AIRCRAFT ACCIDENT REPORT 3/2008

Air Accidents Investigation Branch

Department for Transport

Report on the accident to British Aerospace Jetstream 3202, registration G-BUVC at Wick Airport, Caithness, Scotland on 3 October 2006

This investigation was carried out in accordance with
The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996

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Department for Transport
Air Accidents Investigation Branch
Farnborough House
Berkshire Copse Road
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January 2008

The Right Honourable Ruth Kelly
Secretary of State for Transport

Dear Secretary of State

I have the honour to submit the report by Mr A P Simmons, an Inspector of Air Accidents, on the circumstances of the accident to British Aerospace Jetstream 3202, registration G-BUVC at Wick Airport, Caithness, Scotland on 3 October 2006.

Yours sincerely

David King
Chief Inspector of Air Accidents

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Appendices

GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	Air Accidents Investigation Branch
ADI	Attitude Direction Indicator
agl	above ground level
AIP	Air Information Package
AMM	Aircraft Maintenance Manual
amsl	above mean sea level
ARINC	Aeronautical Radio Inc
ATC	Air Traffic Control
ATIS	Aerodrome Terminal Information System
BITE	Built In Test Equipment
CAA	Civil Aviation Authority
CB	Circuit Breaker
CFIT	Controlled Flight into Terrain
CG	centre of gravity
cm	centimeters
CM	Configuration Module
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
CU	Control Unit
CVR	Cockpit Voice Recorder
DC	Direct Current
DME	Distance Measuring Equipment
EASA	European Aviation Safety Agency
EDX	Energy Dispersive X-ray
FAA	Federal Aviation Administration (USA)
FAF	Final Approach Fix
FAT	Final Approach Track
FCI	Flight Crew Instruction
FDR	Flight Data Recorder
FL	Flight Level
FLTA	Forward Looking Terrain Avoidance
fpm	feet per minute
ft	feet
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
hrs	hours (clock time as in 12:00 hrs)
hPa	hectopascal (equivalent unit to mb)
Hz	Hertz
IFR	Instrument Flight Rules
ILS	Instrument Landing System
in	inch(es)
km	kilometre(s)
kt	knot(s)
lb	pound(s)
LCD	Liquid Crystal Display
m	metres
MDH	Minimum Descent Height
MHz	MegaHertz
mm	millimetre(s)
MPS	Minimum Performance Standards
NITS	Nature of emergency, Intention of captain, Time remaining and Special instructions
nm	nautical mile(s)
PAPI	Precision Approach Path Indicator
PDA	Premature Descent Alert
PF	Pilot Flying
PNF	Pilot Not Flying
psi	pounds per square inch
QNH	pressure setting to indicate elevation above mean sea level
RA	Radio Altimeter
RMI	Radio Magnetic Indicator
rpm	revolutions per minute
SOP	Standard Operating Procedures
SEM	Scanning Electron Microscopy
STC	Supplemental Type Certificate
TAF	Terminal Area Forecast
TAWS	Terrain Awareness and Warning System
TCAS	Terminal Collision Avoidance System
UK	United Kingdom
US	United States
UTC	Co-ordinated Universal Time (the contemporary equivalent of GMT)
V	volts
V_{APP}	Approach speed
V_{REF}	Reference airspeed (approach)
VOR	VHF omni-range
Ω	ohm

Air Accidents Investigation Branch

Aircraft Accident Report No: 3/2008 (EW/C2006/10/03)

Registered Owner and Operator	Eastern Airways
Aircraft Type	British Aerospace Jetstream 3202
Nationality	British
Registration	G-BUVC
Place of Accident	Wick Airport, Caithness, Scotland
Date and Time	3 October 2006 at 1621 hrs Dates and times in this report are UTC unless otherwise stated.

Synopsis

The accident was notified to the Air Accidents Investigation Branch (AAIB) by Wick Air Traffic Control at 1800 hrs on 3 October 2006. The AAIB investigation team consisted of:

Mr A Simmons	Investigator-in-Charge
Mr M Ford	Flight Recorders
Mr P Hannant	Operations
Mr B McDermid	Engineering

The aircraft was on a scheduled flight from Aberdeen to Wick. It was the fourth sector of a six-sector day for the crew, during which there had been no significant delays. The crew flew the VOR/DME procedure for Runway 31, and became visual with the runway during the latter stages of the arc portion of the procedure. They configured the aircraft with the landing gear selected 'DOWN' and flaps set as required for the approach and landing. The commander, who was the Pilot Flying, flared the aircraft for touchdown at the normal height but as the aircraft continued to sink, he realised that the landing gear was not down. He carried out a go-around and, following a recycling of the landing gear, flew past the control tower. The controller confirmed that the landing gear was down and the aircraft diverted back to Aberdeen Airport where a safe landing was made. It was subsequently found that, during the go-around, the underside of the fuselage and the tips of the right propeller had contacted the runway surface.

The investigation found that contamination of the landing gear selector switch points had acted as an electrical insulator preventing current flow to the landing gear lowering system and audible warning systems. The three green landing gear indicator lights, which are independent of this circuit, had functioned correctly. The crew had not checked the indication prior to landing and were therefore unaware that the landing gear was retracted.

The investigation identified the following causal factors:

1. Mechanical wear and arcing across one of the poles in the gear selection switch resulted in a piece of cupric oxide acting as an insulator across the pole which should have energised the gear extension circuit.

2. The flight crew did not identify that the landing gear was not down and locked by visually checking the landing gear green indicator lights.

3. Due to the failures associated with the gear selection switch, the flight crew received no audible warnings of the landing gear not being in the 'DOWN' position.

As a result of the investigation, four Safety Recommendations have been made. Two of these were made at an early stage of the investigation to the US Federal Aviation Administration.

1. Factual Information

1.1 History of the flight

The crew reported to their operating base at Wick Airport in Scotland for a 10 hour duty day. They were to complete six sectors, operating between Wick, Stornaway and Aberdeen. The first 3 sectors were uneventful and there were no significant delays.

Following a normal turnaround, the aircraft departed Aberdeen on schedule at 1545 hrs for the 25 minute flight to Wick. The commander was the Pilot Flying (PF) and the co-pilot, who was also a qualified aircraft commander, was the Pilot Not Flying (PNF).

The flight was conducted under Instrument Flight Rules (IFR) at FL85 before the aircraft descended to join the VOR/DME[1] arc procedure for Runway 31. The weather was good with a visibility in excess of 10 km and the lowest cloud recorded at 2,300 ft.

The aircraft descended to the cleared altitude of 2,000 ft on the Wick QNH[2] of 1002 hPa. The airspeed was reduced to 180 kt and the aircraft joined the DME arc at approximately 8 nm in accordance with the procedure. The crew had expected to gain visual contact with the airport early in the approach but were unable to see it due to the cloud. The commander elected to continue with the procedure and at some point on the arc they were able to see the airport. Just before reaching the 140º VOR radial, airspeed was reduced to 165 kt and 10º flap, was lowered. On passing the 140º radial the aircraft was turned on to a heading of 330º to intercept the Final Approach Track (FAT) of 306º. A target altitude of 1,600 ft was set for when the aircraft became established on the final approach. At approximately 6.5 DME, the descent to 1,600 ft was initiated with the aircraft levelling at about 5.8 DME. Airspeed was reduced and as the aircraft decelerated through 160 kt the PF asked the PNF to lower the landing gear. The PF disconnected the autopilot, reset the yaw damper and continued to fly the approach manually. The PNF selected the gear down.

At the Final Approach Fix (FAF) at 5.5 DME, the PF selected the vertical speed mode of the autopilot and continued the descent. The PNF selected the flaps to 20º in accordance with the normal procedures. The PNF could not recall seeing the three green 'gear locked down' indicating lights but did

1 A VOR/DME procedure is an instrument landing procedure based upon VHF Omni-Range (VOR) and Distance Measuring Equipment (DME) navigation aids.

2 Sea level pressure (QNH), as provided by Air Traffic Control (ATC) and measured in hectoPascals (hPa).

not normally select the next stage of flap until they were visible. Following these actions the PNF read the landing checklist but the PF did not check the landing gear 'gear locked down' indicating lights as this was not required in the operator's Standard Operating Procedures (SOPs). He used the DME/altitude crosscheck table on the approach chart and noted that he was slightly high on the descent profile.

The PF could not see the runway Precision Approach Path Indicator (PAPI) lights and concluded that they were not illuminated. This was confirmed by the PNF although ATC had no record of them not being switched on. The runway was clearly visible and the PF adjusted the approach path visually. At approximately 3 nm from touchdown, the PNF asked the PF if he wanted landing flap selected. He agreed and landing flap 35º was lowered. The crew recalled that, at about 300 ft the Terrain Awareness and Warning System (TAWS) made a "500 ft" call. The PF checked the barometric and radio altimeters and both indicated approximately 300 ft. Whilst he thought this was strange he concentrated on controlling the aircraft on the final approach.

The aircraft crossed the threshold at the calculated V_{APP} speed of 130 kt reducing towards V_{REF} for touchdown. The PF flared the aircraft at the normal height, and allowed it to descend towards the runway. At the point the PF expected the aircraft wheels to touchdown, he sensed that he was lower than he should have been. This alarmed him and he glanced down to see that the gear selector handle was in the 'DOWN' position but no red or green indicator lights were illuminated. He immediately initiated a go-around and the PNF called "go-around" and raised the flap to the 10º setting. Neither of the flight crew had heard any audible warnings which should sound if the landing gear is not in the 'down and locked' position.

Witnesses on the ground saw the aircraft in the flare and realised that the landing gear was retracted. They saw a cloud of dust and then the aircraft climb away. The cabin attendant and the passengers heard a 'scraping' sound but no horn or other audible warnings.

In the climb, the PF instructed the PNF to action the Quick Reference Handbook (QRH) '*EMERGENCY LOWERING OF LANDING GEAR'* checklist. This required the use of the hydraulic hand pump. The PNF located the appropriate drill in the QRH and prepared the pump handle for use. At this point the PF considered recycling the landing gear selector handle. He selected the handle 'UP' and heard the noise of the hydraulics which then stopped. None of the red or green landing gear lights illuminated and so he selected the handle to the 'DOWN' position. The three red 'landing gear in transit' lights illuminated followed by the three green, landing gear 'down and locked' indicator lights.

Wick Air Traffic Control (ATC) cleared the aircraft to make a right hand circuit and perform a flight down the line of the runway in order for the controller to conduct a visual check of the landing gear position. He confirmed that the three landing gear were down. The crew then discussed returning to Aberdeen, as there was no engineering support at Wick. Shortly after this a message was passed by ATC from the operator requesting that the crew return the aircraft to Aberdeen providing they had sufficient fuel. At this stage, the crew were unaware that the aircraft had made contact with the runway, or sustained damage. Before departing for Aberdeen, the cabin attendant was briefed by the PNF on the situation. The cabin attendant in turn briefed the passengers that they would be returning to Aberdeen. The cabin attendant did not mention the scraping noise during the flare to the flight crew.

Having determined that sufficient fuel was available for the return flight with the landing gear down and that there was no indication of damage, the crew limited the airspeed to 160 kt and returned to Aberdeen. During the flight, Scottish ATC informed the crew that debris had been found on the runway and a 'PAN'[3] was declared. Prior to landing at Aberdeen the flight crew briefed the cabin attendant that they intended to carry out a normal approach and landing at Aberdeen but to prepare the passengers in case the landing gear collapsed. This was done, but a normal landing was made and the aircraft taxied safely to the parking stand.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	0
Minor/none	3	3	0

1.3 Damage to aircraft

The blade tips on the right propeller, aircraft pannier (baggage pod) and lower rotating beacon were damaged.

1.4 Other damage

There were minor scrape marks on Runway 31 at Wick.

3 A PAN is a state of emergency in which there is potential, but no immediate, danger to the aircraft or its occupants.

1.5 Personnel information

1.5.1 Commander

Male:	Aged 42 years	
Type of licence:	Airline Transport Pilot's Licence	
Flying experience:	Total all types:	3,596 hours
	On Type:	1,930 hours
	Last 90 days:	161 hours
	Last 28 days:	43 hours
Last LPC/IR:	30 March 2006. (Expiry 31 March 2007)	
Last OPC:	8 September 2006 (Expiry 31 May 2007)	
Line Check:	6 April 2006 (Expiry 30 April 2007)	
Medical:	Class One issued on 18 July 2006	

1.5.2 Co-pilot

Female:	Aged 50 years	
Type of licence:	Airline Transport Pilot's Licence	
Flying experience:	Total all types:	5,300 hours
	On Type:	2,700 hours
	Last 90 days:	55 hours
	Last 28 days:	30 hours
Last LPC/IR:	27 January 2006 (Expiry 31 January 2007)	
Last OPC:	1 June 2006 (Expiry 31 June 2007)	
Last Right Seat OPC:	1 June 2006 (Expiry 31 December 2006)	
Line Check:	20 February 2006 (Expiry 31 August 2007)	
Medical:	Class One issued on 18 April 2006 (Expiry 31 October 2006)	

1.6 Aircraft information

1.6.1 General information

Manufacturer:	British Aerospace PLC
Type:	Jetstream 3202
Aircraft Serial No:	970
Date of Construction:	1992
Certificate of Airworthiness:	Issued 6 March 2004, Valid until 5 March 2007
Certificate of Registration:	Issued 30 January 2001
Engines:	2 Garrett TPE-331-12UHR -7 turboprop engines

Propellers:	2 Dowty R333-4-82F12 variable pitch propellers
Total airframe hours:	15,497 hrs
Total airframe cycles:	15,298

1.6.2 Aircraft weight

The aircraft was last weighed at the Eastern Airways maintenance facility at Humberside Airport on 29 September 2006. With the pannier (baggage pod) fitted the basic weight was established as 10,527 lb and the Centre of Gravity (CG), with the landing gear extended, was 216.2 in aft of the datum point.

