying out a passenger flight at about 1500 hours. The scheduled passenger did not arrive for the flight. As the pilot was preparing to return home, an acquaintance of the pilot requested a flight in the MiG. The passenger had been introduced to the aircraft owner by the pilot's wife. Prior to the flight departure several witnesses saw the pilot apparently briefing the passenger in the cockpit.

Except for the flight from Nowra, the pilot's most recent flight in a MiG 15UTI was on 27 November 1992, i.e. 105 days prior to the day of the accident.

### 1.5.1 Pilot MiG 15UTI experience

The pilot undertook a MiG technical training course which was provided by the organisation which conducted the maintenance on the aircraft. He also discussed various aspects of the MiG 15 operation and flight characteristics with a current and qualified MiG 15 pilot. Prior to his first flight, the pilot conducted several ground runs and taxi tests.

On 14 March 1992 the pilot flew his first flight on the MiG 15UTI solo while positioning the aircraft from Bankstown NSW to Richmond. He then conducted one test flight alone and several later flights with maintenance personnel and the aircraft owner. On 21 April 1992, a CAA flying operations inspector wrote to the pilot and instructed him to have a certification of aircraft endorsement, approval and rating signed by a chief flying instructor. This was done on the 28 April 1992. The person (delegate) signing the document was not qualified on, nor had he flown, the MiG 15UTI. The delegate's signature certifies in part that

> the person named on the Certificate of Aircraft Endorsement has satisfactorily completed the requirements of the relevant Regulations or Orders, has been tested & found competent & is now approved to exercise the authority permitted by the following pilot qualification.

That endorsement was provided on the strength that the pilot had conducted the test flights. The pilot also received CAA authority to conduct endorsement training. During the following year, the pilot flew ten hours on the aircraft.

The pilot had flown with another pilot and had given that pilot his MiG endorsement. They had discussed emergency procedures and had practised the procedure for engine failure immediately after takeoff.

## 1.6 Aircraft information

### 1.6.1 Aircraft

| | |
|---|---|
| Manufacturer | Mikoyan & Gurevich |
| Model | MiG 15UTI |
| Serial number | 1A06015 |
| Registration | VH-LSN |
| Year of manufacture | 1955 |
| Certificate of airworthiness | Not issued |
| Certificate of registration | 13 March 1992 |
| Permit to fly | Valid to 2 April 1993 |
| Maintenance release number | 07482—valid to 2 April 1993 |
| Total airframe hours | 1,599 |
| Fuel | Jet A1 |
| Fuel auto-ignition temperature | 225–245°C |

The aircraft was flown by the Polish Air Force prior to being imported to Australia. When the aircraft was purchased in 1989, aircraft logbooks were not provided to the current owner. However, some basic information concerning airframe and major component histories was made available. That information could not be checked against original logbook entries.

The aircraft maximum take-off weight as stated in the aircraft weight and balance documentation submitted to the CAA was 5,400 kg. The centre of gravity limits were 22.2% to 29.9% of the mean aerodynamic chord. The aircraft was refuelled at Nowra prior to the ferry flight to Canberra on the day of the accident. Estimated fuel usage from Nowra to Canberra was 1,060 L. Witnesses stated that only the two wing- mounted drop tanks were refuelled at Canberra prior to the occurrence flight. Working with each occupant weighing 77 kg, and a basic aircraft weight of 3,747 kg, the MTOW for this aircraft on the occurrence flight was calculated to be 5,076 kg. Accordingly, aircraft weight and centre of gravity were not considered factors in the accident.

### 1.6.2 Engine

The engine was manufactured by V. Ya. Klimov and is a close copy of the Rolls-Royce Nene engine. Most of the data used during the investigation was based on the Nene engine documentation as comprehensive facts regarding the Klimov VK-1/RD-45 engine were not available. The Klimov VK-1/RD-45 engine has some design variations from the Nene engine and the investigation team was required to interpret how those variations would affect the aircraft operational and performance characteristics.

| | |
|---|---|
| Manufacturer | Klimov |
| Model | VK-1/RD-45 |
| Serial number | 52644 |
| Total time in service | 1,184 hours |
| Time since last inspection | 216 hours |
| Last inspection type | Unknown |
| Date of last inspection | 1986 |

## 1.7 Meteorological information

When the pilot was preparing for departure, the current ATIS was relayed to the pilot by the surface movement controller. The information passed to the pilot was: runway 35 in use, wind 030°M at 8 kts, QNH 1021, temperature 22°C, cloud 3 octas at 4,000 ft.

There was no restriction to visibility and no reported turbulence or other significant weather phenomenon at the time of the occurrence.

## 1.8 Aids to navigation

Not relevant.

## 1.9 Communications

During the taxi, takeoff and the duration of the flight, satisfactory communications were maintained between the appropriate ATC agencies and the pilot of VH-LSN.

## 1.10 Aerodrome information

Canberra Airport is at an elevation of 1,888 ft AMSL and is operated jointly by the Department of Defence (Air Force Office) and the Federal Airports Corporation. Two runways are available for operations: runway 12/30 which is 1,679 m long and 45 m wide, and runway 17/35 which is 2,683 m long and 45 m wide.

## 1.11 Flight recorders

Neither a flight data recorder nor a cockpit voice recorder was fitted in the aircraft. Neither was required by regulations.

## 1.12 Wreckage and impact information

The aircraft crash site (figure 2) was located 300 m west and 200 m north of the intersection of the Monaro Highway and Hindmarsh Drive in the suburb of Narrabundah, Canberra. Physical evidence at the site indicated that the aircraft impacted the ground in a near wings-level, 25° nose-down attitude. When the aircraft struck the ground, immediate breakup and disintegration of the structure occurred. Wreckage as shown in figure 2 was scattered over an area about 200 m long in the direction of flight and 100 m wide. The extent of the wreckage and impact area were consistent with the aircraft impacting the ground at a speed in excess of 150 kts.

