Accidents Investigation Branch

Department of Trade

Report on the accident to Britten-Norman Islander BN2A/9 G-BBRP at Netheravon Aerodrome, Wiltshire on 20 February 1982

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Department of Trade
Accidents Investigation Branch
Bramshot
Fleet
Aldershot
Hants GU13 8RX

18 November 1982

The Rt Honourable Lord Cockfield
Secretary of State for Trade

The Rt Honourable John Nott MP
Secretary of State for Defence

Sir,

I have the honour to submit the report by Mr C C Allen, an Inspector of Accidents, on the circumstances of the accident to Britten-Norman Islander BN2A/9 G–BBRP which occurred at Netheravon Aerodrome, Wiltshire, on 20 February 1982.

I have the honour to be
Sir
Your obedient Servant

G C Wilkinson
Chief Inspector of Accidents

Accidents Investigation Branch

Aircraft Accident Report No 7/82
(EW/E22)

Operator:		Joint Services Parachute Centre
Aircraft:	*Type:*	Britten-Norman Islander
	Model:	BN2A/9
	Nationality:	United Kingdom
	Registration:	G-BBRP
Place of Accident:		Netheravon aerodrome Wiltshire Latitude 51° 14′ 40″ N Longitude 01° 45′ 25″ W
Date and Time:		20 February 1982 at 1255 hrs
		All times in this report are GMT All fuel quantities are in US gallons

Synopsis

The accident was notified to the Accidents Investigation Branch on the afternoon of the day of the accident. A military investigation was commenced by the Accidents Investigation and Flight Safety Section of Aviation Standards Branch, Headquarters, Army Air Corps. However it became apparent that the accident should be investigated under the Combined Military and Civil Air Accident Regulations 1969 and the Accidents Investigation Branch commenced such an investigation on 10 March 1982.

The accident occurred whilst the aircraft was taking-off on a parachute dropping flight with the pilot and eight parachutists on board. Shortly after take-off, at a height of about 50 feet above ground level, the pilot detected a loss of power from the port engine. He then selected the flaps up, but whilst he was about to commence the shut down and propeller feathering drills for the port engine, the starboard engine also appeared to lose power. In the subsequent attempt to land the aircraft straight ahead, the pilot was unable to reduce a high sink rate and a heavy landing resulted. The aircraft sustained severe damage that was beyond economic repair, but there were no injuries to those on board.

The accident was caused by the fact that the pilot was unable to reduce the aircraft's rate of descent sufficiently to prevent a heavy landing. Among contributory factors were the loss of all power from the port engine due to fuel mismanagement and the pilot's decision initially to attempt to continue the take-off.

1. Factual Information

1.1 History of the flight

On 14 February 1982 a 'one thousand hour' inspection was carried out on the Islander aircraft, G-BBRP, at Shobdon aerodrome, Herefordshire. After this inspection the aircraft was fuelled to capacity, in preparation for an air test for the renewal of the Certificate of Airworthiness. The air test was satisfactory in all respects and included a 5-minute check, per side, that the fuel flow and cross-feeding operation of the aircraft's wing tip tanks operated normally. At all other times during the air test, the aircraft was flown with the fuel supply selected from the main tanks. On 16 February 1982 the aircraft was delivered to Netheravon aerodrome. After arrival at Netheravon, two further flights were carried out: the first an acceptance air check, the second a parachute drop. Both these flights and the delivery flight were carried out with the fuel supply selected from the main tanks.

On 18 February the aircraft was used to fly four parachute dropping flights. On this occasion, before the first flight, the pilot was reminded that the wing tip tanks were still nearly full. As it was normal practice to run the contents of the wing tip tanks down to a total of 13½ US gallons per side, and to conserve this amount until it was required to be used due to low contents in the main tanks, the pilot flew all these sorties with the fuel supply selected from the wing tip tanks. By the end of the day a total of 40 minutes flying time had been completed and, as the pilot did not consider that the wing tip tank contents had been sufficiently reduced, after engine shut down he deliberately left the fuel supply selected from wing tip tanks in order to draw the attention of the succeeding pilot to further reduce the contents of the tip tanks on the next flight.

The next flight occurred on 20 February when the pilot subsequently involved in the accident arrived at Netheravon aerodrome to carry out the day's flying in the Islander aircraft. As it was a weekend, there were no engineering staff present, and the pilot carried out his own pre-flight inspection of the aircraft. Whilst these checks included the normal fuel and water drain checks, the contents of the wing tip tanks were not checked by dipstick nor was he fully certain which fuel tanks were selected. The weather at the start of the day's activities was considered marginal for parachute dropping, and so the pilot first flew a weather check. During this flight, on checking the cloud base, the pilot reported encountering light airframe icing. Later in the morning the weather improved and the aircraft took off for a further weather check, this time with a load of parachutists on board. The weather proved satisfactory and a successful drop was achieved. The aircraft then landed and the engines were shut down. At this time, according to the pilot, the aircraft's main fuel gauges were indicating 35 US gallons port, 30 US gallons starboard, and the tip tanks three-quarters full by gauge reading.

At 12 50 hrs the pilot restarted the engines and completed the run up checks, which included a check of the operation of the carburettor selection to hot air. As this flight was to be a drop of student parachutists, the ground running time whilst the parachutists boarded the aircraft was slightly longer than usual and, at about 12 55 hrs, the aircraft commenced the take-off run.