The aircraft takeoff gross mass from Aberdeen was 13,402 lbs and landing gross mass at Wick was 13,106 lbs. The aircraft's CG and operating weights were within the normal weight and CG operating limits.

1.6.3 Aircraft description

The Jetstream 3200 is a medium range twin turboprop aircraft with a pressurised cabin for 18 or 19 passengers. It is of a conventional metallic semi-monocoque construction and is equipped with hydraulically operated flaps and a tricycle landing gear. The aircraft can also be fitted with a belly mounted fibreglass pannier (baggage pod).

1.6.3.1 Landing gear

The hydraulic pressure for the lowering and raising of the landing gear is provided by two hydraulic pumps, one fitted to each engine. A gear selection switch is mounted on the pilot's lower centre panel and incorporates an electrically operated safety lock that prevents the gear being selected up on the ground. A gear position indicator is also mounted on the lower centre panel and provides a visual indication of each leg to establish if it is down (green) or in an unsafe condition (red). In the event of the failure of the normal hydraulic system, the gear can be lowered by operating a hand pump in the cockpit to provide hydraulic power through an emergency selector valve.

Movement of the gear selector switch applies electrical power to one of two solenoids in the hydraulic selector valve; these control the flow of fluid to the gear up and down circuits. When a gear selection is made the associated solenoid is continuously energised and a hydraulic pressure of 2,000 pounds per square inch (psi) is maintained in the hydraulic line. When a solenoid is de-energised the hydraulic lines, and associated jacks, are opened via the return lines to the hydraulic reservoir. With both solenoids de-energised the valve moves under spring pressure to a central neutral position, which isolates the hydraulic supply and opens the up and down lines, via the return lines, to the reservoir.

The main landing gear has a retracting/lowering radius rod with an integral downlock mechanism and a separate uplock, whereas the nose landing gear system uses a retracting/lowering jack with a separate uplock and downlock. The separate uplocks and downlock are operated by their own hydraulic jacks. A weight on wheels switch (squat switch) is fitted to the nose leg.

Microswitches are fitted to the uplocks and downlocks so that when each downlock switch closes, the associated green light on the gear position indicator will illuminate. If both uplock and downlock microswitches are open then the associated red indicator light will illuminate. If the downlock microswitch is open and the uplock microswitch is closed then the associated indicator light will be extinguished. See Appendix ‘A’.

A warning horn in the cockpit operates if the landing gear is not locked down and the flaps are selected down beyond 10^{o}, or the aircraft speed is less than 135 kt and the power levers are moved to idle.

Electrical power for the landing gear operating and warning systems is taken from the 28V DC essential busbar. The power for the landing gear control is taken from Circuit Breaker (CB) 1GA1, the landing gear warning from CB 1GA10 and the position indicator lights from CB 1GF1 (see Appendices ‘B’ and ‘C’).

When the landing gear selector switch is moved to ‘DOWN’ an electrical supply from the essential busbar circuit breaker (1GA1) energises the hydraulic selector valve down solenoid, via contacts 1 and 2 in the gear selection switch. Movement of the selector valve allows hydraulic pressure into the ‘extend’ lines and opens the ‘retract’ lines to the reservoir. This allows the nose and main landing gear uplock jacks to retract and release the landing gear. Dissipation of hydraulic pressure in the nose downlock causes it to move under spring pressure to the closed position. The nose landing gear retraction jack and the main landing gear radius rods continue to move and when fully extended the internal downlocks in the main gear radius rods engage. The downlock pin on the nose leg opens the downlock hook, which then closes to secure the leg in the down position. As each uplock unlocks, the corresponding microswitch closes causing the red warning light on the cockpit gear position indicator to illuminate. As the downlock engages the corresponding microswitch closes, the red light is extinguished and a green light illuminates.

Providing the squat switch is closed, an electrical supply from the essential busbar breaker (1GA1) will energise the solenoid in the gear selector switch and allow the selector switch to be moved to the 'UP' position. An electrical supply from the essential busbar breaker (1GA1) will then energises the hydraulic selector valve up solenoid, via contacts 2 and 3 in the gear selection switch. Movement of the selector valve allows hydraulic pressure into the up lines and opens the down lines to the reservoir. Hydraulic pressure causes:

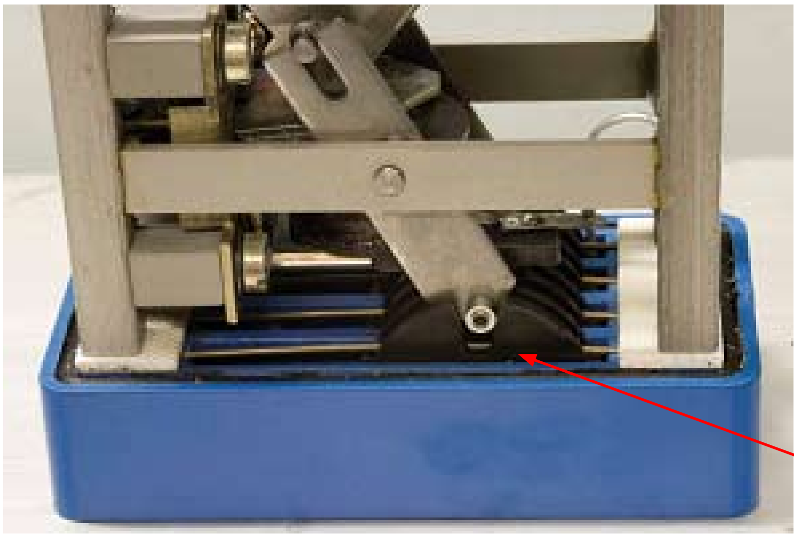
> The nose landing gear downlock jack to retract, which overcomes spring pressure to open the downlock hook and release the nose leg;
>
> The internal locks in the main landing gear radius rods to disengage;
>
> The uplocks to move to the closed position;
>
> The nose landing gear jack and main landing gear radius rods to retract.

As each leg retracts, its uplock pin opens the uplock hook and when the gear is fully retracted a spring closes the uplock to secure the gear in the up position. As each downlock unlocks the corresponding microswitch opens and on the cockpit gear position indicator the green warning light extinguishes and the red warning light illuminates. When the gear is in the retracted position the corresponding microswitches on the uplocks open and the red warning lights on the cockpit indicator are extinguished.

In normal operation with the gear in the retracted position, an electrical supply is provided to the up solenoid and hydraulic pressure at 2,000 psi is constantly supplied to the nose landing gear jack and the main landing gear radius rods. Consequently, there is a small clearance between the lower part of the uplock hooks and the operating pins. If both solenoids in the selector valve are de-energised then the hydraulic selector valve will move under spring pressure to a neutral position, which opens the up and down hydraulic lines to the reservoir. This causes a drop in hydraulic pressure in the landing gear jack, radius rods and nose downlock jack. The gear will, under gravity, start to droop until its movement is arrested by the operating pins coming into contact with the uplocks. The nose downlock will also move under spring pressure from the open to the closed position. However, the uplocks will not break and the gear will not extend until hydraulic pressure is applied to the extend circuits.

1.6.3.2 Landing gear selector switch

The landing gear selector switch is a four-pole device and each pole consists of a slipper contact that moves between three fixed contacts. The switch incorporates an electrically operated safety device that prevents an 'UP' selection being made when the aircraft is on the ground.



Slipper

Figure 1

Landing gear selector switch

The safety device consists of a spring lever and a solenoid. When the nose wheel is on the ground the squat switch is open and the spring lever prevents the selector switch being moved to the 'UP' position. Extension of the nose leg oleo causes the squat switch to close and electrical power to be supplied from CB 1GA1 to the solenoid via the switch contacts A and B (see Appendix 'B'). As the solenoid is energized the spring lever is drawn away from the selector switch, which can then be moved to the 'UP' position.

Only two of the four poles within the selector switch were used on G-BUVC:

> One pole takes electrical power from CB 1GA1 through contact 2. With the selector switch in the 'DOWN' position contact 2 is connected to contact 1 and power is provided to the 'down' solenoid in the hydraulic selector valve. With the selector switch in the 'UP' position contact 2 is connected to contact 3 and power is provided to the 'up' solenoid in the hydraulic selector valve.

The second pole takes electrical power from CB 1GA10 through contact 5. When the selector switch is in the 'DOWN' position contact 5 is connected to contact 4 and electrical power is provided to the TAWS. When the selector switch is in the 'UP' position contact 5 is connected to contact 6 and electrical power is provided to the power lever warning system.

Each of the contacts in the switch is plated with a layer of phosphor bronze, nickel, silver and gold. The thin gold layer is to prevent tarnishing of the silver layer whilst the switch is in storage and the silver layer is used for its good conductivity properties. The nickel is used to improve the switch's resistance to wear and to enhance the resistance stability of the contacts. The use of sliding contacts also ensures that the switch is self cleaning.

1.6.3.3 Radio altimeter

G-BUVC was equipped with a Sperry RT300[4] Radio Altimeter (RA) that provided height information over an operational range of 0 to 2,500 ft. The RT300 provides two DC analogue output voltage signals; precision and auxiliary. The auxiliary output signal conforms to the ARINC 552[5] standard and was interfaced to the TAWS. The RA incorporated a self test function, which swept the height between 0 and 100 ft.

1.6.3.4 Terrain Awareness Warning System

The aircraft was fitted with a SANDEL ST3400 TAWS computer which formed part of the TAWS. The system provided visual and aural warnings to alert the flight crew when the aircraft's flight path might result in Controlled Flight into Terrain (CFIT).

The system provides protection for the following modes)[6]:

- Mode 1: Excessive rates of descent with respect to terrain
- Mode 2: Excessive closure rate to terrain
- Mode 3: Negative climb rate or altitude loss after takeoff
- Mode 4: Inadvertent proximity to terrain and not in landing configuration

4 Sperry RT300; part number 7001840-912.

5 ARINC is an acronym for Aeronautical Radio Inc.

6 The Minimum Performance Standards (MPS) of the TAWS equipment was originally defined by Federal Aviation Administration (FAA) document TSO-C151b. Subsequently the Joint Aviation Authorities (JAA) issued a virtually identical document, JTSO-C151 and later the European Aviation Safety Agency (EASA) published ETSO-C151a. These performance standards stipulate minimum alert envelopes for each of the modes.

- Mode 5: Excessive descent below ILS glideslope
- Mode 6: Audio callout at 500 feet above terrain
- Premature Descent Alert (PDA)
- Forward Looking Terrain Avoidance (FLTA)

The TAWS is an enhancement of the Ground Proximity Warning Systems (GPWS) which have been available since the 1970s. A limitation of GPWS is that they do not have a 'look-ahead' function; if an aircraft is flying towards steeply rising terrain, the system may not be able to detect it in time to enable an avoiding manoeuvre to be performed. TAWS has addressed this by providing two predictive warning modes:

- Forward Looking Terrain Avoidance - an alerting algorithm that uses databases of terrain and runways, together with aircraft position and heading data, to look forward of the aircraft and provide an alert to terrain hazards.

- Premature Descent Alerting - an alerting algorithm that uses a runway database, aircraft height and aircraft positional information to provide an alert when the aircraft is too close to the ground in relation to its distance to the nearest runway.

In addition, TAWS also provides the flight crew with improved situational awareness, providing them with a display of the terrain ahead and to either side of the aircraft.

1.6.3.5 SANDEL ST3400

The SANDEL ST3400 is a multi function unit; it incorporates a TAWS computer, Radio Magnetic Indicator (RMI) and Terminal Collision Avoidance System (TCAS) display option, with information being displayed on an integrated liquid crystal display (LCD) screen. Display selections and configuration settings are made using soft keys which are located around the periphery of the screen. The unit is packaged within a standard[7] three inch instrument chassis and was mounted on the flight crew's main instrument panel on G-BUVC.

7 ARINC 408, 3ATI form factor.

The ST3400 TAWS warning modes relied upon the following parametric information:

- Height above terrain (from RA);
- Airdata (altitude, airspeed and air temperature);
- Aircraft position (from GPS on G-BUVC);
- Heading;
- Flap position;
- Gear position (from gear handle);
- ILS glideslope and localiser.

In addition, the FLTA, PDA and terrain display functions also rely upon a data base that provides terrain, obstacle and airport information.

The unit can be interfaced to a wide range of avionics systems. The ST3400 RA interface can accept data from one of up to nine different types of analogue RA source;

- Bendix/King KRA405;
- Collins ALT-50/50A;
- Collins ALT-55;
- Collins 339H-4/4A;
- Collins DRI-55;
- Sperry RT220/221 (precision output);
- Sperry RT300 (precision output);
- Sperry RT221 (ARINC 552 output);
- Sperry RT300 (ARINC 552 output).