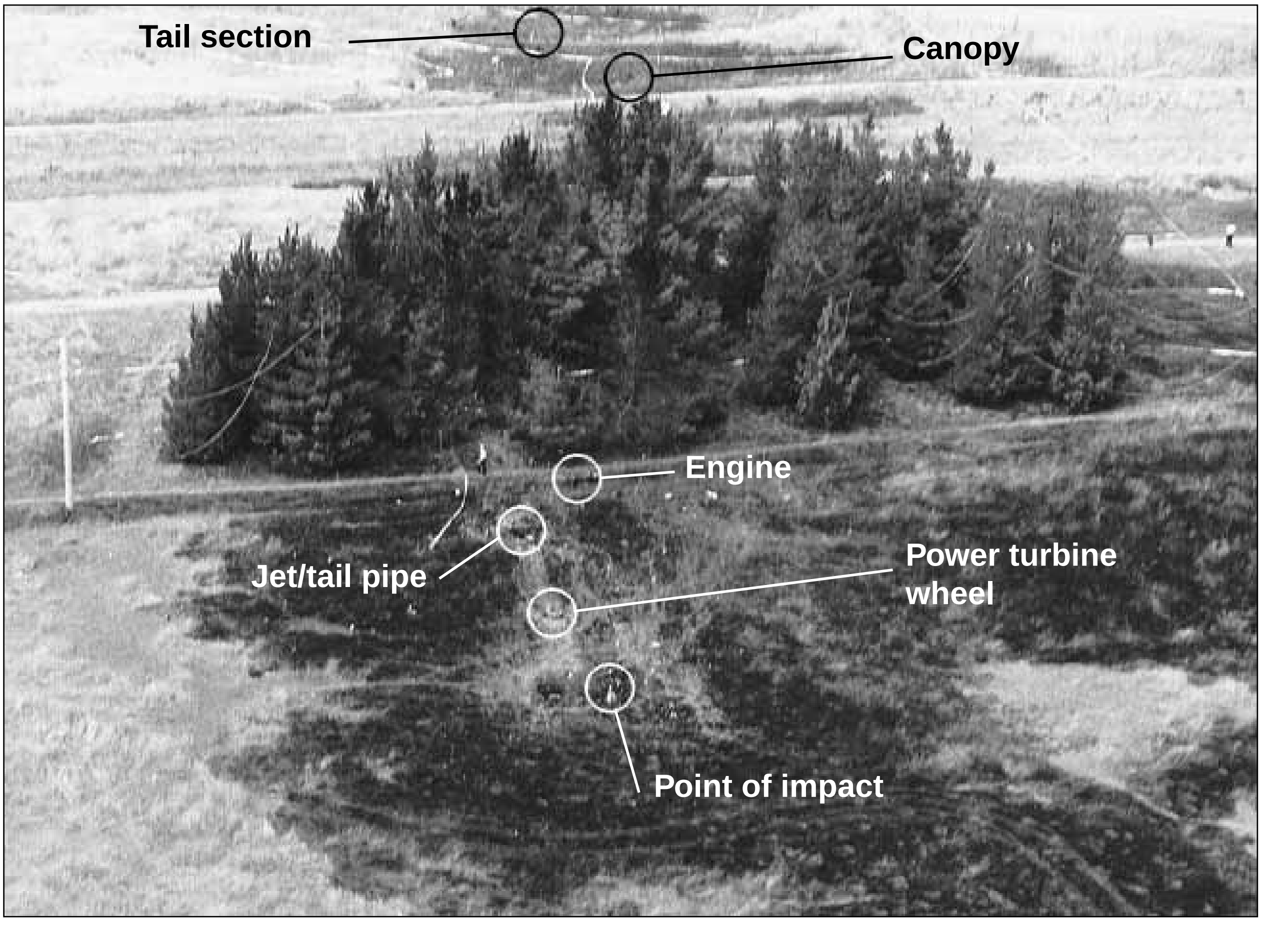


**Figure 2**. Impact point and major wreckage items of VH-LSN.

Examination of the wreckage showed that the landing gear was down, and the wing flaps and speed brakes were retracted at impact. An evaluation of the elevator trim jack shaft position showed that the elevator trim was set at a slight tab-up/elevator-down position. Smoke deposits on the tab and elevator confirmed this position. All flight control surfaces were accounted for, as were the majority of the flight control mechanical actuating systems and push-pull tubes.

### 1.12.1 Engine examination

The engine rotating elements had separated at impact and overload fractures were evident in all examined surfaces. Some of the compressor impeller vanes were damaged and the damage was assessed as impact related. Partial circumferential marks on the inside of the compressor/diffuser case suggest some impact rotation but no sign of in-service tip rubbing was evident. There was no evidence of foreign object damage to, or fatigue failure of, any of the vanes. All bearings had impact-related damage consisting mainly of displaced rollers and bent retaining cages. There was no evidence of service damage to the thrust faces.

The turbine wheel (figure 3) was liberated by failure of the drive shaft coupling attachment bolts and departed the airframe vertically with sufficient energy to cut a slot through the turbine case and jet-pipe entry. It came to rest approximately 50 m from the initial impact point along the direction of flight. All the turbine blades remained in the turbine wheel and there was no evidence of blade dislodgment.

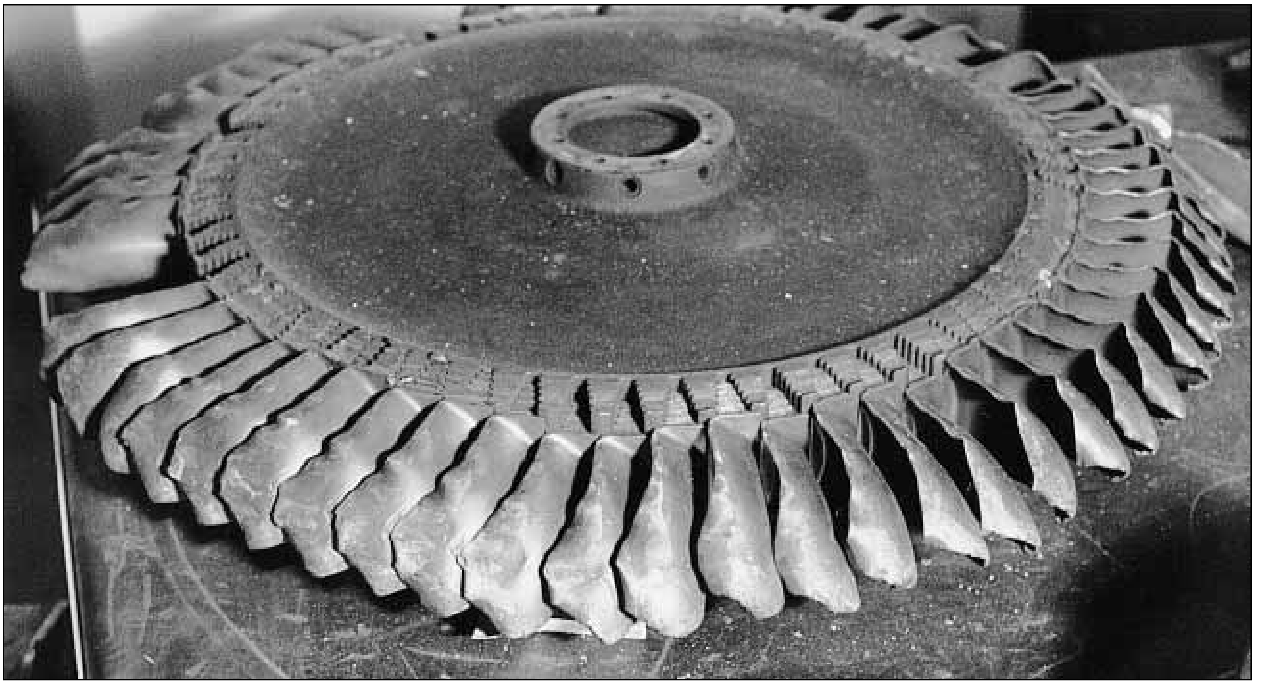

**Figure 3**. Engine turbine wheel showing damage to all blades.
Note: Several blades had been removed for examination.

The turbine nozzle guide vanes were visually examined. Some of the vanes exhibited trailing edge thermal distortion, erosion and/or cracking. However, as the damage was not consistent across all the vanes, it was assessed as being the effects of normal engine operations on older vanes.