The pilot reported that shortly after take-off, at a height of about 50 feet above ground level and at an airspeed of 73 knots, he detected a loss of power from the port engine. He stated that he selected the flaps up and that, as he was about to commence the shut down and propeller feathering drills for the port engine, the starboard engine lost all power. Ear witnesses later confirmed the sound of an engine spluttering at about this time. The pilot then lowered the nose of the aircraft with the intention of landing straight ahead. From a low height, with a high sink rate, he was unable to reduce the rate of descent sufficiently to prevent a heavy landing. At no time did he hear the stall warning. The aircraft slid for a total distance of 72 metres before coming to rest on its belly, with both wings severely twisted nose down near their root ends.

All the occupants vacated the aircraft without injury. When it became apparent that there was no danger of fire, the pilot supervised the crash and rescue personnel in the removal of the aircraft's battery and then himself re-entered the cockpit to complete the shut down checks. During these checks, in attempting to shut off the fuel cocks, he was able to select the starboard fuel cock to OFF, but the port fuel cock jammed in an intermediate setting.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor/none	1	8	-

1.3 Damage to aircraft

The aircraft sustained severe damage that was beyond economic repair.

1.4 Other damage

An area of grass, approximately half a metre square, was contaminated and bleached by the release of fuel from the aircraft's port wing tip tank, which was ruptured upon impact. A larger area was contaminated when fuel was spilled from the aircraft's main tanks during de-fuelling and salvage operations.

1.5 Personnel information

Commander:	Male, aged 35 years
Licence:	Private Pilot's Licence (PPL) first issued on 25 August 1976 for Groups 'A' and 'B', and Self Launching Motor Gliders
Medical certificate:	Last medical on 31 March 1980, Class 3, no restrictions
British Parachute Association authorisation to drop parachutists:	Authorised for BN Islander on 28 February 1978
Total pilot hours:	3,422.40 on powered aircraft 527.00 on gliders
Total hours on Islander:	235.00
Total hours in last 28 days:	41.10
Total hours in last 24 hours:	00.25

At the time of the accident the pilot was employed as a commander on Royal Air Force Hercules C130 transport aircraft. He obtained his PPL as a result of his military flying qualifications and by passing the examinations required by the Civil Aviation Authority (CAA). He had been flying the Islander for the Joint Services Parachute Centre since June 1980.

1.6 Aircraft information

(a) G–BBRP was a Britten-Norman Islander BN2A/9, a twin engined, high wing monoplane of all metal construction, powered by two Lycoming 0-540-E engines driving Hartzell, two bladed, constant speed, fully feathering propellers.

Manufacturer's serial number:	371
Date of manufacture:	December 1973

Certificate of Airworthiness:

Category:	Private
Issued:	15 February 1982
Valid to:	14 February 1983

Last maintenance check:	1,000 hour check for renewal of Certificate of Airworthiness on 13 February 1982 at 5,462.00 hours, valid to 5,562.00 hours or until 1 April 1982	
Total airframe hours since new:	5,466.25	
Engine serial numbers:	Port	L-13517-40
	Starboard	L-13079-40
Engine total hours since overhaul:	Port	218.55
	Starboard	1,114.30
Propeller serial numbers:	Port	AU 4156
	Starboard	AU 4401
Propeller total hours since overhaul:	Port	218.55
	Starboard	218.55

(b) G–BBRP was owned by the Army Parachute Association and operated at Netheravon by the Joint Services Parachute Centre.

(c) Weight and Centre of Gravity (CG)

Maximum weight authorised:	6,300 lbs (2858 kg)
Accident weight (estimated):	6,250 lbs (2835 kg)
CG limits (at 6,250 lbs):	Forward limit 20.6 inches aft of datum
	Aft limit 25.6 inches aft of datum
Accident CG (estimated):	25.2 inches aft of datum
Maximum authorised landing weight:	6,300 lbs (2858 kg)

(d) Fuel type: Avgas 100LL

Quantity of fuel at take-off : (estimated) 80½ US gallons

Quantity of fuel at impact: (estimated) 79½ US gallons

(e) The total fuel capacity is 196 US gallons, distributed as follows:

Main Tanks (2):	65 US gallons gauged, usable fuel (each) 3½ US gallons ungauged, unusuable, fuel (each)
Wing Tip Tanks (2):	27½ US gallons gauged, usable fuel (each) 2 US gallons ungauged, unusuable fuel (each)

(f) Fuel system operation (see Appendix 1)

Fuel from the main or tip tank in either wing is led to an electrically actuated tip tank cock interposed between the inner wing tank and two booster pumps, known as 'auxiliary pumps'. The position of each cock is electrically operated by a switch which is mounted on a small console panel on the windscreen centre post; the selection options are for MAIN or TIP tank to supply fuel to the respective auxiliary pumps. The position achieved on the cocks (not necessarily the position to which they are switched) is indicated by four green lights, labelled MAIN and TIP, adjacent to the selector switches. Between the lights is a switch labelled IND LTS which allows the pilot to render the indicating lights inoperative.