When interfaced to a Collins ALT-55 RA, the ST3400 configuration setting should be set to 'ALT55'; for a Sperry RT300 RA, as fitted to G-BUVC, the setting would be '552'. For each of the avionics that the ST3400 is interfaced to, the unit must be configured to enable the incoming data to be correctly processed.

To configure the ST3400, a menu system is accessed through the display. Configuration settings may be manipulated using the front mounted keys and then stored to a non-volatile memory[8] within the unit. Up to fifteen maintenance pages may be accessed, eleven of which must be entered to ensure the unit has been correctly interfaced to the aircraft. As an aid to in-service equipment changes, the ST3400 is provided with an external non-volatile memory device,

8 Non-volatile memory: a type of electronic memory device that retains information without electrical power being applied to it.

named the Configuration Module (CM). The CM is a small removable device that can be connected to the rear of the unit. Its purpose is to enable the transfer of configuration settings from one unit to another, removing the need to manually enter each setting when a replacement unit is being fitted to the aircraft.

The ST3400 is also equipped with a Built In Test Equipment (BITE) function. The BITE will enable a self test of the display and aural warnings, as well as identifying if either RA or GPS data is not available at any time. If RA data is lost, warning modes 1 through 6 will be disabled and a '**GPWS FAIL**' message will be displayed. For GPS data loss, the FLTA, PDA and terrain display functions are disabled and a **'TAWS FAIL'** message will be generated.

If the ST3400 is to operate correctly, its configuration settings must reflect the avionics with which it has been interfaced. Although the unit incorporates BITE, it is beyond the capability of the system to determine if the unit has been correctly configured; this would need to be accomplished through a suitable operational test of the TAWS.

The ST3400 also incorporates a data recording function, capable of storing up to 10 hours of data into a non-volatile memory at a rate of 1 Hz. Data is stored in a proprietary format, with sections of data being automatically erased after each power cycle of the unit.

1.6.3.6 TAWS Installation

The aircraft had been equipped with a GPWS system, but this was replaced in August 2007 with the TAWS. G-BUVC was the first of the operator's four Jetstream 32 aircraft to be modified, with the installation being carried out by the operator at its engineering facility in Humberside. The installation of the system was accomplished under a European Aviation Safety Authority (EASA) Supplemental Type Certificate (STC), held by a United States Federal Aviation Administration (FAA) approved design organisation; EMTEQ Engineering.

During the installation, the operator had noted that the aircraft was equipped with a Sperry RT300 RA, but the STC instructions were to set the SANDEL ST3400 RA configuration setting to 'ALT55'. Not sure if the setting was correct, the operator contacted EMTEQ Engineering by telephone, upon which they were advised that the setting should be changed from 'ALT55' to the correct setting of '552'. The operator made a note of the change and reported that the new setting was used to continue with the installation. The TAWS subsequently passed the STC ground tests and the aircraft was returned to service.

Shortly after the accident, it was found that the ST3400 RA configuration setting was set at ‘ALT55’. It was not possible to determine whether this setting had been made at the time of installation, or subsequently. It was also discovered that the STC test of the TAWS RA would not have highlighted this incorrect setting. At heights of up to 500 ft, the signal characteristics from both RA’s (Sperry RT300 and Collins ALT-55) were almost identical. The RT300 self test did not extend the height beyond 100 ft. The consequence of setting ‘ALT55’ was that the ST3400 would start to noticeably over-read at heights above 500 ft; the effect on TAWS warnings is discussed in detail in paragraph 1.6.3.8.

After the accident, EMTEQ Engineering corrected the ST3400 RA setting to ‘552’ on G-BUVC. A Service Letter (SL) was also issued, advising operators to carryout a check of the ST3400 RA setting and to perform a test of the TAWS across the entire RA operational range.

1.6.3.7 Collins ALT-55 and Sperry RT300 RA interface

The Collins ALT-55 and Sperry RT300 RA (ARINC 552) analogue output signals do not have the same characteristics; the signals start to significantly differ at heights above 500 ft (see Figure 2). At an output voltage of 16.4 V, an RT300 would indicate 930 ft, whereas, an ALT-55 would indicate 2,500 ft.

1.6.3.8 Effect of setting the SANDEL ST3400 to ‘ALT55’ when interfaced to a Sperry RT300 RA.

If the SANDEL ST3400 is interfaced to a Sperry RT300 RA, and the ST3400 RA configuration is set at ‘ALT55’, the ST3400 height will start to noticeably over-read at heights greater than 500 ft (see Figure 3).

The over-reading of the RA height by the ST3400 will have the following effects on the TAWS warning mode envelopes[9]:

- Mode 1: Excessive rates of descent with respect to terrain.

  At heights less than 500 ft, the warning envelope will not be affected. From 500 to 2,500 ft, the aircraft may have attained a higher rate of descent than specified by the Minimum Performance Standards (MPS), without triggering a warning. At a height of 1,000 ft, the MPS specified warning limit is 2,360 feet per minute (fpm); this trigger point will be increased to 4,900 fpm.

9 Warning envelope limits specified by the MPS.

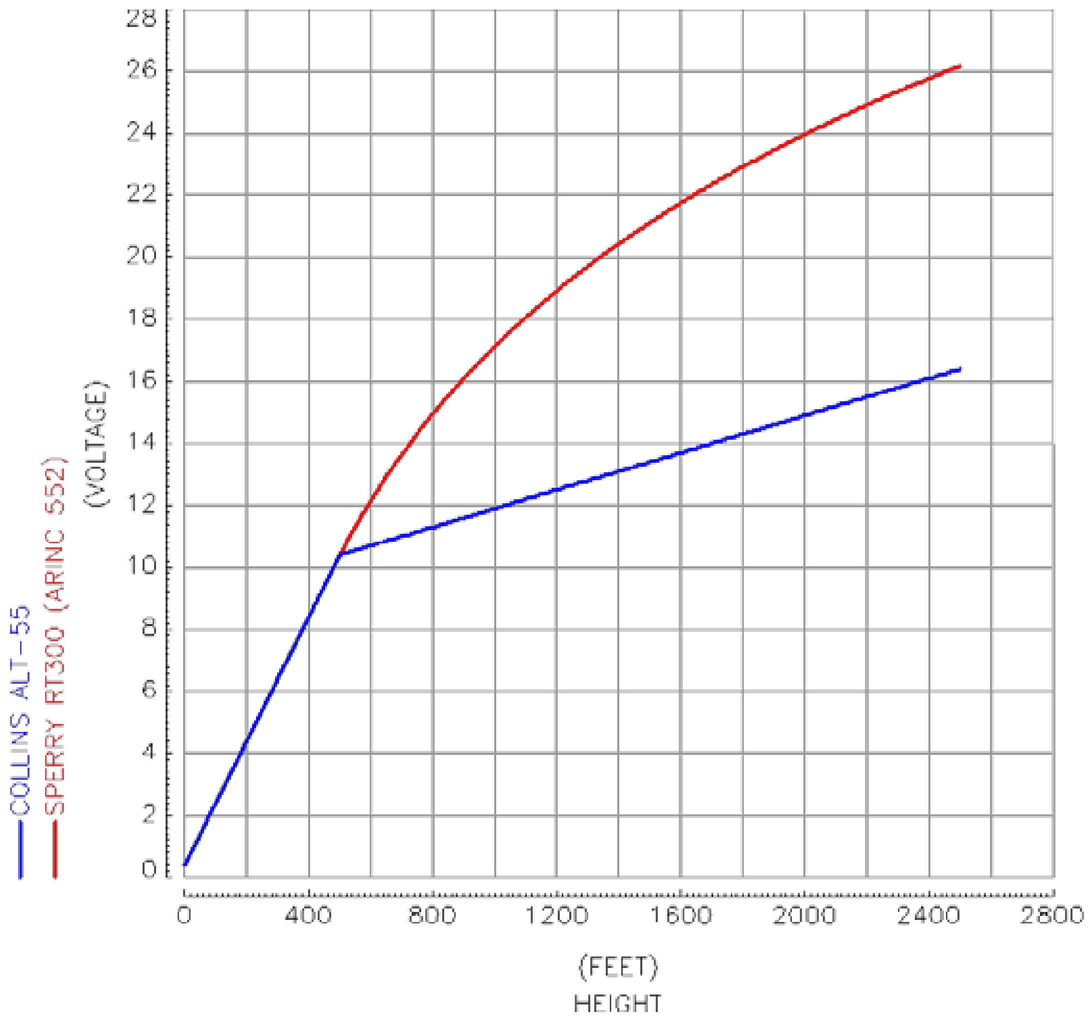


Figure 2

Sperry RT300 – Collins ALT-55 Voltage/Height

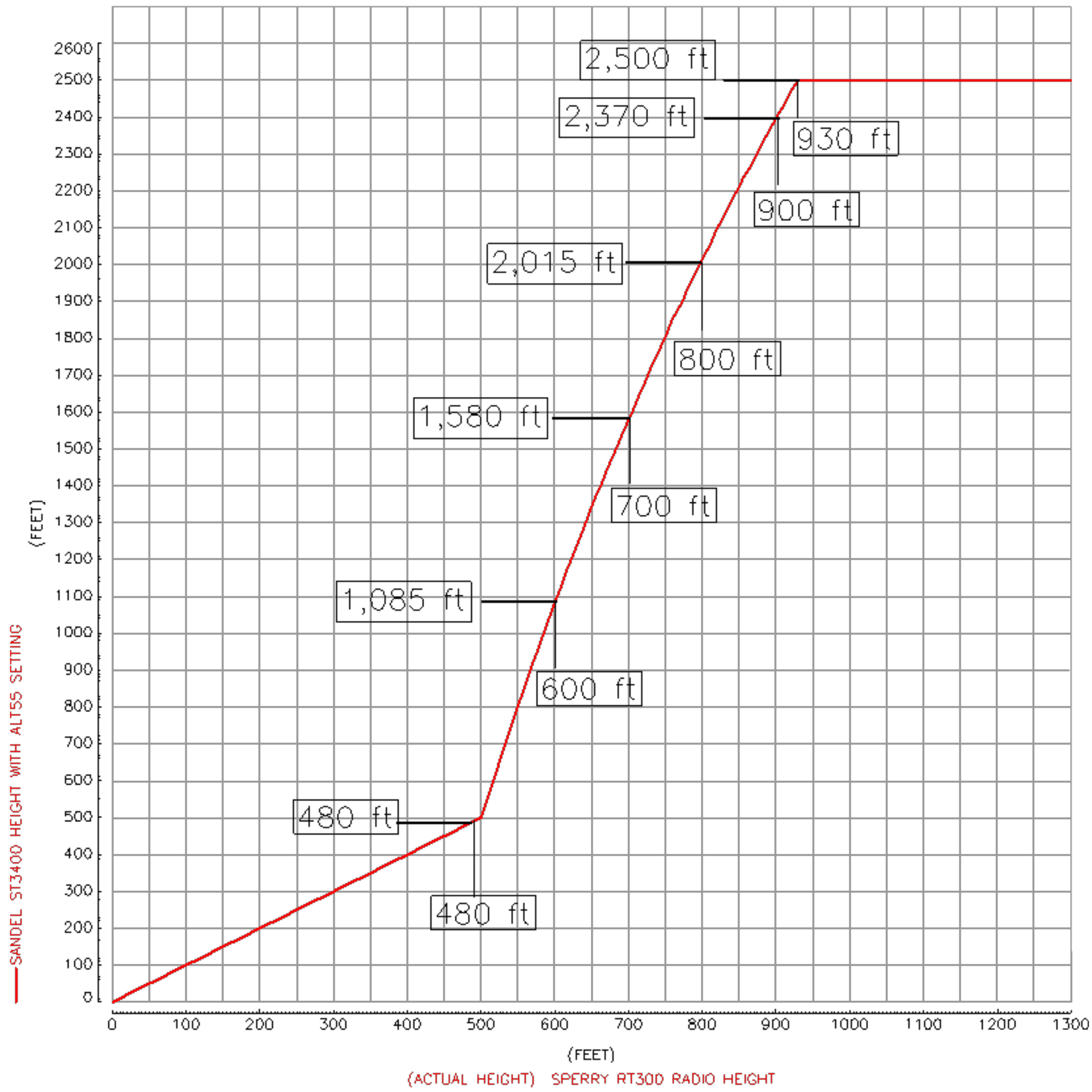


Figure 3

SANDEL ST3400 height/actual height

- Mode 2: Excessive closure rate to terrain

  Mode 2A (flaps not in landing configuration) and Mode 2B (flaps in landing configuration irrespective of landing gear position). At heights below 500 ft, the warning envelope will not be affected. From 500 to 2,500 ft, the aircraft may have attained a higher rate of terrain closure than specified by the MPS. Mode 2B should provide protection from a height of 900 ft and below, this will be reduced to 570 ft and below.

- Mode 3: Negative climb rate or altitude loss after takeoff

  The mode will provide protection up to a maximum height of 770 ft; this will be reduced to 545 ft.

- Mode 4: Inadvertent proximity to terrain and not in landing configuration

  No effect; the warning envelope will not be affected as the envelope height ranges from 50 to 500 ft.