The inner circumference of the turbine case showed signs of turbine blade rub. Microscopic examination of a section of the case revealed build-up of material on the case to a depth of 1 mm. Spectrographic analysis of the material found it to be an alloy, nimonic 80, and of the same composition as the blade material. Further examination of the deposited material showed that, although smearing had occurred, a large proportion of it exhibited the same crystalline properties as the turbine blade tips.

The turbine blades were subjected to detailed metallurgical examination. This examination concluded that the sample turbine blades had failed through creep rupture. Failure resulted in the loss of 25–30 mm from each tip of the blades examined.

Creep is a phenomenon dependent upon strain, temperature and time. The metallurgical examination conducted found no evidence to suggest the blades experienced excessive temperature. Also, no evidence existed to suggest that the engine was subjected to excessive RPM (i.e. strain). Hence, the primary reason for the failure of the turbine blades examined was the length of their time in service.

The nine combustion cans were examined and found to be free of defects.

The jet-pipe, tail-pipe and exhaust nozzle were recovered. Except for remnants of the jet pipe attached to the turbine shroud, the jet-pipe, tail-pipe and exhaust nozzle had been compression-buckled to about one-half their normal length at impact. There were no pre-existing hot gas-path leaks found and all bolts and fasteners remained secure.

### 1.12.2 Barometric pressure controller

The barometric pressure controller was recovered and examined externally and internally. No abnormalities were found.

### 1.12.3 Throttle valve

The throttle valve was recovered from a ground fire area. Examination showed that the main fuel inlet and outlet fittings had failed in overload and the body of the valve sustained external impact damage. Prior to dismantling of the valve a radiograph was conducted. The internal spool was found in the idle position.

### 1.12.4 Engine lower high pressure fuel pump

The lower of the two engine fuel pumps was radiographed and disassembled. The pump appeared to have been serviceable and without signs of abnormal operation prior to impact.

### 1.12.5 Engine upper high pressure fuel pump

The upper fuel pump was examined externally, radiographed and then dismantled. The radiograph examination revealed that the servo piston attachment nut was only engaging a few threads of the servo piston rod. This condition could allow the upper fuel pump to malfunction, overfuelling the engine. However, due to the fail-safe design of the fuel system, any malfunction is accommodated through the integral fuel pressure relief mechanisms within the barometric pressure control unit and the over-speed governors.

### 1.12.6 Number three rear fuel tank

The number three fuel tank (figure 4) comprised two separate half tanks connected with ‘TEE’ plumbing and had a fuel capacity of 166 L. The tanks were manufactured from 2024/3000-series aluminium. A portion of the rear section of the right number three fuel tank was recovered. All right tank fracture surfaces were considered to be cold fractures. The forward section of the left number three tank was also recovered. Hot internal impact fractures were evident and it was estimated that at impact the tank metal temperature was at about 450°C. Some rivet heads in the tank structure showed signs of hot fracture but it could not be determined if the fractures occurred before or after impact.

The number three filler cap was found locked in the filler neck and there was heavy sooting around the filler neck. The rubber cap seal was in good condition and the cap fitted the neck correctly.

### 1.12.7 Number three tank boost pump

The number three tank boost pump (figure 4) was located in a low intensity ground fire area.

The inlet pipe was fractured and the fracture was indicative of overload failure. There were soot deposits in the inlet pipe tube indicative of flash-over from ground fire. Only minor burning was evident on the outer surface of the pump. The outlet was intact, with a section of hose attached. Some burning near the outlet was evident. The area around the main gasket showed signs of external fire.

### 1.12.8 Rudder and elevator control push-pull tubes

The complete run of rudder control tubes and elevator control tube was not recovered. Some of the tube pieces may have been destroyed in the areas of intense ground fire. The elevator tube which runs through the aft cockpit in the area of frame 13 was located and the fracture surfaces showed signs of overload failure. The tube was found outside the ground fire area and was not burnt. The forward rudder tube remained in frame 13 and was burnt. Portions of the airframe skin from both sides of frame 13 were located in the ground fire area.

A mounting bracket with bell crank arms and the control tube ends was located clear of the ground fire area. This was identified as the rudder control. It had been positioned in the aircraft immediately aft of frame 21. The ends of the tubes were burnt. Molten splatter identified as 2024 aluminium was found in an axial direction inside the tube.

Both tubes in the fin base were fractured and remained with the fin when it separated from the aircraft at impact. SEM analysis of the elevator and rudder tube microstructures at the fin base showed that melting and resolidifying had occurred along the grain boundaries with attendant loss of bond strength within the metal structures. The elevator trim screw jack setting was measured and it is estimated that the trim was set for a speed of about 280 kts which is consistent with the speed the aircraft would reach shortly after the pilot completed his climbing turn.

