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Aircraft Accident Investigation Bureau AAIB

Final Report No. 1985 by the Aircraft Accident Investigation Bureau

concerning the accident

to the Gulfstream G-V aircraft, HB-IMJ

operated by the G5 Executive AG company

under flight number EXH 152

on 1 June 2007

at Zurich Airport

Bundeshaus Nord, CH-3003 Berne

Ursachen

Der Unfall ist darauf zurückzuführen, dass am Bugfahrwerk *door actuator* alle vier Befestigungsschrauben des Abschlussdeckels (*gland*) des *shuttle valve* rissen und der Abschlussdeckel brach. Als Folge davon konnte das Bugfahrwerk nicht ausgefahren werden.

Zum Unfall beigetragen haben:

- Versagen des Notsystems infolge eines Lecks, welches durch den abgetrennten Abschlussdeckel des *shuttle valve* verursacht wurde
- Nicht geeignete und unzureichend angezogene Befestigungsschrauben am Abschlussdeckel des *shuttle valve*
- Geringe Materialstärke des Abschlussdeckelflansches

General information on this report

This report contains the AAIB's conclusions on the circumstances and causes of the accident which is the subject of the investigation.

In accordance with Annex 13 of the Convention on International Civil Aviation of 7 December 1944 and article 24 of the Federal Air Navigation Law, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent future accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the accident investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident prevention, due consideration shall be given to this circumstance.

The definitive version of this report is the original in the German language.

All times mentioned in this report, unless otherwise indicated, follow the coordinated universal time (UTC) format. At the time of the accident, Central European Summer Time (CEST) applied as local time (LT) in Switzerland. The relation between LT, CEST and UTC is: LT = CEST = UTC + 2 h.

For reasons of protection of privacy, the masculine form is used in this report for all natural persons, regardless of their gender.

Contents

Final Report

Owner	Besleasing e Factoring, 1006 Lausanne, Switzerland
Operator	G5 Executive AG, CH-6300 Zug, Switzerland
Aircraft type	G-V (Gulfstream Aerospace)
Country of registration	Switzerland
Registration	HB-IMJ
Location	Zurich Airport
Date and time	1 June 2007, 20:53 UTC

General

Synopsis

On 1 June 2007, the Gulfstream G-V aircraft, registration HB-IMJ, took off at 17:53 UTC from Rotterdam (EHRD) on a flight, flight number EXH 152, to Zurich (LSZH). At 18:41:45 UTC, the crew of flight EXH 152 received clearance for an instrument approach on runway 14. After extending the landing gear, the crew established that the nose gear was not down and locked.

During the subsequent go-around, the landing gear was retracted again and the crew established that the hydraulic fluid quantity indication of the left-hand system began to fall. The crew carried out a second approach. After the landing gear was extended, the situation was the same: main gear down and locked, nose gear not extended. The application of the emergency procedure to extend the gear was also unsuccessful.

The crew were able to verify by observation during a low pass over runway 14 that the nose gear was not extended. With consultative support via the aircraft manufacturer's hotline, an unsuccessful attempt was made to release or extend the nose gear by means of g-load flight manoeuvres.

The commander of flight EXH 152 declared an emergency situation by radio at 20:21:41 UTC. An emergency landing with subsequent emergency evacuation of the aircraft was prepared.

The aircraft touched down at 20:52:37 UTC on runway 14 and came to a standstill at 20:53:15 UTC with the nose of the aircraft on the runway. Passengers and crew evacuated the aircraft through the main entry door. No-one was injured. There was considerable damage to the aircraft.

Investigation

The Swiss Aircraft Accident Investigation Bureau (AAIB) was informed on 1 June 2007 at 20:30 UTC by the airline's Flight Operations Manager about the impending landing with nose gear not extended and opened an investigation at 21:00 UTC.

The digital flight data recorder (DFDR) and the cockpit voice recorder (CVR) were removed from the aircraft and analysed.

The accident is attributable to the fact that on the nose gear door actuator, all four shuttle valve end gland retaining screws ripped off and the end gland broke. As a result, it was not possible to extend the nose gear.