- Mode 5: Excessive descent below ILS glideslope

  The effective height of the envelope will be reduced; from 1,100 ft to 585 ft.

- Mode 6: Audio callout at 500 ft above terrain

  The audio callout will not be affected.

- Premature Descent Alert

  No effect; RA is not used by the ST3400 PDA function.

- Forward Looking Terrain Avoidance

  No effect; RA is not used by the ST3400 PDA function.

As a result of these issues, on 14 November 2006, the AAIB made two Safety Recommendations to the FAA, as follows:

It is recommended that the US Federal Aviation Administration review the technical data supporting STC SA3020AT for the introduction of the Sandel ST3400 TAWS to ensure that the post installation test is sufficient to validate the full range of inputs into the system. (Safety Recommendation 2006-135)

It is recommended that the US Federal Aviation Administration take immediate action to ensure that aircraft equipped with the Sandel ST3400 TAWS have the correct radio altimeter type set and that the system is tested to ensure that the radio altimeter signal is correct over the operating range specified in the Sandel ST3400 installation manual. (Safety Recommendation 2006-136)

1.6.3.9 ST3400 Data Download

The ST3400 was taken to the manufacturer to enable them to download and process the recorded data. The download was successful, however, the accident flight was found to have been overwritten.

1.6.3.10 Supplemental Type Certificate approval

An STC is a document that is issued by a National Aviation Authority that approves a modification to an aircraft. Any additions, omissions or alterations to the aircraft's certified layout, built-in equipment, airframe and engines, that are initiated by any party other than the Type Certificate holder, need an approved STC.

STC approvals for European registered aircraft are issued by EASA. Part of the approval process includes a technical review of the submitted modification. The review may extend to an evaluation of the first of type installation, prior to the STC being issued. Once the STC has been issued, any amendments to the modification must then be classified as either 'major' or 'minor' modifications. For each modification amendment, the Design Organisation and its relevant National Aviation Authority would jointly determine whether the amendment constituted either a major or minor change to the original modification; a major classification would be appropriate if the amendment had the possibility of affecting airworthiness, a minor change would be one that has no appreciable effect on the weight, balance, structural strength, reliability, operational characteristics, or other characteristics affecting airworthiness. If the amendment was classified as major, EASA approval would be required, but minor amendments may be approved by the local aviation authority, which for EMTEQ Engineering was the FAA.

In 2005, EASA received an STC approval request from EMTEQ Engineering. The request was for a modification to fit a TAWS to Jetstream 31/32 series aircraft, which were operated by Highland Airways in the UK. The TAWS modification equipped the aircraft with the SANDEL ST3400, which was interfaced to a Collins ALT-55 RA. Before issuing the STC, EASA tasked the UK Civil Aviation Authority (CAA) to carry out a technical review of the modification. In January 2006, the CAA completed an extensive appraisal of the system, which included attendance at the first installation. After successful ground and air tests, the CAA issued a Technical Visa to EASA and an exemption certificate to the operator; the Technical Visa confirmed that the CAA had completed its technical review and that EASA may proceed to issue the STC; the exemption certificate enabled the aircraft to return to service with the modification fitted, pending the issue of the EASA STC.

In May 2006, the modification was amended by EMTEQ Engineering to include the operator's four Jetstream 32 aircraft. The amendment included wiring changes to interface the ST3400 to the Sperry RT300 RA, rather than the Collins ALT-55 which had been fitted to the Highland Airways aircraft. The amendment was classified as 'minor' and approved by the FAA. The modification was released to the operator with the ST3400 RA set to 'ALT55', rather than the correct setting of '552'.

EMTEQ Engineering later advised that the ST3400 RA setting had been an oversight. When queried about the 'minor' classification of the amendment, they advised that the 'minor' classification had been determined as being appropriate as the SANDEL ST3400 equipment was certificated to operate with either the Collins ALT-55 or Sperry RT300 RA.

The CAA was consulted with regards to the 'major' and 'minor' classification that the amendment had received. The RA can be considered as providing a fundamental input to the TAWS, and in view of this, the use of an alternative RA may have been classified as 'major' by them. However, the classification would have been dependant upon the analysis of existing data that may have demonstrated the alternative RA was suitable. This may have required both ground and flight tests to ensure proper operation with the RT300 RA, although it may also have been possible that a 'minor' classification could have been substantiated with appropriate data. The CAA also pointed out that the Technical Visa they had issued to EASA was for the validation of the TAWS modification that utilized the Collins ALT-55 interface, although, since the amendment was classified as 'minor', there was no requirement for the CAA to review the updated modification.

1.7 Meteorological information

The Terminal Area Forecast (TAF) for Wick (EGPC) at 0950 hrs valid until 1800 hours was: Wind 330º/12 kt; visibility 10 km or more; cloud scattered at 1,800 ft and 3,500 ft; temporarily between 1800 hrs and 0800 hrs visibility 6,000 m in showers with broken cloud at 1,200 ft.

The Wick Aerodrome Terminal Information System (ATIS) report current at the time of arrival was information 'Victor' timed at 1550 hrs; Runway 31 was in use with the surface wind 360º/11 kt, visibility in excess of 10 km, scattered cloud at 2,300 ft and broken cloud at 3,300 ft. The temperature was +11ºC with a Dew Point of +7ºC and QNH 1002 hPa; the runway surface was dry.

1.8 Aids to navigation

Instrument approaches are conducted using procedures set out in the UK Air Information Package (AIP) and approved by the UK CAA. The approach procedure being used was based on the WIK VOR which is located at N58º 27.53' W003º 06.02' and radiates on the frequency 113.6 MegaHertz (MHz). The DME is co-located with the VOR and is frequency paired. The approach being used was the VOR/DME approach to Runway 31 which is a non-precision approach with a Minimum Descent Altitude (MDA) of 450 ft corresponding to a Minimum Descent Height (MDH) of 340 ft. Aircraft approaching from the south establish on a DME arc at 8 nm and minimum altitudes are set to which an aircraft may descend depending on its position on the arc and subject to ATC clearance.

When passing the WIK 140º radial, the aircraft should turn left to intercept the Final Approach Track of 306º. When established on the FAT aircraft may be descended to 1,600 ft on the aerodrome QNH. The Final Approach Fix is located at 5.5 nm, at which point the aircraft may descend in accordance with the vertical profile of the approach. Cross check altitudes are provided every 1 nm after the FAF to assist the pilot in maintaining a nominal 3º glidepath. The FAT is offset 6º right of the runway centreline which is 312º Magnetic. The Missed Approach Point is abeam the WIK VOR. If the crew establish the required visual references during the approach then the aircraft may continue to a visual landing.

1.9 Communications

The Wick ATC utilises a single frequency of 119.70 Mhz, for both approach and tower control. A single Air Traffic Control Officer was controlling the aircraft at the time of the accident. There were no communication difficulties which might have contributed to the accident.

1.10 Airport information

Wick Airport is located at N58º 27.53 W003º 06.58 and has an elevation of 126 ft. There are two runways aligned 13/31 and 08/26. The main runway is 13/31 and Runway 31 was in use at the time of the accident. It is 1,825 m long with a width of 45 m and has a grooved, asphalt surface with a 0.02% downslope. The threshold elevation for Runway 31 is 114 ft.

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder system

The cockpit voice recorder system consisted of a Cockpit Voice Recorder (CVR) and a Control Unit (CU) with an integral area microphone. The system provided up to four separate channels of audio recording. Audio was recorded from the commander's and first officer's position and the cockpit area microphone. The CU with integral area microphone was located on the forward instrument panel in the cockpit and the CVR was located in the rear equipment bay, near the empennage.

The CVR fitted was a Model A100 manufactured by L-3 Communications. The A100 is an endless-loop magnetic tape device that records an audio signal for a minimum period of 30 minutes of continuous operation; voice recordings beyond 30 minutes of continuous operation are erased by being overwritten with new audio.

1.11.1.1 CVR data

The CVR was removed from the aircraft and replayed at the AAIB. Due to the duration of the flight from Wick to Aberdeen it was found that the accident at Wick had been overwritten. The CVR recording commenced from when the aircraft was on approach to Aberdeen.

Although the accident had been overwritten, the recording confirmed that the crew had discussed the accident in some detail during the return flight to

Aberdeen. The flight crew both confirmed that they had not heard a warning from either the TAWS or flap/landing gear warning systems.

1.11.2 Flight Data Recorder system

The flight data recording system consisted of a Flight Data Recorder (FDR) and remote FDR failure indicator. The FDR was located in the rear equipment bay, near the empennage, and the FDR failure indicator was located on the upper centre instrument panel in the cockpit.

The aircraft was certificated to be fitted with an L-3 Communications FDR Model F1000 part number 703-1000-00. There was no certificated alternative. However, the recorder fitted to G-BUVC at the time of the accident, and subsequently removed by the AAIB, was manufactured by Honeywell and had a part number 980-4100-GWUS.

Both these models of FDR combined the parameter acquisition and recording functions and were capable of storing a minimum of 25 hours of data. The recording media for the FDR actually fitted was magnetic tape whilst that for the recorder that should have been fitted was solid state. Physically the units were of the same form and fit; both utilised the same standard cases and the same type of electrical and pneumatic connections.

Airspeed and altitude data was provided by pneumatic feeds (from the standby altimeter and airspeed indicators) and the remaining parameters were wired electrically to the unit. At the time of the accident the design of the recording system was compliant with JAR-OPS 1.720 and recorded a total of 29 parameters, although it should be noted that the system was not required to, and did not, record any parameters from the landing gear system.

The FDR fitted to G-BUVC was equipped with a Built In Test Equipment (BITE) system. It was beyond the capability of this BITE to determine if the unit had been fitted to an aircraft for which it was not intended, so when an FDR aircraft installation test was carried out there would have been no indication of a system failure.

1.11.2.1 FDR data

The FDR, part number 980-4100-GWUS, was removed from the aircraft for replay at the AAIB. At a very early stage in the investigation the AAIB became concerned that the wrong part number of FDR may have been fitted and this was later confirmed with the Type Certificate holder, BAE Systems.

Due to significant differences between the electrical interfaces of the two FDR types, not all of the 29 parameters were recorded. Engineering conversion documentation was also not readily available due to the wrong FDR having been fitted, although airspeed and altitude were later converted to engineering units in order to assist the investigation.

1.11.2.1.1 Initial approach and go-around

Altitudes are above mean sea level (amsl) unless otherwise stated. After a short flight of about 16 minutes, the aircraft started its descent for Wick Airport. The aircraft levelled at 2,000 ft, before starting its final descent. When at about 50 ft above ground level (agl), the airspeed started to reduce from 114 kt. Over the next 8 seconds the airspeed and altitude both progressively reduced, until at 90 kt, the aircraft started to climb away, eventually levelling at 2,000 ft.

1.11.2.1.2 Fly past – return to Aberdeen

The aircraft then made a subsequent approach, descending to a minimum altitude of 240 ft. The aircraft then climbed away, landing at Aberdeen 36 minutes later. The total flight time was 1 hour 11 minutes.

1.11.2.2 FDR part number 980-4100-GWUS installation

G-BUVC entered service with the operator in March 2001, joining an operation that included seven BAe Jetstream aircraft (two 31 and five 32 series aircraft). Differences in recording system designs required the operator to stock at least three different FDR part numbers to service its fleet; 980-4100-GWUS, 17M703-274 and S703-1000-00; which was the only one specified by BAE Systems that could be fitted to G-BUVC.

In October 2001, the operator wanted to ascertain if it was possible to equip G-BUVC with an alternative FDR. The operator, after obtaining confirmation from an FDR repair facility, updated its stores system to reflect that part number 980-4100-GWUS was an alternative to S703-1000-00. Unfortunately, the part numbers were not interchangeable on G-BUVC. In addition, part number 980-4100-GWUS was not approved for fitment to the aircraft, as neither the operator nor the repair facility held the necessary approvals to authorise an alternative FDR. The operator advised that they did not have a formal procedure for the control of alternative parts at the time, but this has since been addressed.

Between 2001 and July 2006 part number 980-4100-GWUS was fitted to G-BUVC on four separate occasions; for a period of eight months in 2003, five months in 2004, thirteen months commencing June 2005 and for less than one month commencing 18 September 2006.

In July 2006, the FDR had been removed for an annual readout[10]. Part number 980-4100-GWUS was removed and part number S703-1000-00 fitted. The readout was performed by the same repair facility that had provided the alternative part number information in 2001. During the readout process the repair facility found that it was unable to convert the data to engineering units using documentation supplied by BAE Systems. On 30 July 2006 the repair facility provided a report to the operator detailing the recording deficiency and advising them that it believed that part number 980-4100-GWUS should not be fitted to G-BUVC. The operator promptly checked its fleet, ensuring that only BAE Systems specified part numbers were fitted. The operator had then intended to rectify their stores system, and remove the alternate part information; however, this task had not been performed by the time of the accident.

As an annual readout of the FDR from G-BUVC was still required in order to satisfy continued airworthiness requirements, in August 2006 the operator again removed the FDR for readout. The FDR was replaced with the same part number; S703-1000-00 but on 18 September 2006 the FDR failed and part number 980-4100-GWUS was issued as an alternative fitment. The FDR remained installed until it was removed by the AAIB as part of the investigation.