The auxiliary pumps are operated by two ON/OFF switches adjacent to their respective main tank fuel contents gauges on the roof instrument panel. The tip tank contents gauges are mounted at the forward end of the right side passenger service panel. From the auxiliary pumps fuel is supplied to either engine via the respective main fuel cock, situated just inboard of the nacelle, and operated from its respective three position selector handle in the centre roof panel by means of a Bowden cable and chain-and-sprocket loop. Selector positions, for the port engine, are labelled OFF, PORT TANK, and STBD TANK. With the selector to PORT TANK, the port engine is supplied with fuel from its associated wing. With the selector to STBD TANK, the port engine is supplied with fuel from the opposite wing. The starboard engine fuel selector is labelled and operates similarly in the opposite sense. For the sake of clarity, in this report, the selection of fuel to an engine from its associated wing is described as 'on-normal', and the selection of fuel to an engine from the opposite wing is described as 'crossfeed'. In summary, the options are:

(i) OFF - in which the supply line to the engine and both of the other ports are closed off

(ii) 'On-normal' - in which the engine is supplied with fuel from the auxiliary fuel pump outlet in its own wing

(iii) 'Crossfeed' - in which the engine is supplied with fuel from the auxiliary pump outlet in the other wing.

(g) The rear port door had been removed for the purpose of parachute dropping, as permitted by the Certificate of Airworthiness.

1.7 Meteorological information

Meteorological observations are not made at Netheravon aerodrome during weekends. Pilots can obtain local weather forecasts and actual conditions from the Meteorological Offices at the Royal Air Force Stations at Boscombe Down and Upavon, which are situated respectively 6 nautical miles and 2 nautical miles north of Netheravon. An aftercast, obtained from the Meteorological Office, Bracknell, assessed the weather at the time of the accident as follows:

General situation:	An anticyclone centred over southern Norway, with a ridge extending south-east towards the Brest peninsular
Surface wind:	Mainly from 060° (M) at 5 to 8 knots
Weather:	Cloudy with some very light flurries of granular snow
Visibility:	From 4 to 6 kilometres
Cloud:	Mainly 8 oktas strato-cumulus, base between 2,000 and 2,500 feet
Height of 0° isotherm:	Between the surface and 500 feet
Relative humidity:	Between 75% and 86%
MSL pressure:	1027 mb.

The actual weather recorded at Boscombe Down at 1300 hrs on 20 February 1982, was a surface wind of 070/10 knots, 6 oktas of cloud at 1,500 feet, 8 oktas at 5,000 feet. The temperature was plus 0.6° C, and the Dew Point minus 0.9° C. Boscombe Down aerodrome is 407 feet above mean sea level.

The accident took place in daylight.

1.8 Aids to navigation

Not relevant.

1.9 Communications

The Air Traffic Control at Netheravon is not normally manned at weekends. When week-end parachuting is taking place, all aircraft are required to make an open transmission on

128.3 MHz reporting their position and intentions. This frequency is also monitored by the Parachute Zone Controller and the Crash and Rescue Unit. There is no evidence of any radio transmission on the accident flight.

1.10 Aerodrome and ground facilities

Netheravon is a grass aerodrome operated by the Army Air Corps. The aerodrome is also used by the Joint Services Parachute Centre which is based there. The aerodrome is 455 feet above mean sea level and, at the time of the accident, the runway in use was 06/24 which measured 579 metres by 33.5 metres. The runway was marked by 10 day-glow orange marker boards, placed at equal intervals, 5 each side of the centre line. Beyond the runway, in the take-off direction, 06, there is a further 1100 metres of unobstructed, gently undulating, grassland before the aerodrome boundary. At all times when parachuting is taking place, the Fire Station is manned and an ambulance is available 'on call'.

1.11 Flight recorders

The aircraft was not equipped with a Flight Data Recorder or a Cockpit Voice Recorder, nor were these required to be fitted.

1.12 Wreckage and impact information

1.12.1 Examination of the site

The aircraft was not examined on site but a thorough survey of the accident site itself was conducted after the aircraft had been removed. Witness marks revealed that the aircraft had struck the ground in a wings level attitude, about 215 metres beyond the end of runway 06. At the point of impact the ground was 3.25 metres below runway level, and sloping downwards at a gradient of 1 in 25. At first impact the aircraft was displaced about 15.5 metres to the right of the runway centre line and on a heading of about 068° (M). During the ground slide the aircraft had continued to slew to the right, and finally came to rest on a heading of about 080° (M).

The initial contact was made by both pairs of main wheels simultaneously. The aircraft then appears to have pitched sharply nose down, forcing the nose-wheel onto the ground, and at the same time both mainplanes twisted severely nose down relative to the fuselage, all the deformation occurring near the wing roots. The twisting of the wings allowed the belly of the aircraft and both propellers to strike the ground. The propellers cut the turf at 79 cm intervals on the port side, and 28 cm intervals on the starboard side. Assuming a groundspeed at impact of 50 knots, it is calculated that the port propeller was rotating at about 960 rpm and the starboard at about 2700 rpm at the time.

There was evidence that the port wing tip had struck the ground about 12.5 metres beyond the point of initial impact, and that the starboard wing tip had struck the ground another 7 metres further along. The aircraft slid for a total distance of 72 metres, coming to rest on its belly, with the starboard wing twisted about 30° nose down relative to the fuselage; the port wing was twisted nearly vertically nose down, partially severed at the wing root, and swept back to such a degree that the main wheels were displaced into the rear of the passenger cabin.

The salvage crew reported that, after the aircraft had come to rest, there was a considerable quantity of fuel in both starboard tanks and the port main tank, but that the port wing tip tank was ruptured and empty. There was a small stain on the grass where the port wing tip tank had come to rest, and a much larger stain in the area of the main tanks, where fuel had spilled during the salvage operation.