The following factors contributed to the accident:

- failure of the emergency system due to a leak caused by the separated shuttle valve end gland
- inappropriate and insufficiently tightened retaining screws on the shuttle valve end gland
- marginal material thickness of the end gland flange

1 Factual Information

1.1 History of the flight

1.1.1 General

The recordings of radio communications, radar data and the statements of crew members were used for the following description of the history of the flight. The CVR (cockpit voice recorder) recordings were also available; the last 30 minutes of the flight were recorded.

Throughout the entire flight the commander was pilot flying (PF) and the copilot was pilot not flying (PNF).

The flight took place under instrument flight rules.

1.1.2 History of the flight

On 1 June 2007, the Gulfstream G-V aircraft, registration HB-IMJ, took off at 17:53 UTC from Rotterdam (EHRD) on a flight, flight number EXH 152 (Batman one five two), to Zurich (LSZH). On the ATC flight plan the flight was declared as "N" flight (commercial non scheduled air transport operation). In addition to the cockpit crew, two flight attendants and five passengers were on board. After an uneventful flight the crew of EXH 152 made contact at 18:37:21 UTC with the Zurich Arrival West air traffic control unit. The air traffic controller (ATCO) informed the crew that they were to expect an approach on runway 14 and cleared them for a descent to flight level FL 120. At 18:38:35 UTC, the crew received a first heading instruction and clearance to 6000 ft QNH from the ATCO. At 18:41:45 UTC, they received clearance from the ATCO for an instrument approach on runway 14 and at 18:44:32 UTC the crew were instructed to contact the control tower. According to the commander's statement, the approach was rather fast and the speed brakes were applied to reduce speed. Since their effect was not sufficient, the landing gear was extended relatively early. After the gear had been extended the gear handle remained illuminated red. The green nose wheel indication did not light up, meaning that this at least was not locked. The main gear lights lit up green thereby indicating that the main gear was down and locked normally.

At 18:45:01 UTC, the crew of flight EXH 152 received clearance from the control tower ATCO to land on runway 14, which the crew confirmed immediately. Since the nose gear was still not shown as down and locked, the crew decided to go around and reported this to the ATCO at 18:45:55 UTC as follows: "*Batman one five two, going around*".

The crew followed the published standard missed approach and retracted the landing gear. At 18:46:56 UTC, the crew responded to the ATCO's enquiry about the reason for the go-around: *"We have some problems with the gear and we try to figure it out now"*. The ATCO acknowledged this message and the crew were instructed at 18:47:01 UTC to change to the Zurich Arrival East frequency.

During go around, while still climbing, the crew noticed the amber warning L HYD QTY LOW on the crew alerting system (CAS). After selecting the hydraulic synoptic page, the crew realised that the quantity in the left hydraulic tank was falling slowly but continuously. In view of this fact, the crew decided to leave the flaps in the 20° position.

At 18:48:20 UTC, the crew received clearance to climb to 7000 ft QNH and approximately one minute later a heading instruction to fly direct into AMIKI holding, as the crew had requested.

In AMIKI holding, on the commander's request, the copilot investigated the L HYD QTY LOW indication. According to the commander's statement, at this time the L HYD SYS FAIL warning was not being displayed. The hydraulic pressure indication varied between 0 and 2800 psi and the hydraulic tank indication was showing nearly zero.

The crew decided on a second approach on runway 14 and requested radar vectors. They decided to extend the gear already upon leaving the AMIKI holding. The result was the same as on the first approach. The main gear lights lit up green, i.e. down and locked, and the gear handle again lit up red and the green nose gear indication did not light up. At 18:55:49 UTC, the ATCO informed the crew that they still had 37 miles to go until touch down. About eight minutes later, the crew requested a 10 mile extension of the flight path. When asked for the reason for this flight path extension, the crew reported at 19:04:04 UTC: *"Ya, we have lost the left hydraulic system, so we have to use the alternate system to release the gear"*.

On the commander's order, the copilot performed the "Landing Gear Failure to Extend" emergency checklist, in accordance with the Quick Reference Handbook (QRH). This procedure, in which hydraulic pressure is substituted by nitrogen pressure from two bottles carried on board, also had no effect. The gear position indication remained unchanged.