On 17 October 2006, following the incident to G-BUVC, the operator corrected its stores system and removed the erroneous alternate part number information.

1.12 Wreckage and impact information

1.12.1 Impact marks

Witness marks indicate that G-BUVC had been in contact with the surface of Runway 31 at Wick for approximately 84 m (see Figures 4, 5 and 6). The marks started approximately 6 m from the intersection of Runway 26 and were slightly to the left of the runway centre line. The first contact was made by the lower rotating beacon followed by three separate scrape marks which had been made by the pannier. There were 87 propeller slash marks, 42 cm apart, over the last 37 m of the contact area. The marks from the pannier and propeller stopped at the same point on the runway.

10 All UK operators are required to perform an annual readout of the FDR to ensure the recording system and those parameters recorded by it are serviceable.

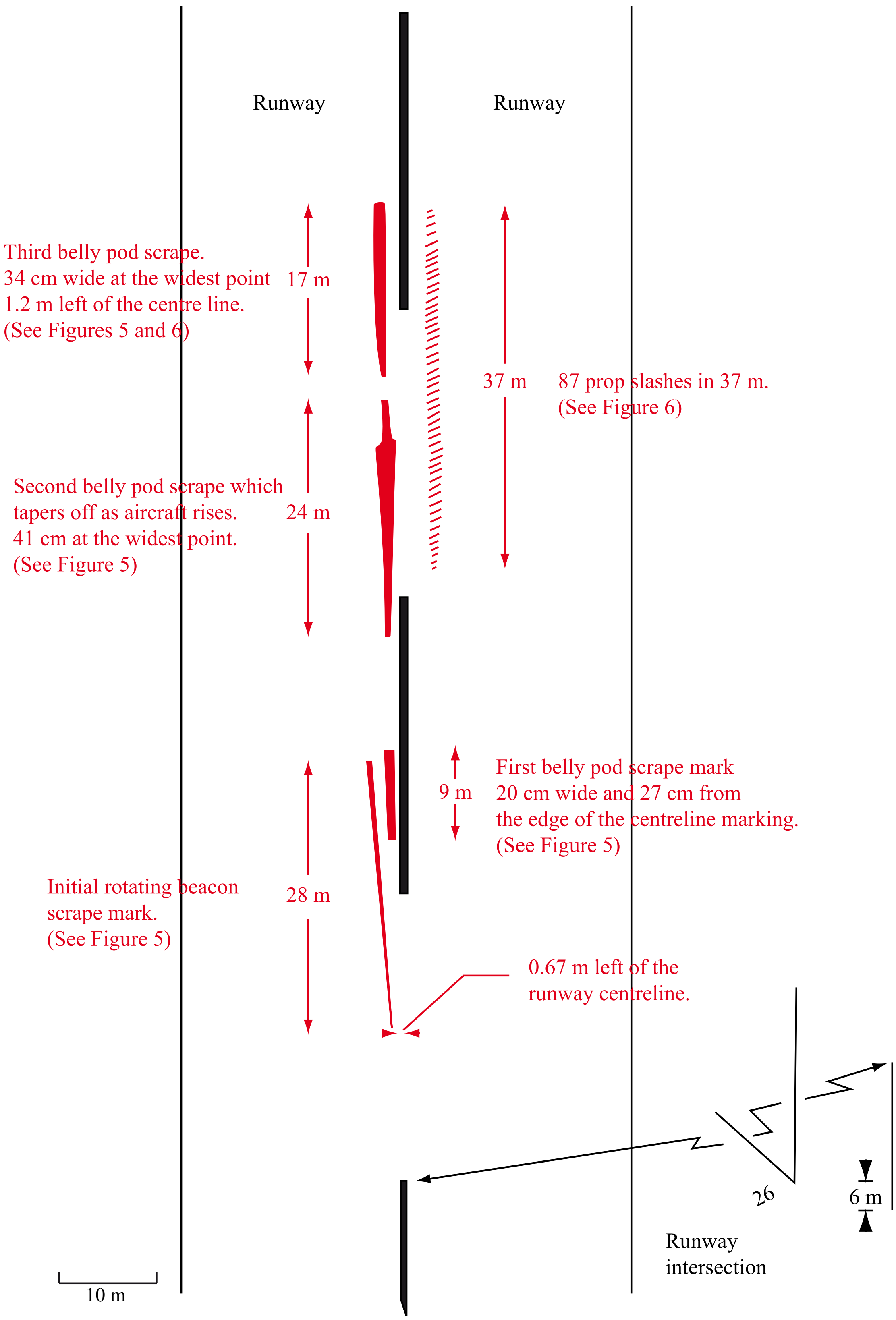


Figure 4

Runway Witness Marks

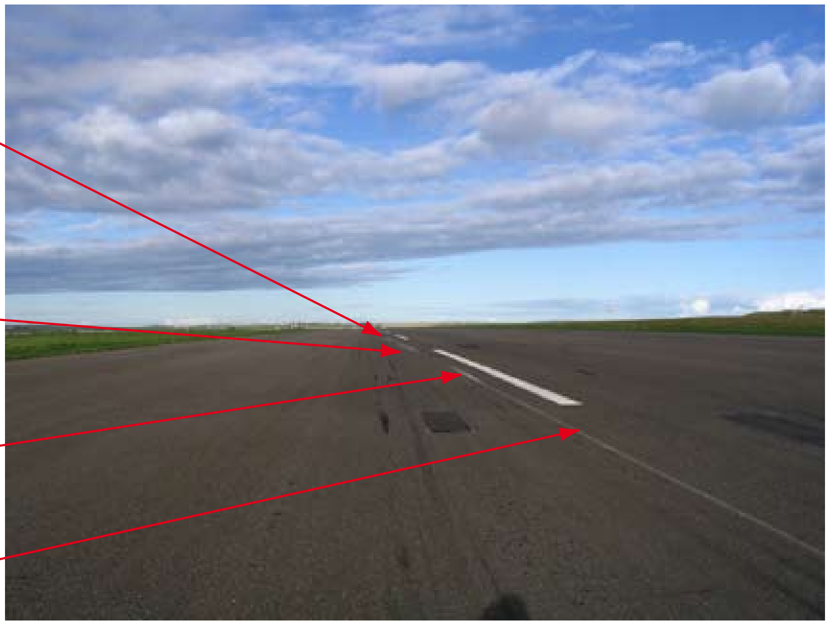


Figure 5

Pod and beacon scrape marks

Figure 6

Pod scrape and propeller slash marks

1.12.2 Examination of the aircraft

The aircraft had been recently painted and appeared to be in good condition.

The outer 9 cm of all the blade tips on the right engine had bent backwards by approximately 110°; the bend started at 12 to 13 cm from the tips. The end of all the blades were scored and did not appear to have been bent either forward or backwards, which suggests that the engine was producing relatively little power when the blades contacted the runway.

Figure 7

Damage to propeller blade tips

There were several small dents on the right flap which might have been caused by parts of the runway surface being thrown up by the propeller. An area on the bottom of the pannier, in line with the rear spar, approximately 40 cm long and 46 cm wide had worn through the gel coat and the first layer of fiberglass: the wear was slightly more extensive on the right side of the pannier. There was also a small crack on the top left side of the pannier just forward of the wing leading edge.

Figure 8

Damage to pannier

The lower anti-collision light cover was missing and the forward face of the mounting pylon had pulled away from the fuselage. It was estimated that approximately 1.5 cm of the mounting pylon had been either worn away or bent over.

Figure 9

Damage to anti-collision beacon

1.13 Medical and pathological information

Not applicable.

1.14 Fire

None.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

1.16.1 Landing gear systems

Functional tests of the landing gear operating, indicating and warning systems were carried out in accordance with Aircraft Maintenance Manual (AMM) Chapter 32-30-00 and AMM Chapter 32-6-00 201. The tests identified no faults in any of these systems, which all operated satisfactory.

1.16.2 TAWS

Using the information in the Sandel ST3400 Installation Manual 82002-IM-J1 and the configuration set in the ST3400, connector P2 was disconnected from the ST3400 and the signals at Pin 14 and 44 from the gear and flap discretes were checked and found to be of the correct voltage and sense. With connector P2 fitted to the ST3400, the logic voltage required by Maintenance Page 6 (which identifies the logic levels required for specified gear and flap positions) was checked against the position of the gear and flap selector levers. The logic levels were correct for all positions of the gear and flaps.

A radio altimeter test signal was fed into the ST3400 by pressing the test button on the pilot's Attitude Direction Indicator (ADI), which swept the height through 0 to 100 ft. The height readout on both ADIs and on Maintenance Page 8 in the ST3400 manual corresponded at all times during this test. A radio altimeter test set was then used to feed a signal into the radio altimeter and ST3400. The readout on the ADIs and ST3400 were the same until 500 ft when they started to deviate such that with a test signal of 1,000 ft the ADIs read 1,000 ft and the ST3400 read 2,748 ft. On checking Index 8 on the ST3400 Maintenance Page it was established that the radio altimeter type had been incorrectly set to Type 55 in the ST3400. The radio altimeter type was changed to Type 552 and when retested the readout on the ADIs and the

ST3400 corresponded at all times. The system configuration that was set in the ST3400 is recorded at Appendix D.

A full test of the ST3400 was carried out in accordance with the procedure in Chapter 7 of the Installation Manual, with both radio altimeter Type 55 and 552 set in the ST3400. The following note was at the start of Chapter 7.2.17, which details the procedure to test the radio altimeter interface.

> *'**Note**: The Radar Altimeter test may be performed by pressing the Radar Altimeter self test button, or by utilizing a Radar Altimeter test set. This manual references the use of the Radar Altimeter self test button and does not provide the information to setup and test the Radar Altimeter with a test set. For those applications utilizing relying on the use of a Radar Altimeter Test set, the operator should consult Radar Altimeters manufacturers test setup and procedures for operation of the test set. The test that will be performed to validate the ST3400 TAWS/RMI operation with the Radar Altimeter will be tests defined below.'*

The test was undertaken using the test button on the pilot's ADI to generate a radio altimeter test signal. The test was run twice and all the signals met the pass criteria with the ST3400 configured for a Type 55 and Type 552 radio altimeter and the test results are at Appendix E.

1.16.3 Full functional test

A full functional test of the TAWS and the landing gear warning and indicating system was undertaken in the maintenance hangar at Aberdeen. During the test the aircraft was placed on jacks and a hydraulic rig was used to pressurize the hydraulic system, a pitot static test set was used to set the barometric altitude and aircraft speed, and a radio altimeter test set was used to set the radio altimeter. All the aircraft avionics were switched on and the radar set to standby. The ST3400 was configured as per the accident flight and Type 55 was set as the radio altimeter. Information provided by the commander and data taken from the Wick approach plates were used to determine the key height and speeds at which the flaps and gear were lowered.

The test was run with: the gear and flaps up; gear up and flaps correctly configured; and with the gear and flaps correctly configured. During all three test runs the gear deployed correctly and the TAWS and gear warning and indicating systems displayed the correct aural and visual warnings.

1.16.4 System isolation tests

A number of tests were undertaken on the aircraft in an attempt to reproduce the symptoms described by the pilot when he commenced the go-around.

1.16.4.1 Test 1

Hydraulic power was applied to the aircraft and the gear and flaps were moved to the retracted position. The electrical plugs were removed from the hydraulic solenoid valve and the power levers were moved to the fully forward position. When the flaps were moved beyond 10^{o} the warning horn sounded and would not cancel. The warning horn also sounded, but would cancel, when the power levers were pulled back to idle.

1.16.4.2 Test 2

Hydraulic power was applied to the aircraft, the gear and flaps were moved to the retracted position and the power levers moved fully forward. With the electrical plugs connected to the hydraulic solenoid valve, jumper leads were used to connect electrical power to connection 2 and 3 on the selector switch, which applied electrical power to the up and down solenoids. There was no movement of the landing gear.

The gear was then selected down; the gear did not move and none of the gear indicator warning lights illuminated. When the flaps were moved beyond 10^{o} the warning horn sounded and could not be cancelled. The power levers were then pulled back to idle, and at this point the warning horn sounded. It was possible to cancel the warning horn.

1.16.4.3 Test 3

Hydraulic power was applied to the aircraft, the gear and flaps were moved to the retracted position and the power levers moved fully forward. Circuit breaker 1GA1 (gear control) was pulled out. When the gear selector lever was moved to down:

- The gear did not move.
- The ST3400 input went to 25v, gear down.
- The gear indicator lights did not illuminate.
- The warning horn did not sound when the flaps were moved to 20^{o} then 35^{o}.

- The warning horn did not sound when the power levers were moved to idle.
- The gear selection switch could not be moved back to the up position.

1.16.4.4 Test 4

Hydraulic power was applied to the aircraft, the gear and flaps were retracted, and the power levers were moved to the fully forward position. As CB 1GA1 was pulled a loud 'clunking' noise could be heard from the nose gear bay and the aircraft shook slightly on the jacks. At the same time the engine note on the hydraulic rig changed suggesting that the hydraulic load had changed. The noise and the shaking of the aircraft also occurred when the CB was reset.

The noise was caused by the movement of nose leg downlock under spring pressure and the shaking of the aircraft was caused by the landing gear settling on to the uplocks. When the CB was pushed back the nose leg downlock again made a clunking noise as it moved to the release position and the aircraft shook as the gear moved off the uplocks.