1.12.2 Examination of the aircraft.

The aircraft's wings had been removed during salvage, and all pipes, control cables, and wiring had been cut to allow their removal. The port engine, with most of its bearer frame, had been almost completely severed from the wing. Both wings had been severely distorted, twisting nose down near their root ends. The main fuselage structure was intact, but the nose-wheel support structure had collapsed, allowing the nose leg to fold rearwards. The baggage door on the port side had been stove in by the port main undercarriage wheels entering the fuselage during the ground slide. The port main cabin entry door was not fitted, as it is removed for all parachute flights. The tailplane showed evidence of overstress in down load, resulting in wrinkling of the under surfaces, near the tailplane roots, on both sides of the fuselage.

The flaps were found to have been in the retracted position at impact. The fuel settings, when examined, showed that wing tip fuel tanks were selected on both sides, and their associated indicator lights were selected OFF. The main fuel cock controls were selected to between 'on-normal' and 'crossfeed' on the port side, and to OFF on the starboard. The fuel cocks in the wings were found at 'crossfeed' on the port side, and OFF on the starboard. The electrically actuated TIP/MAIN change-over cocks in each wing were found to be in the TIP position.

The fuel lines within the wings were checked for obstructions and leaks and found to be satisfactory. Both air filters were found to be clean. The operation of the fuel cocks and non-return valves in the fuel pumps was also checked. It was found, whilst checking the operation of the fuel cocks, that, when a cock was at intermediate positions between 'crossfeed' and 'on-normal' all three ports were open, and, on the starboard fuel cock in particular, when turning from 'crossfeed' to 'on-normal' the cock had to be turned through 80° of a 90° travel, before the crossfeed line closed. The 10° of further travel in order to position the cock accurately at the 'on-normal' position, equated to 3.5 mm travel of the fuel cock operating mechanism.

When checking the auxiliary fuel pumps, it was found that fuel would flow in the reverse direction through the pumps when they were not electrically powered. (A series of tests to quantify potential fuel flow rates under various conditions is described in paragraph 1.16.3).

In a separate test, the starboard wing tip tank was set up at the approximate attitude it was in when the aircraft came to rest. This attitude was calculated from photographs taken immediately after the accident. The tank was filled with fuel to the level estimated by witnesses who had examined the tank contents before it had been de-fuelled after the accident. The quantity of fuel assessed to have been remaining in the tank was about 11 US gallons.

The engines were examined and, after some minor damage had been repaired, were run on a test installation. Although, on both engines, the power output obtainable in rich mixture was below that acceptable after an overhaul, the maximum possible power output obtainable by leaning the mixture was not checked. This check was not considered necessary because fully rich mixture running, only, was used throughout the accident flight. The engines both ran smoothly and operated satisfactorily at high power on single magnetos. The components damaged in the accident were checked and examined separately, and no evidence of any pre-impact defects was found.

The longitudinal crash switch, which isolates the cabin heater, was found to have operated on impact. It is set to operate at a nominal 3g.

1.13 Medical and pathological information

There was no evidence that any medical condition contributed to this accident.

1.14 Fire

There was no fire.

1.15 Survival aspects

All the occupants of the aircraft survived the accident without injury. The port passenger door of the Islander is removed for parachute dropping flights, and the parachutists vacated the aircraft via that door space. The pilot left the aircraft via the front door. The aerodrome Fire Brigade arrived at the scene of the accident one minute after the impact and, having ascertained that all occupants had vacated the aircraft, they removed the aircraft battery. Light water foam was then sprayed onto the hot engines, and a carpet of foam was laid around the aircraft. Units from the Wiltshire County Fire Brigade and Wiltshire Constabulary arrived at the scene within 22 minutes of the accident.

1.16 Tests and research

1.16.1 Fuel contents and consumption

The aircraft was de-fuelled and removed from the accident site before the investigation by AIB was commenced; the amount of fuel removed from the aircraft was not measured. However, it was established that the aircraft had been fuelled to capacity at Shobdon on 14 February 1982, and that no further refuelling had been carried out between then and the accident flight. The times and flight profiles of all flights carried out in the aircraft since it was fuelled to capacity were known. Therefore, in order to establish, as near as possible, the quantity of fuel remaining in the aircraft at the time of the accident, it was decided to fly similar flight timings and profiles in another Islander aircraft, and measure the amount of fuel consumed.

The flight trials were carried out in another Islander, model BN2A/8, which had been modified for parachute dropping. Live parachute drops were carried out from the trials aircraft on all flights simulating similar drops from the accident aircraft; thus, during the trials, the aircraft's weight was representative at all times. Although the trials aircraft was of a different model to the accident aircraft, the possible difference in the fuel consumption of the two models can be discounted. The manufacturer confirms that "as the fuel system is essentially the same for both aircraft types, (ie same engines, pumps, etc., except that with wing tip tanks the option exists to draw fuel directly from an alternative source), fuel consumption for the two types must be the same".

In order to achieve the best possible accuracy, the measurement of fuel consumed during the flight trials was done in two ways. Firstly, a measurement was made of the total fuel consumed by the test aircraft during the simulation of all the flights carried out in the accident aircraft since it was fuelled to capacity. Secondly, a separate measurement was made of the fuel consumed during simulation of those flights during which the accident aircraft was known to be flying with fuel supply selected exclusively from the tip tanks. The total fuel consumed during the complete flight trials was 107 US gallons. The total fuel consumed during the flights simulating fuel supply from tip tanks only was 43½ US gallons.