The crew now decided to fly a low pass over runway 14 so that ground units could verify whether the nose gear was extended. At 19:06:59 UTC, they requested the following from the ATCO, among other things: *"... requesting a low pass to verify, if you can see our nose landing gear down"*.

Radar vectors were given again and once the aircraft was lined up on the runway centreline and glide path, the crew received the following clearance at 19:12:54 UTC from the ATCO in the control tower: *"... runway one four, cleared low approach"*.

At 19:15:16 UTC, the crew received confirmation from the ATCO that the nose gear was not extended. During the subsequent go-around the aircraft configuration was left as it was. The crew now requested clearance into AMIKI holding to solve the problem.

In AMIKI holding, the commander handed control of the aircraft over to the copilot, informed the passengers and then contacted his company. The consultation between the operator's experts and the responsible maintenance company did not show any results. The crew were now requested to make contact via satellite telephone with the aircraft manufacturer's hot line. In a conference circuit two technical specialists and a test pilot with the aircraft manufacturer were available to provide the crew with advice. After an initial analysis, the latter advised releasing a possible mechanical blockage of the nose gear by means of flight manoeuvres with positive g-load.

At 19:58:48 UTC, the crew informed the ATCO of their intentions, among other things, as follows: *"... we would like to try the following procedure: we would like to have a vector where we can descend to round about two thousand feet and, ten miles vector, and where we can do some positive g-loads on the plane to see*

if the nose wheel will extend, so give us a vector where we can fly for ten miles, descend to two thousand feet and do positive g-loads on the plane".

The ATCO informed the crew that he could not allow them to descend lower than 4000 ft. He offered an altitude between 6000 ft QNH and FL 90 within AMIKI holding. The crew agreed, but wished to maintain the same heading over a distance of approximately 10 miles. At 20:00:16 UTC, the crew then received the following clearance from the ATCO: *"Okay Batman one five two, then heading two niner zero then between six thousand feet on one eight and level niner zero"*.

After a good six minutes, the crew reported again at FL 90 and asked if they could run through the same procedure once more. They received the corresponding clearance at 20:06:56 UTC, this time on a 270 degree heading. The manoeuvres carried out by the commander in consultation and in constant contact with the aircraft manufacturer had no effect.

The crew decided to abort the manoeuvres and at 20:11:48 UTC requested clearance back into AMIKI holding. After another discussion with the manufacturer's test pilot, the crew requested the following at 20:14:51 UTC: *"Yeah, could we try the same procedure again with a turn, may be that helps more"*. The ATCO gave the clearance immediately and reported that he had no other traffic in the region.

The recordings show that the above-mentioned flight manoeuvres were carried out relatively abruptly. The combination of movements[1] about the longitudinal and lateral axes within a few seconds led to peak loads of more than 3g. All the manoeuvres were carried out with an unchanged landing flap position of 20°.

All the manoeuvres which were carried out had no effect and at 20:19:58 UTC the crew reported the following to the ATCO: *"Yeah, we couldn't solve our problem, so, I guess, we have to make an emergency landing here in Zurich, no nose wheel gear, so we might make a nose wheel gear up landing, request a long wide runway here somewhere in Zurich"*. At 20:20:15 UTC, the ATCO replied as follows, among other things: *"... We have several possibilities, the longest runway we have is one six, but there, we don't have any ILS at the moment ... so actually you can chose, depending on weather and on, ähm, on navigational equipment we have at the moment, so VOR one six would be available, ILS one four, ILS three four, I think, I think, these are three possibilities"*.

In view of the rather poor weather, the crew opted for runway 14. They informed the ATCO of this and declared an emergency at 20:21:41 UTC.

The crew replied at 20:21:56 UTC to the question as to whether they were ready for an approach that they would need about another 15 to 20 minutes in AMIKI holding to inform the passengers.

At 20:22:31 UTC, the crew asked the ATCO whether a foam carpet would be laid for the landing. The ATCO replied that foam carpets were no longer used.

After consulting with the copilot, at 20:23:43 UTC, the commander went aft into the passenger cabin to inform the passengers and the two flight attendants. The commander reported back after nearly seven minutes. The copilot informed him

[1] The movements about the lateral axis were within plus 8° and minus 14° and the movements about the longitudinal axis indicated values of up to 52°.

that AMIKI holding was no longer activated in the FMS (Flight Management System) and that he was now flying using heading entries and the stopwatch.