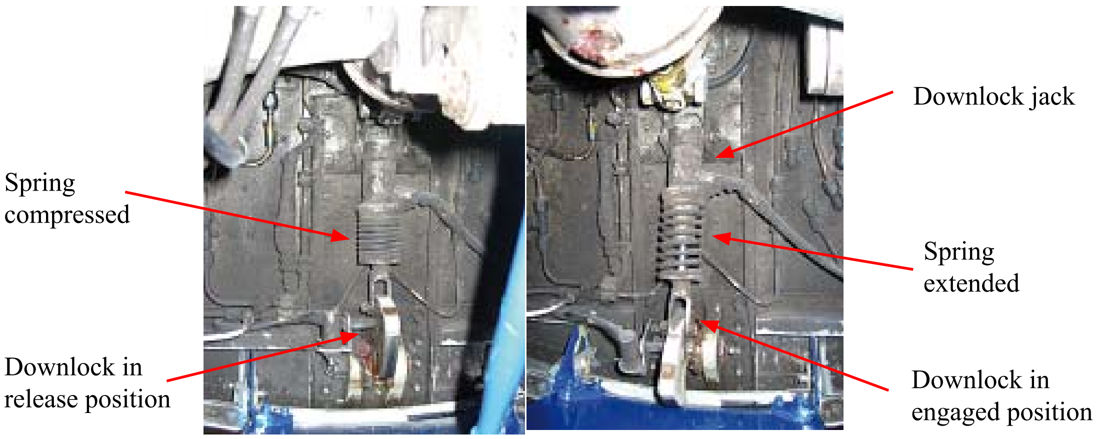


Figure 10

Nose leg downlock

1.16.5 Hydraulic selector valve solenoids

1.16.5.1 On aircraft testing

The aircraft manufacturer carried out the coil suppression checks of the solenoids in the hydraulic selector valve whilst they were still fitted to the aircraft, under the supervision of the AAIB and in accordance with the relevant design data (BAe Drawing No 866108).

The test established that the up solenoid had a peak transient voltage of -120 volts (v) and a resistance of 78.2 ohm (Ω), and the down solenoid had a peak transient voltage of -60 v to -100 v and a resistance of 75 Ω. The drawing specified a maximum allowable peak voltage of -180 v. Whilst the transient voltages were within the specified limit, which indicates that the suppression had not broken down, the test deviated from the test schedule requirement that the solenoids should be cycled 100 times before the readings were taken; moreover the oscilloscope available did not have the specified bandwidth or input impedance and capacitance. As it was not possible to fully test the hydraulic selector valve whilst it was fitted to the aircraft it was decided to remove the selector valve for further testing.

1.16.5.2 Testing at overhaul facility

The hydraulic selector valve was returned to an overhaul facility where it was tested in accordance with the Acceptance Test Schedule in Section III of Drawing 86622 and the Solenoid Assembly Drawing 866108. The results of the tests were as follows:

Test	Acceptable Limits	Solenoid A	Solenoid B
Coil resistance at 32 V DC	Min 71.25 Ω Max 78.75 Ω	77.2 Ω	73.8 Ω
Installation between coil and frame at 500 V DC	Min 20 MΩ	30 GΩ	26 GΩ
Residual magnetism. Operate solenoids 10 times at 32V and no hydraulic pressure	Armature should not stick	Pass	Pass
Pressure test	No leaks	Pass	Pass
Operation of solenoids at 1000, 2000, 4000 and 5400 lb/in^2.	Solenoid should operate drawing a maximum of 0.16 A	Fail	Pass
Solenoid load test	Lift not less than 5.25 lbs at an applied current of 0.16 A	Pass	Pass

Solenoid A failed the Operation test at a pressure of 5,400 lb/in^2 and would only operate, intermittently, when the current was raised to 0.19A. Further testing established that solenoid A would only operate satisfactorily when the current had been raised to 0.3A (24V). In comparison solenoid B passed the test at a pressure of 5,400 lb/in^2 with a current of 0.16A (10V).

1.16.5.3 Testing at AAIB

Further tests were undertaken at the AAIB facilities to establish the properties of the resistive capacitor and to undertake a suppression test of both solenoids in accordance with Drawing 866108. The results of the tests were as follows:

Test	Acceptable Limits	Solenoid A	Solenoid B
Resistance of suppressor	3 KΩ	2.27 KΩ	2.19 KΩ
Capacitance of suppressor	Minimum of 0.20 µF	0.3 µF	0.36 µF
Peak voltage when solenoid operated at 28.5 V	-180V	-170 V	-120 V
Rise time for voltage spike	0.1 milliseconds	Fail 0.5 milliseconds	Fail 0.45 milliseconds

The test proved that whilst the peak voltage was within acceptable limits, the capacitance of each suppressor was slightly high and the voltage rise time was too long. This discrepancy would, however, reduce the peak voltage and therefore reduce the likelihood of arcing.

1.16.6 Landing gear selection switch

The landing gear selection switch (serial number 107-91) was returned to the Design Authority where it was tested, under the supervision of the AAIB, in accordance with the production test schedule 1076Z2.

The switch passed all the mechanical and electrical checks that included: continuity, insulation and voltage drop tests. Whilst the outside of the switch was very dusty all the seals were intact and the inside of the switch was clean. There was also no evidence of any foreign objects or mechanical damage to the switch and all the parts operated correctly. It was noted that the contacts at the end of each of the four switches had sustained a significant amount of wear. It was also noted that there was a blackish deposit along the track of contacts 1, 2 and 3 and evidence of metal splatter and arcing between contacts 1 and 3 and the end of the sliding contact.

The Design Authority stated that they had not overhauled any of these switches for 7 years and the engineer who stripped and tested the switch had not seen one for about 10 years. They, therefore, felt they were not in a position to say if the black deposit was normal.

1.16.7 Metallurgical examination of the landing gear selector switch

A metallurgical examination of the landing gear selection switch was carried out by a QinetiQ Forensic Engineering Team to identify the composition of the black powder and to quantify the extent of the wear on the electrical contacts. QinetiQ was provided with the switch from G-BUVC (serial number 107-91) and a second switch from G-CBDA (serial number 91-91), which had flown for 12,710 hrs and 16,162 cycles.

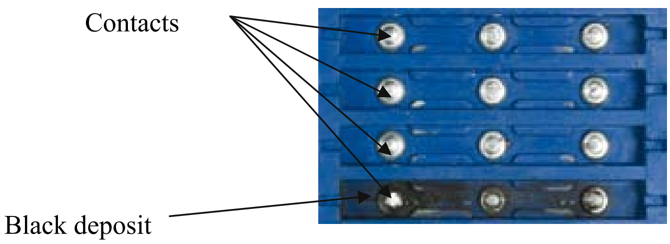


Figure 11

Contacts within the landing gear selector

A sample of the black deposit from both switches was analyzed using Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray (EDX) techniques. The analysis revealed that the black powder consisted of a large range of particle shapes and sizes many of which were spherical in shape. The major constituents in the powder from switch 107-91 were silver, gold and copper, with lesser amounts of the elements tin, silicon, oxygen and carbon. In addition to these elements, nickel was also found in the black powder taken from switch 91-91.

Drawing 1076Z16, which was provided by the switch Design Authority, specified that the fixed and sliding contacts were constructed of four layers consisting of phosphor bronze, silver, nickel and gold. An SEM and EDX examination of the slipper (see Figure 1) associated with contacts 1, 2 and 3 from each switch determined that whilst switch 91-91 conformed to the drawing, the nickel layer was missing from switch 107-91.

All the fixed contacts in switch 107-91 displayed evidence of heavy wear and varied in height by 0.1 mm. There was also evidence of localized melting at fixed contacts 1 and 3. The heights of the fixed contacts were measured relative to the top of the switch base to establish if the combination of wear and deposits of black powder on the raised lands was sufficient to cause the sliding contacts to break contact with the fixed contact. It was concluded that the combination of the wear and deposits on the lands would have been insufficient to cause a break in the contacts.

Examination of the sliding contacts from both switches revealed evidence of heavy wear on all the contacts and evidence of localized melting at the ends of the sliding contacts that touched the fixed contacts 1 and 3. The silver layer on the fixed and sliding contacts had worn away and contact across the switch was achieved through the copper sub-layer.

The black deposit was not of sufficient thickness to determine its electrical properties. Nevertheless, QinetiQ surmised that the spherical particles were an indicator that the powder had experienced high temperatures and the black colour suggested that surface oxidization of the metal particles had occurred to give silver oxide, cupric oxide and carbon (graphite). Whilst silver oxide is a good conductor, cupric oxide is known to have a high resistivity. From reference documents the specific resistivities (in ohms per cubic centimetre) of the materials was determined as:

Silver	$1.59 \times 10^{-8}\ \Omega/cm^3$
Copper	$1.68 \times 10^{-8}\Omega/cm^3$
Cupric oxide	0.104 to $0.51\ \Omega/cm^3$

QinetiQ calculated that the surface area of each contact is approximately 7 mm^2. A good metal contact would have negligible resistance, whereas a 0.1 mm thick layer of cupric oxide would have a resistance of approximately 5 Ω. If the contact area was less, due to wear, then the resistance would be significantly greater than 5 Ω.

QinetiQ concluded that a one-off failure of the switch may have been caused by a combination of poor surface contact due to wear and arcing and a build up of the black powder that contained cupric oxide.

1.17 Organisational and management information

1.17.1 Standard Operating Procedures

The operator had adopted Standard Operating Procedures (SOPs) from the procedures set out in the manufacturer's Flight Manual for non-precision approaches and landing checks, and included them in the company Operations Manual. They were as follows:

> ***'2.5.22 Non-Precision Approach***
>
> *Outbound, reduce speed to 150 kt and select flap 10º. Passing the F.A.F. inbound start the stopwatch, select gear down and Flaps 20º and initiate descent to minima, speed 130 kt. When landing is assured, select Flaps 35º.*
>
> *Below 200 ft reduce speed to achieve the appropriate speed at the threshold'.*

The landing checks were carried out by the PNF. The company Operations Manual at Para 2.3.1 requires the PF to 'monitor' the 'calls and actions' of the PNF but no requirement is placed on the PF to 'confirm' the actions. In the case of lowering the landing gear, the expanded normal checklist simply states:

> *'Gear……………………3 Greens'*

The company procedure as understood by the flight crew, was for the PNF to lower the landing gear when requested by the PF. The PNF then checked that the three greens illuminated on the landing gear position indicator.

1.17.2 Terrain Awareness Warning System crew training

The TAWS had recently been installed in G-BUVC and the operator had not, at the time of the accident, developed a crew training programme. There was no Flight or Operations Manual Supplement issued setting out the operation, limitations or capabilities of the system.

On 1 November 2006, a Flight Crew Instruction (FCI) for the J31/32 aircraft type was issued by the Flight Operations Manager Scotland. Included with the FCI was a copy of the Sandel ST3400 TAWS/RMI Pilot's Guide. The FCI stated:

> *'Please find enclosed a self-briefing pilot's guide to the TAWS system fitted to the Jetstream 32. Note that the version fitted to our aircraft does not have the Traffic Capability function; TCAS information continues to be displayed on the EVSI*
>
> *In particular please study the tabular presentations on pages 47/48 "Responding to an (EGPWS) Alert". Where a difference exists, clarification should be taken from FCI Operational 07/2006 GPS WARNINGS, or the J31/32 Part B1 where appropriate.*
>
> *This Pilot's Guide should be inserted in each crew member's FCI folder'.*

1.18 Additional information

1.18.1 Operation of a solenoid

A solenoid consists of a wire coil wrapped around an iron core. When a current flows down the wire a magnetic field is generated around the solenoid which can be used to activate a switch.

Energy is stored in the magnetic field set up around the solenoid by the current flowing in the coil. When the switch is opened, current stops flowing and the magnetic field collapses. This can generate a large voltage, which in turn can cause arcing across the switch. To prevent arcing at the switch a suppressor, in the form of a capacitor and resistor, is connected in parallel with the solenoid to absorb the electrical energy when the switch is opened.

1.18.2 Landing gear system safety analysis

The aircraft manufacturer's safety analysis of the landing gear system, dated 27 June 1983, assessed landing with the gear not locked down but with the gear position indication system working correctly as being 'Hazardous', with the associated probability being assessed as 'Extremely remote'. However, if there is no indication of the gear position available to the crew, the condition is evaluated as 'Catastrophic' but the probability is assessed as 'Extremely improbable'.

The safety analysis assumes that the gear position indicator is monitored adequately by the crew, and that the crew will be alerted by the indicator lights or the audible warning. The assessment does not consider the possibility of a fault allowing the gear selector to be moved to the 'DOWN' position with the gear remaining in the 'UP' position and the audible warning inhibited.

2 Analysis

2.1 Operations analysis

The pilots were correctly licensed and qualified to conduct the flight. The aircraft was configured with Flap 10º during the arc portion of the procedure and speed was reduced to 165 kt. The failure of the landing gear to extend was not observed by the crew. The audible warnings did not activate for the reasons set out in the engineering sections of the report.