The pilot has stated that, before the accident flight, the aircraft's main tank contents gauges were indicating 35 US gallons port, and 30 US gallons starboard. Thus, by adding the 3½ US gallons per side of ungauged, unusable fuel, it can be assumed that the total contents of the main tanks at that time amounted to about 72 US gallons. Bearing in mind that 107 US gallons were consumed during the total flight trials simulation, it follows that some 17 US gallons would have remained in the tip tanks. However, if the fuel consumed during trials simulating flight with fuel supply selected from the tip tanks only (43½ US gallons) is deducted from the total tip tank contents of 59 US gallons (including 4 gallons of unusable fuel), the total quantity remaining in the tip tanks should have been 15½ US gallons. Due to operational factors during the flight trials, the second calculation is considered likely to be the more accurate.

1.16.2 Unusable fuel tests

The Flight Manual states that, due to attitude limitations, there are 2 US gallons of ungaugeable and unusable fuel in each wing tip tank. A series of tests were carried out to determine precisely the variation of unusable fuel with pitch attitude. The starboard wing tip tank from the accident aircraft was used.

The starboard wing tip tank was supported in a cradle which held it in a dihedral attitude equivalent to 1g wing bending. The cradle could be tilted to simulate changes in pitch attitude. After the tank had been completely drained, a measured quantity of water was put into the tank which was then pitched nose up to an attitude such that the spar webs were inclined 20° to the vertical. The nose attitude was reduced in stages and the contents allowed to run out into a calibrated container until flow ceased. The attitude of the tank during these tests was determined relative to a vertical angle bracket attached to the inboard tank closing rib. The manufacturer confirmed that the angle of this bracket relative to aircraft attitude is 2 degrees. The quantity that ran out at each stage was observed and recorded, and, knowing the initial contents, a graph of fuel contents remaining in the tank with varying pitch attitudes was constructed. Results of the tests are included in Appendix 2 (Graph A).

1.16.3 Fuel reverse flow tests

In order to determine whether it was possible for fuel to gravity feed from one side of the aircraft to the other, the main fuel system components were removed from the aircraft wreckage and re-assembled on a test bench. The two auxiliary fuel pump sets were connected opposing each other; firstly with no restriction between the outlets of the sets, and secondly with a main fuel cock installed in the line between the two pump outlets. The inlet of one set of pumps was fitted with a small reservoir, and the inlet of the other set with an open pipe discharging into a measuring flask.

The height of the reservoir was set to give a known head between the inlet and the discharge. Fuel was introduced into the reservoir and the fuel pipes were initially primed by electrically operating the pump set to which the reservoir was fitted. After priming the system the gravity flow rate was allowed to stabilize for about 10 minutes, and then the time taken for a fixed quantity (½ Imperial pint) to flow through the system was measured. The flow time was measured at three different heads in the port to starboard direction, and at one head in the opposite direction, with no restriction between the pumps. The flow time was next measured at one head in the port to starboard direction with the fuel cock interposed between the pumps.

In each case the fuel cock was installed with the engine feed port blanked off, and the pump outlets connected to the wing and crossfeed ports. The cock was then set by turning it from 'crossfeed' to a position about 10° short of the 'on-normal' detent. This equated to a cockpit selection of 'on-normal', allowing for 3.5 mm backlash in the cock operating chain and cable system, as found to be present on the accident aircraft.

The results of the tests were as follows:

	Head	Flow time (1 US gal)
Flow port to starboard (unrestricted)	24 in (61 cm)	4 hrs 10 mins
	16 in (41 cm)	6 hrs
	10 in (25 cm)	11 hrs 30 mins
Flow starboard to port (unrestricted)	24 in (61 cm)	4 hrs 30 mins
Flow port to starboard (fuel cock installed)	16 in (41 cm)	8 hrs 40 mins

The tests showed that back flow, under gravity, against the non-return valves in the fuel pumps could occur even with a severe restriction in the connecting line. When relating the head of fuel to aircraft roll attitude, considering the transfer of fuel from one wing tip to the other, a 24 inch (61 cm) head represents a bank angle of $2\,^1/_3{}^\circ$ from wings level; 16 inches (41 cm) represents 1½° and 10 inches (25 cm), $^2/_3{}^\circ$. These figures ignore the changes in fuel level in each tank as transfer takes place (see graph B at Appendix 2).

1.16.4 Determination of fuel head in tip tanks

The level of the fuel above the outlet pipe of the tip tank, with the tank in various attitudes, was measured over a range of fuel contents. The starboard tip tank from the accident aircraft was used for this purpose. To measure the fuel levels a manometer was connected to the tank outlet pipe and the tank installed in a pivoted cradle which held it securely in roll attitude. The results of the measurements are included in Appendix 2 (graph B).

1.17 Additional information

1.17.1 Islander fuel management

The manufacturer stipulates that, for structural considerations, a minimum of 13½ US gallons of fuel should be retained in each tip tank at all times, except that this fuel may be used as a reserve for flights to alternate airfields and holding. There is no prohibition on conducting take-off and landing operations with fuel supply selected from the tip tanks. The Flight Manual contains the instruction that the tip tanks should always be filled first and used last, and that take-offs and landings are prohibited when the contents of the main tanks read less that 3 US gallons above zero. The following placard is displayed on the Instrument Panel:

WING TIP TANKS – FILL FIRST, USE LAST

TAKE-OFFS AND LANDINGS ARE PROHIBITED ON MAIN TANKS

WHEN GAUGE READS LESS THAN THREE GALLONS ABOVE ZERO

A yellow sector is marked on the tip tank contents gauges to indicate the 13½ US gallon structural reserve fuel.