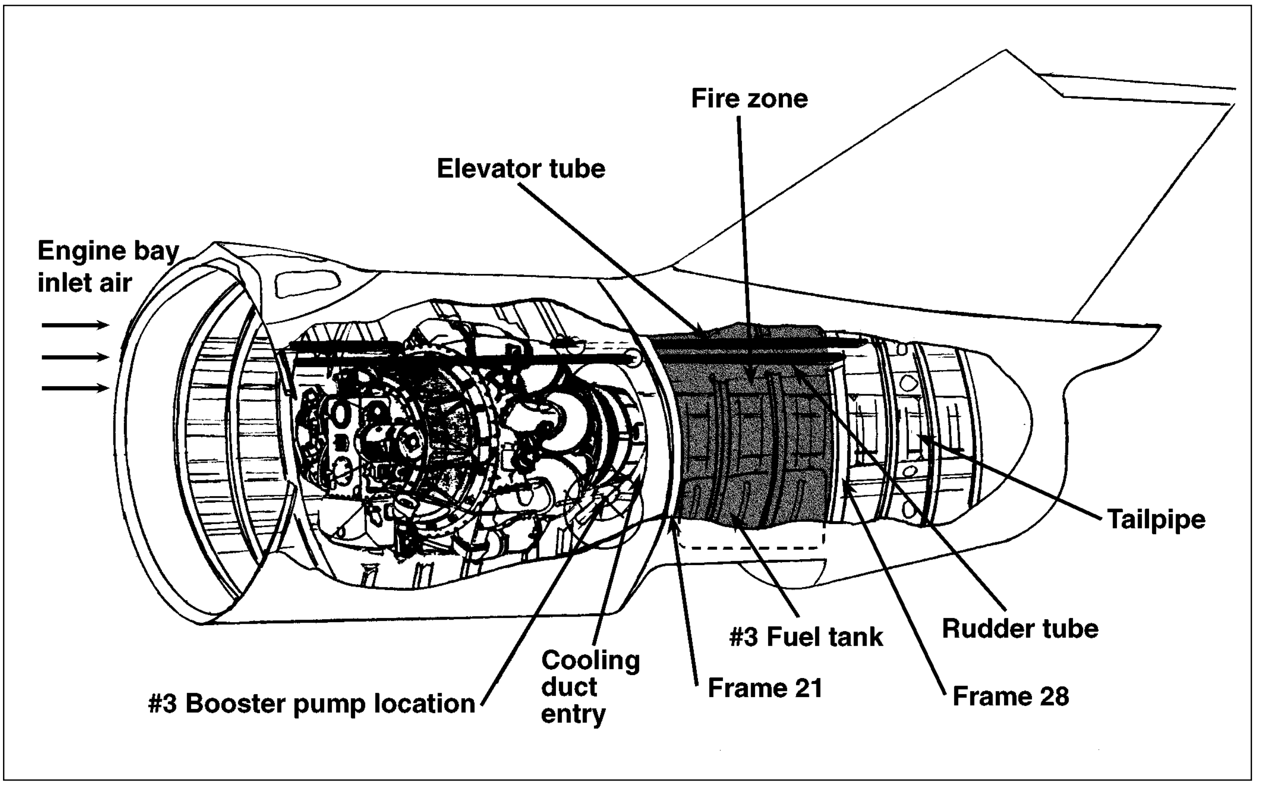


**Figure 4.** Fuselage showing approximate locations of controls, rear fuel systems, engine and tail pipe.

### 1.12.9 Fire extinguishing system

Portions of the panels containing both front and rear cockpit fire-bottle firing buttons were located. The condition of the front firing button and the remains of the system precluded any determination as to whether or not the fire extinguishing system had been activated by the pilot. The rear cockpit fire-bottle firing button cover was lock-wired in the closed position.

Both fire extinguisher bottles were recovered. The firing heads, which were broken from the bottles, were recovered and matched to the bottles by matching fracture surfaces. The firing heads have within them an electrical firing mechanism below which is located a thin metal diaphragm which seals the extinguishing agent inside the bottle. When the firing button in either cockpit is activated, the cartridges in both bottles are fired simultaneously and the extinguishing agent is directed into the engine bay area.

The diaphragm of one firing head was dented from the striker. Evidence of the cartridge having fired was shown by the remains of green/yellow nitrate based explosive primer-mix in the cylinder and piston top. The external electrical contacts were impact damaged.

The striker of the second firing head had penetrated the diaphragm. The associated cartridge and connections were lost. There was no evidence of the green/yellow primer mix in the piston/cylinder cavity.

## 1.13 Medical and pathological information

There is no evidence that the pilot had any prior medical or psychological condition which might have contributed to the accident.

## 1.14 Fire

Examination of the wreckage and impact area revealed evidence of in-flight and ground fire. Witnesses who viewed the aircraft just prior to impact confirmed the presence of fire in the rear of the aircraft. The in-flight fire zone is shown in figure 4. Also shown is the interrelationship of the engine, the number three fuel tank, the number three tank boost pump and the rudder and elevator flight control tubes.

The fire was confined to the area between frames 21 and 24. Evidence of extreme temperatures and in-flight fire was identified on all major structures aft of frame 24, whereas evidence of relatively lower temperatures was revealed forward of frame 21 (engine bay). This was confirmed by the following observations:

- Deposits of combustion products were found throughout the number three fuel tank bay.
- In the area between frames 21 and 24, soot shadows were left on the inner skin where stringers and frames had pulled out during impact (figure 5).
- A clearly defined burning of red painted skin was found aft of frame 21 with unburnt silver painted skin immediately forward of frame 21. Evidence of ground fire was apparent about 20 cm forward of frame 21.
- The fuselage cooling duct was burnt away between frames 21 through 24 and aft. Some of the duct material remained from frames 24 to 28 forward of the tail cone area with the forward facing fractures having either melted ends or hot shear fractures from impact disruption.
- The left speed brake flexible hoses had burned through, and signs of intense heating of nearby steel hydraulic lines were evident.
- Paint had started to burn away from the left sides of the fin, lower rudder and tailplane in areas exposed to the airflow. This section of the aircraft was located outside the ground fire area.

- Blistering of the red paint occurred in the cavity at the top of the fin of the upper rudder mass-balance. This section of the aircraft was located outside the ground fire area.
- Strawbroom fractures were found in the aluminium structures aft of frame 21. This type of fracture is indicative of simultaneous grain-boundary failures within the metal structure of near-molten aluminium subject to shock loading at impact (*ICAO Manual of Aircraft Accident Investigation,* appendix 12).
- The electrical wiring including the wiring to the elevator trim motor was fire damaged by the in-flight fire.

**Figure 5.** Exposed internal skin showing airborne fire sooting. Areas free of soot (arrow) indicate where overlapping metal was pulled apart at impact.

No large complete skin sections forward of frame 21 to the engine bay were recovered. No areas of burn-through of the skin forward of the empennage was found. Most of the outer skin surfaces were destroyed by ground fire.

The immediate area of the initial impact was subjected to an intense ground fire. Outside the immediate impact area, the ground fire was fed by sprayed fuel and dry grass. However, the resultant fire damage to aircraft components in this area was not significant.

## 1.15 Survival aspects

The deceleration forces to which the occupants were subjected at impact were not survivable.

The MiG 15UTI was fitted by the manufacturer with ejection seats. Operational specifications concerning the ejection seats were not available. The ejection seats were disarmed in VH-LSN and the pilot was aware that he did not have an ejection capability. CAA regulations permitted the seats to be armed in those instances where the owner/operator could comply with specific requirements. At the time of the occurrence none of the operators of MiG 15 aircraft in Australia maintained an ejection seat capability in their aircraft.