Having realised that the landing gear was not extended, the PF executed a late go-around and maintained control of the aircraft. The PNF retracted flap to the go-around setting of 10º in accordance with the procedures. The impact with the runway did not create vibration or handling difficulties that might have alerted the crew to the airframe and propeller damage. The passengers and the cabin attendant heard a scraping noise but this information was not passed to the flight crew.

As the aircraft climbed away the flight crew prepared to use the emergency landing gear lowering procedure. Before the QRH was actioned, the commander elected to re-cycle the landing gear 'UP' followed by 'DOWN'. On the 'DOWN' selection the landing gear operated normally and the landing gear indicator lights showed 'three greens'. With the landing gear indicator lights showing 'down and locked', the crew had the option to land at Wick or to return to Aberdeen as requested by their Operations Department. They were unaware that the aircraft had contacted the runway and therefore did not know that it had sustained damage. They calculated that they had more than sufficient fuel to return to Aberdeen with the landing gear remaining down and they therefore decided to return.

The cabin attendant had heard the scraping noise of the aircraft underside contacting the runway surface as had some of the passengers, and received a NITS[11] brief from the PNF but did not communicate the scraping noise to the flight crew. The runway inspection at Wick was carried out promptly and revealed evidence of possible damage to the aircraft. Had the crew been aware of the possibility that damage to the propeller and airframe had occurred, they could have landed at Wick. It is important that any unusual sounds detected in the cabin are passed by the cabin attendant to the flight crew.

11 Some operators have SOPs for precautionary landings, which include a NITS (Nature of emergency, Intention of Captain, Time Remaining and Special Instructions) brief or similar.

When informed by Scottish ATC that the aircraft had sustained some form of damage, the crew declared a PAN and monitored the aircraft systems but all indications were normal. The flight crew had briefed the cabin attendant on the situation and the possibility that the landing gear might collapse during the landing run or whilst taxiing. The cabin attendant had prepared the passengers in case of such an event but the landing and taxi to the stand were normal.

2.1.2 Human factors

The aircraft was being operated by two pilots, both of whom were qualified aircraft commanders. They were on their fourth sector of the day as a crew and had not experienced any difficulties on the previous three sectors.

The PF did not feel under any pressure during the visual approach and had adequate time in which to configure the aircraft for the landing. The PNF prompted the commander regarding the lowering of landing flap which he confirmed should be selected. Whilst the SOPs required the 'monitoring' of the checklist actions, they did not require 'confirmation' of the 'three greens' by the PF after the landing gear was selected DOWN. The PF did not therefore confirm the landing gear indications. The PNF did not normally select Flap 20º until the three green landing gear indicator lights were illuminated. The PNF could not recall seeing the 'three greens' on this approach.

It is probable that during the visual approach in good weather the crew were relatively relaxed. Given the uneventful previous three sectors and their equal status, they may have had a mutual confidence in each others actions. This, combined with the routine nature of the approach, may have caused the flight crew to relax, although discussion of the lack of PAPI information may have created an element of distraction. The attention of the PF, who was concentrating on the visual picture and initiating his descent, was occupied whilst the landing gear was lowered by the PNF. The crew also had an expectation that the audible warnings from the horn and TAWS would activate had the landing gear not been lowered. The shortcomings of the warning system had not been identified prior to the accident and they were therefore unaware of them.

The aircraft manufacturer's generic procedures for the lowering of the landing gear do not require the PF to 'confirm' the landing gear handle is down and the three green indicator lights are illuminated, therefore the following Safety Recommendation is made:

It is recommended that BAE Systems amend the generic procedures contained in the manufacturer's Flight Manual to include confirmation by both PF and PNF that the landing gear handle is selected down and that three green indicator lights are illuminated. They should encourage operators of the Jetstream aircraft to adopt the revised procedure in their own Standard Operating Procedures. (Safety Recommendation 2007-079)

2.1.3 Operator's safety actions

Immediately following the accident, the operator conducted an internal investigation and identified a number of issues requiring consideration. Of relevance to the AAIB investigation, the following safety actions were taken:

1. The Jetstream 32 SOP was amended to require both pilots to cross check the landing gear selector handle and position indicator lights to confirm the landing gear was 'down and locked'.

2. The operator amended its policy on NITS briefs to cabin attendants to introduce 'QNITS' which requires aircraft commanders to **Q**uestion the cabin attendant as to any unusual observations before continuing with the remainder of the NITS mnemonic.

3. Improved co-ordination between the Operations and Training departments was put in place for the introduction of aircraft modifications such as TAWS, to ensure proper information and training is provided for the flight crew.

2.2 Engineering analysis

There was no damage to the landing gear legs, doors or tyres, which indicates that the landing gear was probably retracted when the aircraft touched the runway. The pilot stated that the propeller would have been at fully fine (1,591 rpm) during the flare. From the runway marks and damage to the aircraft it was established that the parameters when the aircraft touched the runway were as follows:

Ground speed	87 kt
Airspeed, with a head wind of 5 kt	92 kt
Right wing down	0.9 deg
Pitch up	9 to 11 deg
Aircraft in contact with runway for	1.9 sec
Propeller in contact with runway for	0.8 sec

With the exception of the gear selector switch, an inspection of the landing gear mechanical and associated electrical systems could not identify any faults which would have prevented the gear from lowering or the warning systems from operating. Full functional checks were also carried out on the TAWS and the landing gear operating and warning systems. During the checks the gear was cycled approximately 30 times during which all the systems functioned correctly.

The pilot stated that during the flare he noticed that the gear selector lever was in the 'DOWN' position and neither the red nor green indicator lights were illuminated. He was then able to move the selector lever to the 'UP' position. For the lever to move to the 'UP' position the internal safety lock must have been disengaged, which means that there must have been electrical power at terminals A and B on the selector switch. As the solenoids in the gear hydraulic selector valve take their electrical power from the same CB as terminals A and B (1GA1), it was concluded that when the selector lever was in the 'DOWN' position there must have been electrical power at junction L9 on terminal block T1 AB (Appendix 'B'). Moreover, the gear did not move to the down position, which indicates that there was no electrical power at the down solenoid in the gear hydraulic selector valve. With the selector switch in the 'DOWN' position electrical power from contact 1 would have been provided to the flap horn warning system via contact L2 on terminal block T1 AB. The system isolation test (Test 1) proved that providing there is electrical power at contact L2 the horn will sound if the aircraft is in the incorrect landing configuration. Both pilots stated that the warning horn did not operate during the accident, which indicates that there was no electrical power at contact L2.

The electrical power to operate the warning horn when the power levers are at idle and to provide the gear position signal to the TAWS both come from CB 1GA10 via contact 5 in the gear selector switch. Had the gear selector switch been in the 'UP' position then contact 5 and 6 would have been closed and the horn would have sounded when the power levers were brought back to idle. Moreover, contact 4 and 5 would have been opened providing the TAWS with a gear up signal and the system would have generated numerous aural and visual warnings. Had the selector switch been selected to 'DOWN', then there would have been no power source to operate the horn and the TAWS would have received a gear down signal; consequently, no warnings would have been generated.

The only plausible explanation, which fits the symptoms described by the crew, is that when the gear selector was moved to the 'DOWN' position, contact 5/6 changed to contact 5/4, contact 2/3 opened and contact 1/2 stayed in the open condition. In this condition:

> There would have been electrical power at the gear selector switch internal safety lock, which would allow the selector switch to be moved back to the 'UP' position.
>
> A valid gear down signal would have been provided to the TAWS.
>
> There would have been no electrical power supply to the horn warning systems.
>
> Both the up and down solenoids in the gear hydraulic selector valve would be de-energised. The gear would settle on to the uplocks and the nose downlock would make a clunking noise as it moved under spring pressure to the locked position.

When the selector switch was moved back to the 'UP' position the crew would have heard the nose downlock moving back to the open position. They might also have sensed the gear moving off the uplocks as the up lines were pressurised. However, the gear indicator lights operate from an independent power source (CB 1GF1) and for the green/red indicator lights not to have illuminated on this one occasion there would have had to have been a further intermittent fault. The lack of damage to the landing gear supports the conclusion that a second intermittent fault was unlikely and that the indicator lights were serviceable and the gear was retracted when the aircraft touched the runway.

From the work undertaken by QinetiQ it is concluded that the most likely explanation for the intermittent contact in the selector switch is that a piece of cupric oxide became trapped and acted as an insulator between contacts 1 and 2. When the switch was subsequently recycled, the sliding contact would have cleaned the powder off from the contact areas and the switch would then have operated normally.

Both selector switches which were examined during this investigation were heavily worn and covered in black powder. They are subject to an 'On Condition' maintenance policy on the grounds that there is an alternative method of lowering the landing gear. In this event, the fault would have cleared if the gear selector lever had been recycled; had the fault not cleared then the gear could have been lowered on the emergency system. The warnings from the horn and TAWS were suppressed; however, the gear indication lights functioned correctly and would have informed the crew of the gear position. The aircraft manufacturer's safety analysis did not consider any failure mode of the gear selector in which the gear extension solenoid was not energised but the audible warnings were inhibited. Therefore, the following Safety Recommendation is made:

> It is recommended that BAE Systems should review the safety analysis for the Jetstream 32 landing gear system to include cases where the gear selector lever can be moved to the 'DOWN' position with the landing gear remaining retracted and the audible warning inhibited. (Safety Recommendation 2007-080)

Whilst the radio altimeter type had been incorrectly set in the ST3400, this action played no part in this accident as the closing of contact 4 and 5 in the gear selector switch would have sent a valid gear down signal to the TAWS.

3. Conclusions

3.1 Findings

1. The operating flight crew members were correctly licenced and qualified to conduct the flight.

2. The Company SOPs, which were based on the manufacturer's Flight Manual procedures, did not require monitoring or cross-checking of the gear position by the PF. This deficiency has been subsequently rectified.

3. The failure of the landing gear to extend and the indicator lights to illuminate was not observed by the crew, and no audible warning was received.

4. The PF sensed that the aircraft was descending below the normal gear down position during the landing and expeditiously initiated a go-around minimising the damage to the aircraft.

5. The cabin attendant heard a scraping noise as the aircraft touched down at Wick, but this information was not passed to the flight crew. The briefing procedure has been amended to require the flight crew to question the cabin crew regarding any observed anomalies.

6. The crew were unaware of any damage to the aircraft when they decided to return to Aberdeen.

7. The landing gear did not extend because of damage to the contacts of one pole of the selector switch, caused by electrical arcing.

8. The remaining poles of the landing gear selector switch functioned correctly, inhibiting the warning horn and the TAWS audible warning.

9. The Radio Altimeter type had been incorrectly set in the TAWS, causing an incorrect predictive response from this system. However this had no bearing on this accident.

3.2 Causal factors

The investigation identified the following causal factors:

1. Mechanical wear and arcing across one of the poles in the gear selection switch resulted in a piece of cupric oxide acting as an insulator across the pole which should have energised the gear extension circuit.

2. The flight crew did not identify that the landing gear was not down and locked by visually checking the landing gear green indicator lights.

3. Due to the failures associated with the gear selection switch, the flight crew received no audible warnings of the landing gear not being in the 'DOWN' position.

4 Safety Recommendations

The following Safety Recommendations were made to the FAA during the investigation:

4.1 **Safety Recommendation 2006-135:** It is recommended that the US Federal Aviation Administration review the technical data supporting STC SA3020AT for the introduction of the Sandel ST3400 TAWS to ensure that the post installation test is sufficient to validate the full range of inputs into the system.

> **Response**: The FAA responded that EMTEQ had changed the ground test procedure to fully test the system for proper configuration and had implemented corrective action to retest aircraft in service for possible configuration errors. EMTEQ issued mandatory Service Letter No 2-25975-1—1 on 1 January 2007 to require these corrective actions.

4.2 **Safety Recommendation 2006-136:** It is recommended that the US Federal Aviation Administration take immediate action to ensure that aircraft equipped with the Sandel ST3400 TAWS have the correct radio altimeter type set and that the system is tested to ensure that the radio altimeter signal is correct over the operating range specified in the Sandel ST3400 installation manual.