The pilots who fly the Islander for the Joint Services Parachute Centre have stated that they do not consider the tip tank contents gauges to be particularly accurate. It is their normal practice, whenever the tip tanks are full, to run down the contents of the tanks by timing, and, subsequently to dip the tanks to ensure that the correct structural reserve of fuel has been achieved. The tip tanks were rarely filled above the 13½ US gallon structural reserve, with the result that the pilots carried out the majority of their flying with fuel supply selected from the main tanks only.

The Flight Manual, in the 'Checks after Stopping', contains no instructions on switching the fuel selectors. It was the practice, at Netheravon, to leave the main fuel cocks at 'on-normal', ie wing to engine.

In April 1982, the AIB recommended to the CAA that a modification be made to the Islander tip tank selector switches in order to draw the attention of pilots to the fact that fuel supply is being drawn from the tip tanks.

1.17.2 Islander handling characteristics

The Islander is described, in the Flight Manual, as being easy to fly at all speeds and as having no unusual features. Pilots' reports confirm this description. The following changes of trim are quoted:

Flaps – TAKE-OFF to UP	Nose down tendency
Application of power	Large increases in power produce a marked nose-up tendency

The flap operating time from TAKE-OFF to UP is about 6 seconds. Dependent upon pilot technique the pitch attitude on take-off is normally between 12 and 15 degrees nose up.

Flight with the rear port door removed does not produce any abnormal handling characteristics; however, a manufacturer's flight test report on this flight condition contained the following information:

> 'Flight in this configuration produces a drag increase, sufficient to reduce the single engine rate of climb by approximately 50 to 70 ft/min at gross weight. The drag rise is not sufficient to embarrass any normal operation such as take-off or climb out on two engines.'

During the flight tests described in paragraph *1.16.1*, the opportunity was taken to check the total time of the accident flight. The average time from brakes off to climb to 50 feet above ground level was established as 23 seconds, and the time from 50 feet to touchdown as 11 seconds.

At an indicated airspeed of 65 knots, throttle closed and fully fine pitch selected, the propellers stabilised at 1200 revolutions per minute.

1.17.3 Stall warning

An electrically operated stall warning system provides visible and audible warning at a safe margin above the stall. The system was checked as part of the air test for the renewal of the Certificate of Airworthiness, at Shobdon, and operated satisfactorily. The scheduled stalling speed at a weight of 6,200 lbs (2812 kg), with the flaps retracted, is 49 knots indicated airspeed (IAS). On the air test, at this weight and configuration, the stall warning operated at 60 knots IAS. The stall warning system reportedly did not operate at the time of the accident.

1.17.4 Carburettor icing

A chart showing the probability of icing with a float type carburettor is included at Appendix 3. This shows that at the time of the accident, the meteorological conditions were conducive to serious icing at descent power. It should be noted that the accident aircraft's engines were at full power during the take-off, and that during the two flights immediately prior to the accident, in identical meteorological conditions, there had been no indications of the formation of carburettor icing.

1.17.5 Performance

The Islander is a twin-engined aircraft classified in Performance Group C. This Performance Group comprises twin-engined aircraft with a performance level such that a forced landing should not be necessary if an engine fails after take-off and initial climb. Single engine performance data for aircraft certificated within this Performance Group is presented assuming that both engines will be operating until a height of 200 feet. Accountability for engine failure below this height, either on take-off or landing, is not a requirement.

According to the aircraft's Flight Manual, under the accident conditions but with the flaps up and the propeller of the failed engine feathered, the aircraft should achieve a climb gradient of about 1½%. Removal of the port rear door would significantly reduce this gradient.

The Islander Flight Manual includes the following instructions concerning action to be taken in the event of engine failure: 'If an engine fails before take-off safety speed is reached, close the throttles and decelerate to a stop.' Instructions for handling an engine failure after take-off safety speed is achieved are also included, and detail the shut down and feathering drills to be carried out. Take-off safety speed at the weight of the accident aircraft was 58 knots. The port engine reportedly lost power at a speed of 73 knots.

The pilot on the accident flight was, in his primary occupation, flying as commander on Royal Air Force Hercules transport aircraft. This aircraft performs to the requirements of Performance Group A, a performance level that accounts for an engine failure at every stage of flight. The pilot, from his military training, could be expected to be well practised in handling engine failures during critical times on take-off. In particular, he had frequently practised, in flight simulators, the action to be taken in the event of failure of the critical engine after the (whether to stop or continue) decision speed had been reached.

1.17.6 Aircraft parking arrangements – Netheravon

The aircraft of the Joint Services Parachute Centre, Netheravon, are normally parked either in a hangar, on the hardstanding or grass outside the hangar, or, when parachuting is in progress, on the grass adjacent to the Parachute Centre. It has been established that G-BBRP was parked exclusively in these areas from the close of flying on 18 February 1982, when it was flown with fuel supply selected from the tip tanks and remained in that configuration, until the morning of 20 February 1982. The exact length of time during which the aircraft was parked in one particular position could not be established. However, it was established that, during this period, the aircraft was always parked in the same direction. The slope of the three parking areas was measured, with the following results:

Hangar floor	Slope varied between slightly less than one degree to two degrees – always right wing down
Hangar hardstanding and grass area	Slope varied between one and five degrees – always right wing down

Parachuting area	Slope varied between one and one half to five degrees — always right wing down.