## 1.16 Prior event

On 27 November 1992, immediately after takeoff from Avalon Victoria, the pilot was reported to have experienced fluctuating jet pipe temperature gauge readings. A definitive explanation of what occurred could not be obtained as differing versions of the occurrence were related to the investigation team. It was reported that upon noticing that the jet pipe temperature had increased to a reading above the maximum allowable for the engine, the pilot immediately retarded the throttle to idle. The jet pipe temperature reduced to a reading of zero then fluctuated. When the throttle was advanced the jet pipe temperature readings returned to normal. Changes in throttle settings produced normal readings. The pilot assessed the situation as a gauge problem and continued the flight. The incident was reported to the maintenance organisation as a possible gauge problem. A post-flight inspection did not reveal any specific fault and an engine run confirmed that the gauge was operating to specified requirements. It was suspected by maintenance personnel that moisture ingress into one of the electrical connections may have caused the erratic indications as the aircraft had been parked outdoors while awaiting repairs at Avalon. This malfunction was not recorded in any aircraft logbook nor was there a record of the actions taken by maintenance personnel.

## 1.17 Fuselage fire detection system

The aircraft was fitted with a fuselage over-temperature or fire detection system. This system was fitted on the forward face of frame 21. As the in-flight fire did not extend forward of frame 21, the fire detection system would not have activated. The temperature sensing range above which the cockpit warning is activated is 140–160°C.

## 1.18 Aircraft documentation

The MiG 15UTI was purchased in Poland and had been operated by the Polish Air Force. Documentation which would normally accompany an aircraft when a change of ownership occurred was not available for review during the investigation. The owner stated that when the aircraft was purchased, the Polish Air Force would not release any maintenance documentation or logbooks pertaining to the aircraft.

A document with a Polish Ministry of Trade and Commerce letterhead dated in Warsaw on 1 December 1989 provided the following information:

- The aircraft airframe 1A06015 had 1,582 hours total time in service, with a time since last inspection of 450 hours. Last inspection was in 1984.
- The engine SN 52644 had a TTIS of 1,167 hours and a TSI of 199 hours. Last inspection was in 1986.
- No defects stated at time of retirement of all aircraft and engines.
- All modifications applied in the Polish Air Force are incorporated.

The document did not provide any information on the type of inspection carried out nor did it indicate what type of inspection was next due or when.

The Australian logbook shows that the following 'lifed' components were installed in VH-LSN: generator, starter, system hydraulic pump, aileron hydraulic pump, upper fuel pump, lower fuel pump, barometric control, throttle valve and HP shut-off cock. The logbook annotation indicates that all the components were installed on the aircraft at 1,383 hours time since new and had a mandatory component life of 1,800 hours. At installation, these component times since overhaul as annotated in the Australian logbooks were 0 (zero) hours with the components due for removal at 3,183 airframe hours. The components were installed on the engine and/or airframe in Poland and there was no documentation to support the data contained in the logbooks of VH-LSN.

Information received from the CAA states that the main fuel pumps were identified for inspection every 900 hours TIS and the engine hot end required inspection at intervals of 200 hours.

Unfortunately, the data relating to individual airframe, engine and component lives cannot be used with confidence. This data is subject to an Australian Federal Police investigation as it is suspected of being forged.

## 1.19 Permit to fly

A CAA Permit to Fly for historical and ex-military aircraft was issued on 3 April 1992 and was valid for one year. Sub-paragraph (d)(ii) of the permit states the following limitation:

> The aircraft shall not be flown over a populous area except that, where a positioning flight is required, the aircraft may be flown over a populous area to the minimum extent necessary along a route approved by the Authority.

Sub-paragraph (c) which prohibits the carriage of passengers was deleted and under the Special Conditions section paragraph 2 was added which states:

> The carriage of passengers is permitted only for the purpose of regulation 134(1) (bc) of the Civil Aviation Regulations.

Civil Aviation Regulation 134(1)(bc)(i) states:

> 134. (1) The Authority or an authorised person may give permission to fly an aircraft in Australian territory on a particular flight, or on all flights during a specified period, for the purpose of:
>
> (bc) carrying passengers on a flight of the aircraft, being a flight that:
>
> (i)begins at a particular place and ends at the same place without the aircraft landing at any other place during the flight…

## 1.20 Aircraft test flight

The accident pilot flew a test flight on VH-LSN on 14 March 1992 at RAAF Richmond. The following extracts are taken from the test flight schedule document:

- stalling flaps retracted – 113K (IAS)
- stalling flaps extended T/O – 110k
- stalling flaps extended landing – 110k
- stalling flaps extended landing gear down – 110k

A note with reference to the stalls on the document states: 'Wallows longitudinally below 120k-125k clean & 115k (approach config). A/C not flown to point of stall (for safety considerations)'. The test flight document did not state at what altitude or weight the stall portion of the flight was conducted.

In the comments section, paragraph 12 of the document, the following note was inscribed: 'Stable in all planes >160k clean (min. man. IAS)'. The comments in brackets are believed to be in reference to the minimum manoeuvring indicated air speed.

## 1.21 CAA endorsement requirements

Civil Aviation Orders, part 40, section 40.1.0 details the requirements for the issuing of type endorsements for specific aeroplanes. Subsection 6.1 which was current at the time the pilot received his endorsement identifies the specific requirements for the issue of a type endorsement for aircraft such as the MiG 15UTI. Subsection 6.1 states in part:

> 6.1 – The endorsement of a pilot licence for a type or category of aeroplane not exceeding 5,700 kg maximum take-off weight shall be conditional upon the applicant undergoing training and passes(sic) tests of his or her knowledge of the operating limitations of the type or category of aeroplane and of his or her ability to perform all normal and emergency flight manoeuvres in the particular type or category.

In addition, Flying Operations Instructions No. 13-1 titled ‘Operation of ex-military aircraft’ issued by the CAA contains information concerning the endorsement requirements for pilots flying ex-military aircraft. The MiG 15UTI is classed as a Group C aircraft in that document. With reference to endorsement training the FOI states:

> 4.6 – To gain endorsement on a Group C aeroplane, an applicant shall demonstrate to a person specifically approved by a Manager, Flying Operations of the CAA that he/she has completed a flying training sequence in a suitable two-place dual control aeroplane. Aeroplanes which have been assessed as suitable for the flying training for turbojet aeroplanes include the DH115 Vampire T Mk 35 and the dual place MiG 15 and 17. On completion of this training the applicant shall carry out 6 hours of command flight time under the direct supervision of an approved person on the aeroplane type for which the endorsement is sought, including at least 6 take-offs and 6 landings to a complete stop.

Part 3.5 of the FOI details the currency requirements of a pilot of a Group C aeroplane and states in part that the pilot must have flown one hour on type with at least three takeoffs and three landings in the preceding 90 days or if he has not met these requirements he must undertake supervised training or obtain the approval of a CAA examiner prior to conducting unsupervised flights.

At the time the pilot requested an endorsement and at the time of the accident, FOI 13-1 formed part of the instructions issued by the Authority to their officers. The document contains obligatory words such as ‘shall’.