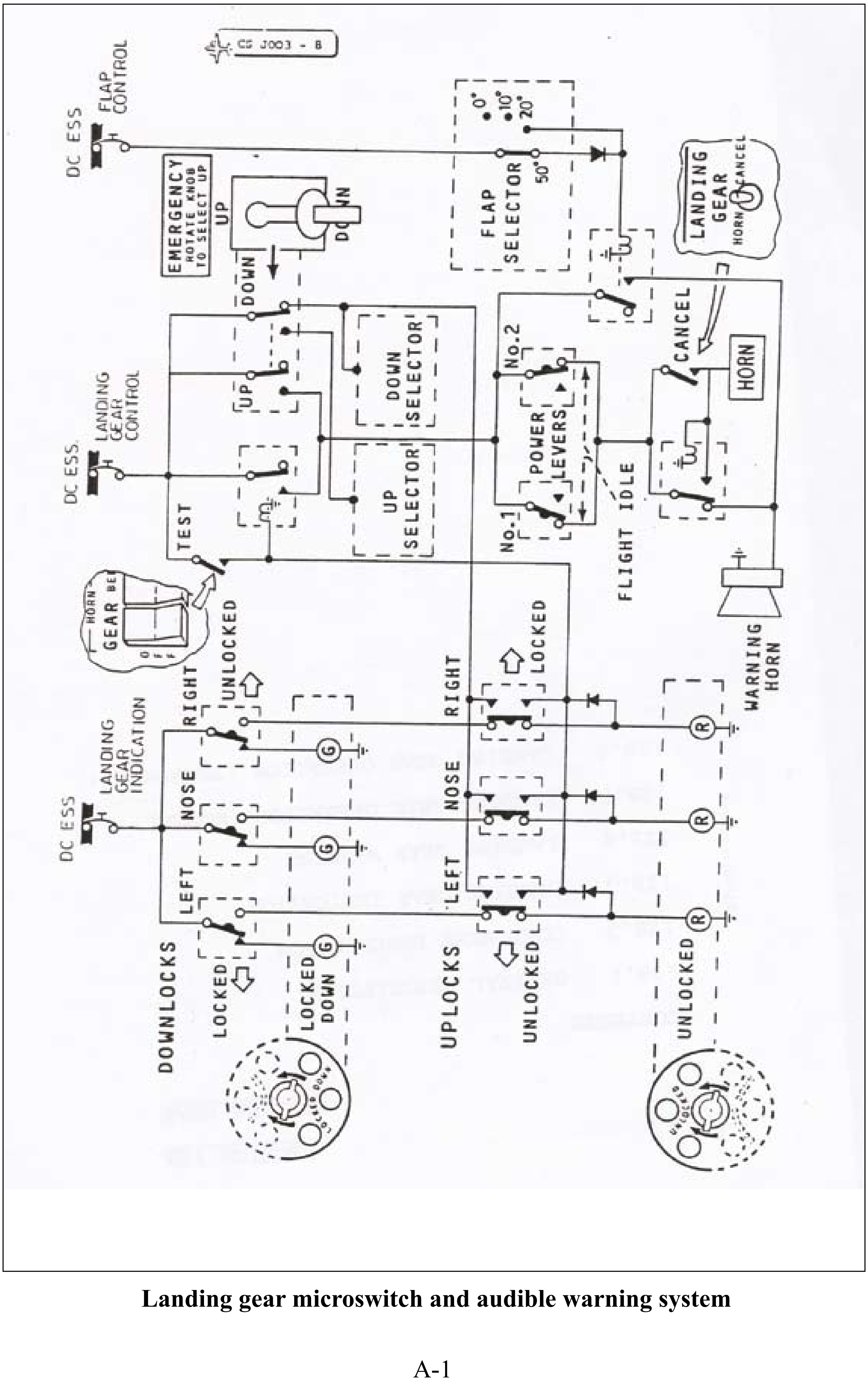
> **Response**: The FAA responded that a programme of testing seventy five modified Jetstream 3202 aircraft was under way and that, at that time, no other incorrectly configured aircraft had been found.

The following additional Safety Recommendations are made:

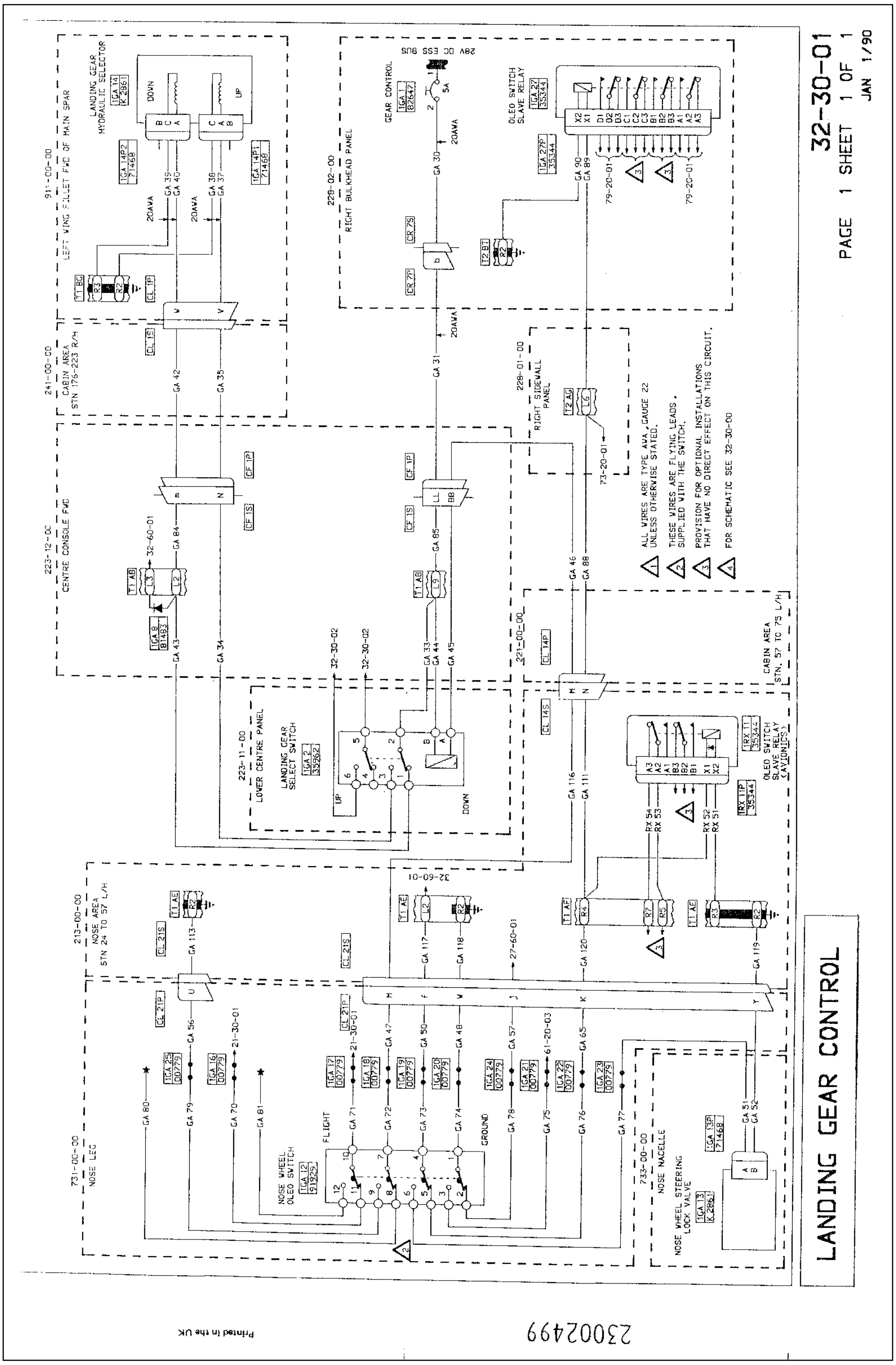
4.3 **Safety Recommendation 2007-079:** It is recommended that BAE Systems amend the generic procedures contained in the manufacturer's Flight Manual to include confirmation by both PF and PNF that the landing gear handle is selected down and that three green indicator lights are illuminated. They should encourage operators of the Jetstream aircraft to adopt the revised procedure in their own Standard Operating Procedures.

4.4 **Safety Recommendation 2007-080:** It is recommended that BAE Systems should review the safety analysis for the Jetstream 32 landing gear system to include cases where the gear selector lever can be moved to the 'DOWN' position with the landing gear remaining retracted and the audible warning inhibited.

Alan P Simmons
Principal Inspector of Air Accidents
Air Accidents Investigation Branch
Department for Transport
January 2007

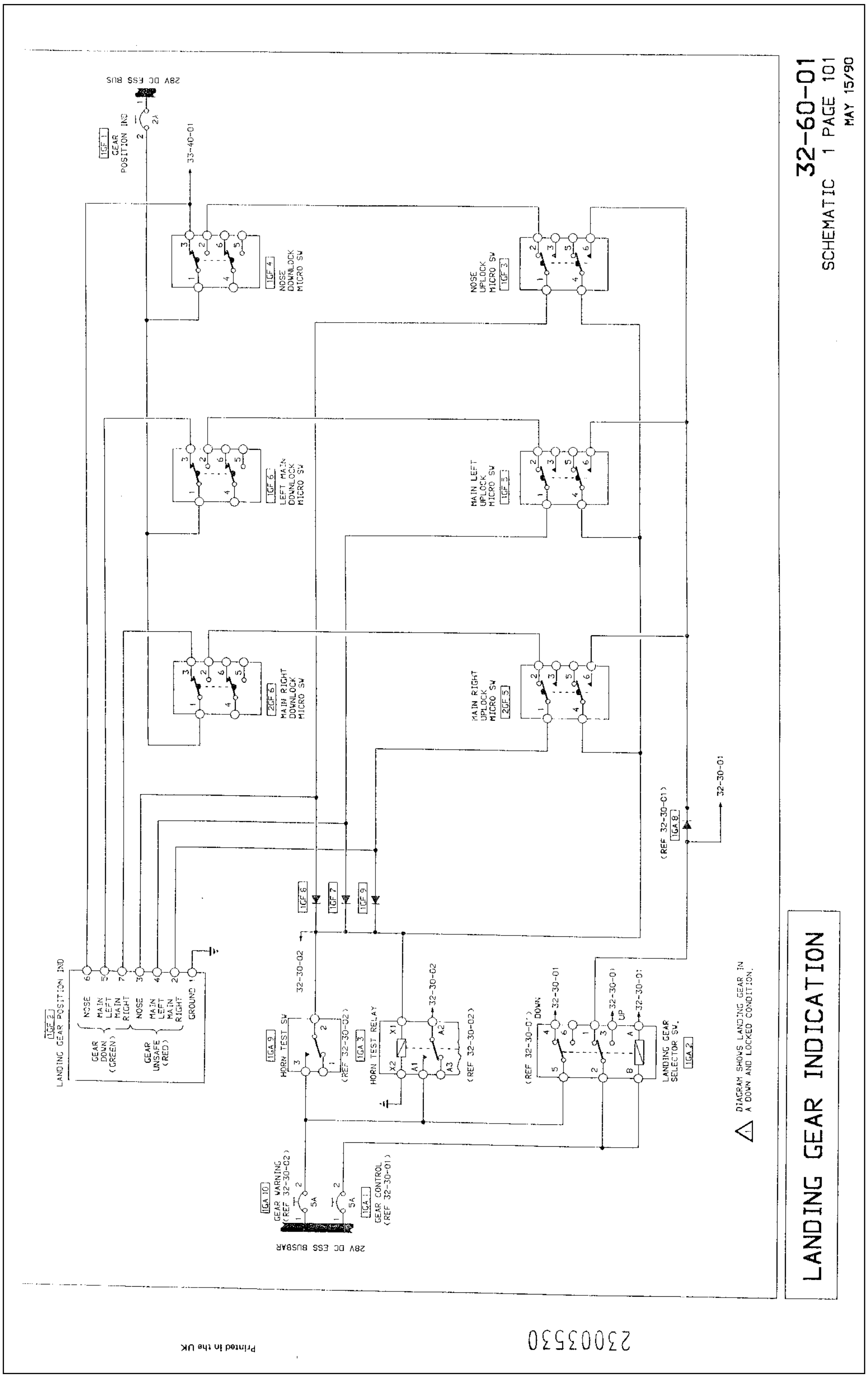


Landing gear microswitch and audible warning system



Landing gear control system

Appendix C



Landing gear indication system

Configuration settings on ST3400		
Index 2	Serial number CPU CCA.FPGA I/O CCA FPGA PWR CCA REV Software Rev Boot Rev Terrain Rev Airport Rev Aircraft type Install position A/c ident P3-8 output set	3355 00.107 00.103 0 A3.08 B2.03 14 Oct 05 Europe 27 Oct 05 Aeroplane Plt only TCAS INHIB
Index 3	Air Data 1	AZ-648PA AZ-648VS TYPE2 HIGH NONE
Index 4	Air Data 2	NONE
Index 5	ADF & Heading	S/C DC HIGH S/C DC YYZ NONE
Index 6	Discretes	NONE INHIBIT L ENABLED L UP L 004V DOWN H NONE
Index 7	NAV &ICS	COMP 17.0^{o} ON NAV 1 FACE COMP 17.0^{o} ANALOG ANALOG ACTIVE L
Index 8	Rad Alt	ALT 55 HIGH 000 ACTIVE L
Index 9	GPS / FMS1	KING KLN90
Index 10	GPS / FMS2	FREE FLGT (232)

Configuration settings on ST3400

Appendix E

ADI[1] (ft)	**ST3400** (ft) (Type 55)	**ST3400** (ft) (Type 552)	**Difference between ADI and ST3400** (ft)	
			Type 55	**Type 552**
0	-1	-2	-1	-2
100	101	100	1	0
200	203	199	3	-1
300	302	300	2	0
400	396	395	-4	-5
450	439	448	-11	2
500	495	502	-5	2
550	777	549	227	-1
600	1063	592	463	-8
650	1357	647	707	-3
700	1591	704	891	4
750	1802	747	1,052	-3
800	1988	788	1,188	-12
850	2169	839	1,319	-11
900	2355	889	1,455	-11
950	2557	943	1,607	-7
1000	2748	996	1,748	-4

[1] Pilot and co-pilot's ADI radio altimeter readout monitored throughout the test, both read the same.

Readouts from the ADI and ST3400 when subject to a radio altimeter test signal between 0 and 1,000 ft