1.17.7 *Parachuting operations*

All parachute operations at the Joint Services Parachute Centre, Netheravon, are conducted in accordance with the British Parachute Association and Army Parachute Association regulations. There is evidence that the latter are the more stringent. The selection and training of pilots is the responsibility of Headquarters No. 38 Group, Royal Air Force; however, all pilots must also be approved by the British Parachute Association as qualified to drop parachutists. The pilot of G-BBRP was so approved.

The fact that parachutists were on board the aircraft was not a causal or contributory factor to this accident.

2. Analysis

2.1 General

The accident was initially notified as a heavy landing following a double engine failure. It was soon apparent that the landing was indeed heavy, to the extent of causing irreparable damage to the aircraft.

The absence of stall warning suggests that the indicated airspeed at the time was not less than 60 knots. From this evidence and that of the propeller slash marks it was deduced that, at the moment the aircraft struck the ground, the port propeller was rotating at about 960 rpm and the starboard at about 2700 rpm. As flight tests have shown that, at 65 knots, with the propeller selected to fully fine pitch and throttle closed, the propeller windmills at 1200 rpm, it must be concluded that the port engine had failed prior to impact, but that the starboard engine was still rotating under power to an extent that it was not possible to quantify.

The subsequent detailed examination and test-bed running of the engines did not reveal any mechanical defects, although they did show that both engines were slightly down on power. It therefore became necessary to try to establish the reason for the loss of power of the port engine, why the pilot considered that both engines had failed, and why a well-trained and experienced pilot was then unable to land safely, straight ahead, with over 1000 metres of usable landing area in front of him.

2.2 The engine failure(s)

In view of the absence of evidence of mechanical failure, another possibility to be considered was carburettor icing. The relevant icing probability chart, Appendix 3, shows that, in the prevailing meteorological conditions, there was a probability of serious icing at descent power. However, it is not considered that, under take-off conditions at full power, carburettor icing was a likely factor. This was the third take-off, on the day of the accident, in identical temperature and humidity conditions, and carburettor icing had not been previously experienced. In addition, evidence from ear witnesses, who reported the sound of an engine spluttering before the accident, does not support the theory of carburettor icing, which would tend to produce rough running before failure.

There remains the possibility of fuel starvation; in this context the evidence concerning the quantity and distribution of the fuel remaining in the aircraft after the accident is significant. The subsequent flight tests revealed that the total quantity of fuel that could be expected to be in the two tip tanks at the start of the accident flight was about 15½ US gallons. Reliable evidence concerning the contents of the starboard tip tank immediately after the accident assesses the contents as 11 US gallons. The witness marks left by the spillage of fuel from the port tip tank were of the size that would be expected from a spillage of between 3 and 4 US gallons. Thus it would seem likely that, at the start of the accident flight, the tip tank fuel was distributed in the proportion of about 4 US gallons in the port tip tank and 11½ US gallons on the starboard.

Of equal significance to the distribution of the tip tank fuel contents is the evidence concerning the position of the TIP/MAIN tank selector switches and electrically operated change-over cocks. At the end of flying on 18 February 1982, the pilot of G-BBRP on that day reported leaving the fuel supply selected from the tip tanks. Immediately after the accident the aircraft's battery was removed. Examination of the aircraft some time after the accident revealed that the TIP/MAIN tank switches were still selected to TIP, and that the electrically operated change-over cocks were in the TIP position. As no electrical power could have been applied to the aircraft since the accident and subsequent removal of the aircraft's battery, the fuel supply must have been selected from tip tanks at the time that the engine failed. It follows that the fuel supply selection was almost undoubtedly left in the TIP position from the end of flying on 18 February until the accident at 1255 hrs on 20 February.

To achieve the out of balance distribution of fuel in the tip tanks, as found after the accident, required the transfer of 3¾ US gallons from the port to the starboard side tip tanks. The reverse flow tests demonstrated that a significant cross flow could take place between tip tanks, even if the aircraft was parked on a surface with a slope of as little as $^{2}/_{3}{}^{\circ}$. There is evidence that the aircraft was parked on slopes that were always greater than this throughout the period 18 to 20 February, and always with the right wing down. Thus, even if the tip tank fuel had been equally balanced when the aircraft was parked at the end of flying on 18 February, and there is no evidence that it was, it is highly probable that a significant transfer of fuel between tip tanks took place between that time and the time of the accident. In this context it should also be noted that such a transfer could not have taken place had the fuel selection been from main tanks, due to the lower head of fuel, nor could any transfer have taken place at all had the aircraft been parked with the main fuel cocks selected OFF.

Although there are no consumption figures available for ground running and take-off operations, it is reasonable to assume that at least ½ US gallon per side would have been consumed during the 5 minutes ground running and full power take-off and climb to 50 feet on the accident flight. The port engine failed at the 50 feet above ground point, by which time the estimated contents of the port tip tank would have been about 3½ US gallons. The unusable fuel tests showed that at a pitch attitude of 16° nose up, the unusable tip tank fuel is 3½ US gallons. Evidence from ear witnesses is of the sound of an engine 'spluttering', and then failing, which is characteristic of an engine failure due to fuel starvation.