Civil Aviation Regulations require the pilot, within the period 90 days immediately before the day of the proposed flight, to have carried out at least three takeoffs and three landings while flying an aeroplane as pilot in command. The pilot met this requirement by virtue of flying another aircraft type.

### 1.22 CAA documents

The CAA regulates the operation of aircraft, pilot qualification requirements and maintenance requirements in part by promulgating orders and regulations, issuing licences and permits, and monitoring civil aviation activity. With respect to the operation of ex-military or warbird aircraft, the CAA has issued a separate Permit to Fly, FOI 13-1 and AWI. The FOI and AWI were produced by the CAA to provide direction and guidance for its staff and unless specifically requested are not made available to an aircraft owner or operator. During the investigation, it was determined that some operators and pilots of ex-military aircraft were not aware of the contents of the various CAA documents which detail flight restrictions and recommend the training requirements of that class of aircraft.

### 1.23 Video tape

A home video was taken of the aircraft during the start, taxi to the runway, the takeoff and climb, portions of the flight, and the descent of the aircraft just prior to impacting the ground. It showed the aircraft taxiing onto the runway and commencing an immediate takeoff. The acceleration appeared uniform. As the aircraft lifted off it was levelled at about 15 ft and the landing gear was raised. The aircraft then commenced a smooth, coordinated climb and left turn to an altitude of about 1,200 ft AGL. The aircraft then continued in a gradual left turn, away from the airfield. A puff of dark smoke was observed behind the tail pipe shortly after the aircraft completed its climbing turn. As the flight progressed the height appeared to remain constant. As the aircraft reached a downwind position, a plume was visible behind it; however, it could not be determined if the plume was smoke or some other form of vapour. The aircraft then gradually lost height and turned left. As the aircraft lost height it returned to a wings-level attitude and appeared to slow. The pitch attitude then changed from a level or slight nose-up attitude to about 30–40° nose-down (figure 6). When the nose initially dropped, the right wing dropped a few degrees and then immediately returned to a wings-level attitude. The aircraft then descended out of sight behind some trees.

**Figure 6.** Final flight path of VH-LSN (video tape).

# 2. ANALYSIS

## 2.1 Introduction

The investigation focused on the flight of the aircraft which led to the ground impact. The evidence gathered was analysed in detail in an attempt to determine and understand the events leading to the pilot's apparent loss of control. Aircraft operational data specific to the MiG 15UTI was sparse and where available its origin could not be verified. Because of the limited information on the MiG 15UTI, the documentation including the logbooks for VH-LSN was reviewed in an attempt to determine the status of various aircraft components and the impact the component status may have had on the occurrence. The CAA process of certifying the aircraft and providing pilot endorsements was reviewed.

## 2.2 In-flight fuselage fire

The effects of the in-flight fire on VH-LSN were contained in the aft fuselage. As such, a reasonable conclusion to reach would be that the source of combustible material and the ignition source were located in the aft fuselage. However, a flammable liquid leak (JetA1 or hydraulic oil) could be carried from the forward fuselage through to the tailpipe before encountering a suitable ignition source. With all aircraft systems working normally, suitable ignition sources could be the hot metal of the nozzle guide vane casing and the turbine shroud, or hot engine exhaust gases. Hence, for this purpose of this analysis, all flammable liquids carried on the MiG-15 aircraft were considered.

With the engine operating above ground idle, the gas temperatures in the jet pipe would be in excess of 500°C. Even when considering the time taken to heat-soak the nozzle guide vane casing and the turbine shroud, the temperature of these items would eventually exceed the auto-ignition temperature for JetA1 and MIL-H-5606C hydraulic oil (max. 230°C). However, if this assessment is incorrect, or the fuel vapour did not contact these hot surfaces, the temperature of the surrounding air would be rapidly rising as it carries away heat from the engine hot section and jet pipe. Eventually, this air would be at the auto-ignition temperature of the flammable liquid being considered, either within the confines of the cooling duct or as it meets the engine exhaust gases aft of the tail pipe. Therefore, a flammable liquid leak from the forward fuselage or engine bay would eventually be ignited. With the effects of the ram air in the cooling duct, the temperature of the burning fuel (estimated to be a minimum of 1,300°C) would be well in excess of that required to melt the cooling duct and jet pipe lining material. This fire would rapidly burn into the aft fuselage cavity and weaken the elevator control rods.

Flammable liquid sources aft of frame 21 are the number three fuel tank and transfer piping, and the speed brake actuator hydraulic system. The number three tank normally holds 166 L of fuel. However, this tank was not refuelled at Canberra before the accident flight. As it was last filled at Nowra, prior to the flight to Canberra, and as it feeds first when holding fuel, the number three tank must have been empty on the accident flight. Even considering tank unusable fuel (estimated to be less than 1 L) or possible fuel spillage accumulating in the tank access hatch (less than 1 L), there is insufficient fuel to sustain a fire of sufficient energy to burn around the cooling duct and melt the control rods. Therefore, the number three fuel tank system was not the source of the flammable liquid of the in-flight fire.

The speed brake actuator hydraulic lines are steel and are located in the same region of the aft fuselage as the control rods. For this hydraulic system to be the source of flammable liquid, these lines would have to be compromised. This could occur by failure due to a pre-existing defect or being severed. A ruptured hydraulic line would spray fluid around the fuselage cavity, creating the mist required for ignition. However, the normal operating temperature of this cavity would be below the auto-ignition temperature of hydraulic fluid. Further, as the aft fuselage cavity around the cooling duct would not be well ventilated, there is little likelihood that a suitable air/fuel mixture could exist for combustion to occur. Accordingly, under these circumstances, the speed brake hydraulic system is unlikely to have been the source of fuel for the in-flight fire.

The in-flight fire occurred on VH-LSN in the fuselage aft of frame 21. As a result of this fire, the elevator control rod was burnt, or melted, and control of the aircraft was lost. Examination of the evidence available failed to positively identify the source of flammable liquid and the ignition source responsible for the fire. However, based on the circumstances of the fire, a reasonable hypothesis can be drawn. This hypothesis is that a JetA1 fuel or MIL-H-5606C hydraulic oil leak from forward of frame 21 ignited in the airframe cooling duct from contact with either the hot metal of the turbine section of the engine, hot gases in the duct, or the engine exhaust aft of the aircraft. This fire could have been contained to the cooling duct due to the lack of a suitable air/fuel mixture forward of frame 21. The fire quickly burnt through the cooling duct wall, and subsequently weakened the elevator control rod.

## 2.3 Turbine blade failures

The metallurgical analysis of the turbine blades conducted by the CASA Materials Evaluation Facility concluded that they had failed through creep rupture. Failure resulted in the loss of 25–30 mm from each blade tip. The damage was consistent across the nine sample blades available for examination.

The Materials Evaluation Facility report stated that the creep phenomenon is dependent upon three variables—temperature, strain and time. This report stated there was no evidence that these blades experienced excessive temperature during their operating life. Witness comments have highlighted instances where the jet pipe temperature apparently exceeded the specified limits. As metallurgical examination failed to identify crystalline structure changes due to excessive temperature, the instances of over-temperature were obviously very minor, or were gauge problems as suggested by the pilot. Notwithstanding this uncertainty, established turbine blade theory states that the operating life of a blade is reduced when it experiences temperatures in excess of the specified maximum value. Hence, if these turbine blades experienced temperatures in excess of the maximum specified limits, they would have a reduced operating life.

The post-accident review of both fuel pump over-speed governors found no evidence of malfunctioning. Therefore, excessive strain, caused by out-of-tolerance rotor RPM, should not have contributed to the observed blade creep.

With temperature and strain removed as contributing factors to the creep failure of these blades, their operating life becomes the prime consideration.

In simple terms, creep is the gradual lengthening of a material subjected to temperature, strain and time. A turbine blade suffering creep will eventually contact the outer casing, resulting in tip rub. Turbine blade tip rub is typically discernible through longer engine start and shorter engine run-down times due to increased friction in the engine. Such symptoms should be discernible to an experienced pilot and would, as a minimum, result in an inspection of the engine by qualified maintenance personnel. However, no evidence exists to indicate whether the pilot of VH-LSN was aware of the tip rub occurring in his engine, or whether he discussed this problem with the aircraft owner or maintenance organisation.

## 2.4 Airframe and aircraft component documentation

When the aircraft was imported from Poland it was not accompanied by any documentation specific to the defective engine-driven fuel pump. The Australian aircraft logbooks indicate that the fuel pump was installed as a 0 (zero) time component at 1,383 airframe hours or 216 hours before the accident with an overhaul life of 1,800 hours. Due to the fact that the figures used by the owner could not be verified, the assumption of time remaining on the component might be in error by several hundred hours and the component might have been near time expiry when the aircraft was imported to Australia. This premise is further supported by the allegations that the original figures were forged.

During the examination of the aircraft documentation and CAA approval process, it was evident that the logbook documentation for the aircraft was almost non-existent and in the instances of time life components, the times inserted into the logbooks could not be verified or validated. Nor could it be determined how the time of installation, time since overhaul or mandatory overhaul life on the component were determined. The CAA provided the Bureau with information on some time life components which varied significantly from the times inscribed in the Australian logbooks. Even though the times were at variance, the CAA issued a Permit to Fly for the aircraft.

It is not uncommon for airframe and engine sub-components to be changed in-service without ensuring that the time remaining is matched to other components; thus it is possible that none of the components other than the engine and airframe had the hours remaining as listed in the Australian aircraft logbooks.

## 2.5 Flight crew qualifications for the operation of ex-military aircraft

At the time the pilot obtained his CAA authority to fly the MiG 15UTI on test flights and later, when he obtained his endorsement, there were no regulations or orders specific to the MiG aircraft. There were, however, appropriate regulations, orders and instructions within Flying Operations Instructions No. 13-1 which provided specific guidance for CAA inspectors for the issuing of endorsements to pilots flying ex-military aircraft. In the case of the accident pilot, these instructions were not followed by the CAA inspectors, or if they were, documentation of the process was incomplete.

In addition to the FOIs not being followed, the files held by the CAA did not indicate what process was used by them to determine whether or not the pilot was qualified to conduct the test flights. If the CAA inspector considered the pilot qualified to conduct the test flights, then he should have granted written approval to the pilot to fly the MiG on the test flight under Regulation 66(4) prior to the test flights being conducted.

When the pilot did request an endorsement, he was instructed by a CAA inspector to obtain the signature of a CFI on a certificate of endorsement, approval and rating. The pilot was advised that this was a formality. The certificate was then signed by an individual who did not have any knowledge of the operation of the MiG aircraft. The CAA accepted the endorsement document. Thus, the pilot was endorsed on type without anyone in authority ensuring that he understood the normal and emergency operation of the aircraft. Anecdotal evidence suggests that the pilot was aware of the limitations of the MiG 15UTI and was cautious in his approach to piloting the aircraft.

## 2.6 Ex-military aircraft operations

A number of inconsistencies were identified during the investigation which indicated that some owners, operators, pilots and CAA field inspectors were probably not conversant with the orders, regulations or instructions governing the operation of ex-military aircraft. Some of these issues were:

- The CAA issued a Permit to Fly for test flight purposes even though the owner of the aircraft could not provide detailed records of the aircraft history. Times entered into the Australian aircraft logbooks could not be verified.
- The CAA did not document the process it applied when approving the pilot to test fly the aircraft.
- While the test flight Permit to Fly was in effect, the aircraft was flown for other than test flight requirements and the carriage of other crew and passengers occurred.
- On the accident flight the pilot planned a city scenic flight which would place the aircraft over a built-up area, which was not in accordance with the restrictions of the existing Permit to Fly.

Based on discussions with various individuals, it is probable that the inconsistencies identified above were not an intentional disregard of orders, regulations and instructions but were, rather, well-intentioned efforts in support of the ex-military aircraft movement. The MiG was a new arrival in Australia and its appearance on the aviation registry brought to Australia an aircraft of historical significance. What the above events do emphasise is the importance for all the groups involved in aviation activities, especially those which are not conventional in nature, to ensure that they are fully conversant with all the regulations governing their particular activity.

During the investigation it became apparent that there is a need to consolidate all orders, regulations and instructions which pertain to aircraft generally referred to as ex-military or warbirds. Aircraft flown in this category generally do not meet CAA certification requirements as the aircraft were built for a specific military role. As in early fighter aircraft, their service life expectancy was often low. Because of this short life expectancy, design criteria often did not take into consideration the high stresses imposed on the aircraft during their extended military operation, especially where the aircraft were used for training.

Aircraft such as the MiG 15UTI entered military service 40–45 years ago. The technology used in the production of jet aircraft was in its infancy and cannot be compared to the second or third generation of military jet aircraft operated today. These aircraft may appear to be simplistic in construction when compared to modern aircraft, but a pilot operating a modern aircraft has the benefit of multiple backup and warning systems not available in older aircraft. During the investigation it was apparent that there were inconsistencies in the application and understanding of the orders, regulations and instructions applicable to the operation of ex-military aircraft. In view of the inconsistencies identified during the investigation, the Bureau believes there is a need for the CAA to develop Civil Aviation Regulations and Civil Aviation Orders which are specific to the registration, certification and pilot endorsements for all ex-military aircraft flown with an Australian registration.