2.3 Operational considerations

It is clear that the port engine eventually ran out of fuel because the pilot concerned had assumed that the TIP/MAIN switches were both selected to draw fuel from the main tanks, as had become the normal practice at Netheravon, whereas the previous pilot to fly the aircraft had left the switches at the TIP position to remind his successor that there still remained more than the required minimum of 13½ US gallons in the tip tanks. This confusion would not, of course, have occurred, had the pilots concerned been in the habit of switching the fuel selector to OFF after shutting down an engine. However, this action was not included in the 'Checks after Stopping' in the aircraft Flight Manual – presumably because the action was left to pilots' discretion. Although it is understandable that, in cases of high intensity flying, the action might be omitted, it is desirable that it should be included in the Flight Manual, as a general rule. In any case, as a matter of airmanship, the pilot concerned should, before each flight, have checked not only the fuel contents, which he apparently did, but also the position of the fuel selectors and switches. The tests undertaken in the course of the investigation proved almost conclusively that tip tanks *must* have been selected throughout the last day's flying; it was the pilot's duty to confirm that there was sufficient fuel for the flight in the tank(s) selected, and clearly he did not do so. The one check on fuel is largely useless without the other. As a further reminder to pilots, it is recommended that the TIP/MAIN switches be modified to draw pilots' attention to the fact whilst fuel is being drawn from the tip tanks.

From the pilot's account of the accident, it is apparent that, immediately he had diagnosed a failure of the port engine, his first reaction was to 'clean up' the aircraft and continue the climb out. This was an arguably justifiable decision, in view of the fact that his airspeed was some 15 knots above the single engine safety speed. However, after selecting the flaps up and as he was starting the shut down and feathering drills for the port engine, he gained the impression that the starboard engine had also failed. It has now been established that, in fact, this engine continued rotating under power until impact. However, if the pilot's reaction is examined against his background as a commander of a Performance Group A aircraft, his supposition that both engines had failed becomes more understandable.

If an engine fails in a Performance Group A aircraft, after the decision speed has been reached, the take-off must be continued. The pilot's military training ensured that he was well practised and prepared for this emergency. However, in a Performance Group C aircraft, such as the Islander, the actions in the event of an engine failure during the take-off and initial climb phase cannot be so clear-cut. Single engine performance is presented assuming that the propeller of the failed engine is feathered and the flaps are up. In fact, at the weight of the accident aircraft in this configuration, the Flight Manual shows that a shallow climb gradient of about 1½% should have been achieved. However, when the port engine failed on the accident flight, the propeller remained wind-milling and time was needed in which to feather it, the flaps were at the 'take-off' position, and performance had been further reduced by the removal of the rear port door. The combined effect of the sudden loss of power, the drag from the windmilling propeller, and the loss of lift as the flaps were retracted, may well have led the pilot to believe that he had lost both engines. In addition, flight with the door removed would have had the effect of making most of the engine noise appear to come from the port side, and the marked decrease in noise from that side following the failure could well have further added to the illusion. With hindsight it can be said that, knowing that he had over 1000 metres of unobstructed grass ahead of him, had the pilot taken the alternative decision and, immediately the port engine failed, landed straight ahead, the aircraft would probably have survived intact. It was also unfortunate that his first action, that of raising the flaps, made a difficult situation even more difficult to recover from.

Partial simulation of the accident flight has shown that, from the 50 feet above ground point to touchdown takes approximately 11 seconds. During this time the pilot would have had to make a large adjustment to the pitch attitude, from take-off to approach, and also handle a constantly changing trim situation. The sudden loss of power would have produced a marked nose down change of trim; this effect would have been increased by the retraction of the flaps over a period of about 6 seconds. In addition, there was probably a steady decrease in elevator effectiveness as the speed decayed on approaching the attempted flare. The pilot had very little time in which to judge the touchdown and failed to reduce the aircraft's rate of descent sufficiently to prevent a heavy landing. His subsequent actions in ensuring the safety of passengers, supervising the removal of the aircraft battery and re-entering the cockpit to complete the shut down drills are worthy of note.

3. Conclusions

(a) Findings

(i) The aircraft had a valid Certificate of Airworthiness and its documentation was in order.

(ii) The aircraft had been maintained in accordance with an approved maintenance schedule.

(iii) The pilot was properly licensed, well experienced, and qualified to drop parachutists.

(iv) The aircraft's port engine failed on take-off due to fuel starvation.

(v) The fuel starvation was caused by the pilot failing to ensure that there was sufficient fuel for the flight in the tanks selected.

(vi) The aircraft's starboard engine was rotating at governed rpm at impact; however, it has not been possible to quantify the power it was producing.

(vii) The pilot's initial decision to continue, and to raise the flaps, created a situation from which he was unable to recover and land safely.

(b) Cause

The accident was caused by the fact that the pilot was unable to reduce the aircraft's rate of descent sufficiently to prevent a heavy landing. Contributory factors were the loss of all power from the port engine due to fuel mismanagement and the pilot's decision initially to attempt to continue the take-off.

4. Safety Recommendations

It is recommended that:

4.1 The Islander TIP/MAIN selector switches be modified in order to draw the attention of pilots to the fact that fuel is being drawn from the tip tanks.

4.2 The Flight Manual be amended so that the checks after engine shut-down include the instruction to select the main fuel cocks to 'OFF'.

C C ALLEN
Inspector of Accidents
Accidents Investigation Branch
Department of Trade

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