## 3. CONCLUSIONS

### 3.1 Findings

1. The aircraft was within operational weight and centre-of-gravity limitations.
2. The pilot held a MiG 15UTI endorsement.
3. The CAA did not document the pilot test flight approval which was granted under Regulation 66.
4. The CAA did not issue the pilot's MiG 15UTI endorsement in accordance with the existing CAOs or CAA instructions as specified in FOI No. 13-1.
5. The pilot did not receive any dual training on the MiG 15UTI nor was any required.
6. There was no available documentation from the Polish Air Force concerning the life history of the aircraft and its components.
7. Documentation concerning component installation, last inspection type and date, and next inspection time, type and date as imported from Poland was not available.
8. The in-service time of the aircraft components could not be verified.
9. An in-flight fire occurred aft of frame 21 and because the area is not monitored by a fire warning or overheat sensing device, the pilot was probably unaware of the fire.
10. The in-flight fire burned the electrical wiring which resulted in the loss of elevator trim control during flight.
11. The source of combustible material was probably located forward of frame 21.
12. The source of ignition of the combustible material was located aft of frame 21.
13. The effects of the resulting fire were restricted to aft of frame 21.
14. The in-flight fire weakened the elevator control tubes located in the fuselage cavity aft of frame 21.
15. The in-flight fire melted and burned the rudder and elevator control tubes which led to uncontrolled flight and ground impact.
16. The ejection seats were disarmed and the pilot was aware that he did not have an ejection capability.

### 3.2 Significant factors

1. There was probably an undetected flammable fluid leakage from forward of frame 21.
2. This flammable fluid ignited and burned in the cooling duct, destroying this duct and raising the temperature of the fuselage cavity behind it significantly.
3. No overheat or fire detection sensors were installed in the area of the fire.
4. The melting and burning of flight controls deprived the pilot of control of the aircraft.

# 4. SAFETY ACTION

## 4.1 Safety action taken

During the course of the investigation the Bureau of Air Safety Investigation made the following recommendations.

**IR930105**

It is recommended that the Civil Aviation Authority produce a single publication which brings together all of the various requirements which relate to the operation of aircraft issued with a Permit to Fly under Civil Aviation Regulation 134.

The document should include all relevant information which is currently contained in Airworthiness Instructions, Flying Operations Instructions, Civil Aviation Orders, Civil Aviation Regulations and the General Permission issued in relation to Regulation 134. This single document should be made available to the public.

**IR930108**

It is recommended that the Civil Aviation Authority review its procedures that relate to the use of ejection seats in civil registered aircraft to ensure that:

- information on the requirements for ejection seats is included in documentation that is readily available to the public; and
- the CAA's approach to ejection seats is standardised.

**IR930109**

It is recommended that the Civil Aviation Authority amend the General Permission under Regulation 134, CAO 29.4 para. 4.1f and the Permit to Fly document to prohibit the carriage of non-essential passengers or crew on display flights in 'warbird' aircraft, which are not designed for the carriage of passengers.

A collective response was received for interim recommendations IR930105, IR930108 and IR930109, which stated in part:

> *we are hosting an Ex-military Aircraft Conference in Canberra on 15 July and it is expected that all of the above issues will be considered at that meeting.*

**IR930107**

It is recommended that the Civil Aviation Authority remind all operators of aircraft operating on a Permit to Fly under Regulation 134, of their obligation to comply with the restrictions contained in the Permit to Fly and to standardise the interpretation of the restrictions among the various CAA offices, in an effort to ensure that all persons involved are aware of the restrictions.

The response from the CAA in part stated:

> *A new Permit to Fly document is being developed in consultation with the 'warbird' industry. A meeting of 85 representatives of the industry was held on 15 July 1993 which covered the points raised in the Interim Recommendation amongst other matters. When the new permit is finalised, existing permits will be withdrawn and operators will be reminded of their obligations under the Permission to fly these aircraft.*

**IR930286**

The Bureau of Air Safety Investigation recommends that the Civil Aviation Authority:

1. introduce a mandatory requirement to strip-inspect/overhaul the upper and lower fuel pumps of the engines fitted to MiG 15 aircraft to ensure integrity of assembly and their subsequent operation; and
2. introduce and detail repetitive inspection/overhaul requirements for the upper and lower fuel pumps of the engines fitted to MiG 15 aircraft.

The response from the CAA stated:

*We have discussed your fuel pump concerns with the industry organisations concerned, with our specialists and with our regional inspection staff.*

*The matter is complicated by the fact that we do not know why the internal mechanism of the pump became disassembled. Your further advice on the matter would be appreciated. If it was caused by a mistake in some earlier strip down there is a telling argument that the risk is only increased by further attempts to take the pumps apart. As you know, it is common aeronautical practice to carry out regular performance checks to assess the adequacy of equipment and, in certain cases, this includes the complete engine. Overhauling is but one way to be assured of mechanical performance and may not be appropriate or necessary in all cases.*

*In this instance, there is a direct correlation between indicated EGTs and pump performance which should flag a tendency for over-fuelling. Subsequent maintenance investigation associated with pump set up and isolation valve setting should, in turn, have identified the problem.*

*AD/MiG15/1 specifically addresses the fuel pump set up as requirement 3.*

*Please be assured that the Authority is well aware of our responsibilities with respect to this issue and that aircraft will not be released for flying until we are satisfied that this area has been adequately addressed.*

**R930298**

The Bureau of Air Safety Investigation recommends that the Civil Aviation Authority review the procedures used to assess the safe life of aircraft and components imported without adequate historical documentation before approving a Permit to Fly under Regulation 134.

The response from the CAA stated:

*The Ex-Military Aircraft Conference, which was held in Canberra on 15 July 1993, identified the need for a Maintenance Review Panel to review the maintenance procedures not only of the MiG 15 aircraft but also all Australian registered 'warbirds' aircraft.*

*The Authority accepts the recommendation and has established a Maintenance Review Panel which is chaired by a senior CAA Officer and consists of representatives from the Authority and the Warbirds Association.*

*The Panel is developing a means to be able to establish an appropriate level of integrity for entry into service and continuing airworthiness of this class of aircraft.*

**R930299**

The Bureau of Air Safety Investigation recommends that the Civil Aviation Authority:

1. introduce a standardised process for approving pilots to carry out training on aircraft operating on a Permit to Fly under regulation 134; and
2. adopt standard endorsement requirements for pilots who wish to operate aircraft on a Permit to Fly under regulation 134, with special attention to training, experience and currency.

The response from the CAA stated:

> *This Authority agrees with R930299 and will take action to implement the recommendations contained therein.*

BASI note: The Civil Aviation Safety Authority has undertaken to incorporate all the Bureau of Air Safety Investigation recommendations in a new publication titled *Guidance Material of Intending Operators of Historic or Ex-Military Aircraft*.