The commander informed the copilot of the instructions which he had given to the flight attendants in the cabin. He was going to make a "*five minutes*" announcement five minutes before the landing. Once the aircraft had come to a standstill, they would clarify from the cockpit whether the main entry door could be used and if affirmative the order would be given to use it. In any event, the flight attendants were to open only the two front emergency escape windows; all four did not need to be opened.

At 20:32:27 UTC, the commander commenced the approach briefing. He noted: *"approach briefing is all the same as before"* and briefly repeated the navigation aids which had already been set and the corresponding minimums. The commander mentioned his intention to set the flaps in the 39° position if possible; otherwise they would be left in the 20° position. The copilot added that he would switch on the auxiliary hydraulic pump beforehand and they would then see whether the flaps would move. The copilot also asked whether he should arm the spoilers. The commander replied that he should do this only if the flaps would go to the 39° position.

The individual points for the emergency evacuation of the aircraft were now discussed. The copilot read out the individual points on the "Emergency Airplane Evacuation" checklist. It was then determined which actions were to be carried out by the copilot and the commander respectively. Points 4 and 5 of the checklist specify that the fire handles must be pulled and rotated. The commander noted that these would only have to be rotated if this were necessary. The copilot responded that that was not what the checklist stated but that he was in agreement.

At 20:35:12 UTC, the commander discussed the impending landing with the copilot. He said that after landing he wanted to keep the aircraft's nose up as long as possible using the thrust reverser, before setting it down on the runway. Half a minute later, the copilot once again read out the points for "Abnormal Gear Condition – Emergency Landing" in the QRH.

At 20:36:29 UTC, the crew of EXH 152 requested radar vectors for an approach on runway 14. The ATCO replied as follows: *"Batman one five two, roger, heading two eight five, vectors for ILS approach runway one four, and fire brigade is ready, everything is organized and ready for you, the surface wind one eight zero degrees, five knots"*.

At 20:37:32 UTC, the commander once again contacted the aircraft manufacturer's test pilot. The landing on runway 14 in Zurich, and in particular the procedure in the "Abnormal Gear Condition – Emergency Landing" checklist, were discussed. This conversation lasted for more than six minutes.

In the meantime, the ATCO had asked the crew whether lining up on the runway centreline at a distance of ten miles would be acceptable to them. The copilot then requested a distance of approximately 14 miles at 20:39:51 UTC.

At 20:44:17 UTC, the commander informed the copilot about the conversation with the test pilot. The latter had said that deliberately landing the aircraft's nose on the runway would be much more important than using the thrust reverser, which would probably not be available on the left engine. If there was a tendency to keep the nose up, it would drop down suddenly and the damage to the aircraft would be much greater. To the copilot's question about using the speed

brakes, the commander replied that the test pilot had said that they could forget all about that. However, setting the flaps to the 39° position would be appropriate, if this were possible.

At 20:46:07 UTC, the crew of EXH 152 received clearance for a descent to 4000 ft QNH and for an approach on runway 14.

At 20:47:32 UTC, the copilot asked whether he should shut down the engines immediately after the aircraft's nose touched the runway. The commander answered in the negative explaining that electrical power would be lost as a result. This would be "too wild a procedure".

At 20:48:22 UTC, the commander instructed the copilot to switch on the auxiliary hydraulic pump and extend the flaps to the 39° position. Five seconds later, an acoustic warning sounded[2]. This warning is triggered when the flaps reach a position in excess of 22° and the gear is not extended or not fully extended. The copilot realised that this warning was related to the gear and tried to switch off this acoustic warning using the HORN SILENCE pushbutton. This did not work.

At 20:48:31 UTC the copilot confirmed that the auxiliary pump was switched on. Nine seconds later he reported that the flaps were in the 39° position. A brief discussion followed about why the very intrusive acoustic warning could not be switched off. Various attempts to suppress the warning were unsuccessful[3].

At 20:49:56 UTC, the crew of EXH 152 received landing clearance from the ATCO in Zurich control tower; this was acknowledged immediately.

At 20:50:17 UTC, the call-out "*one thousand"* sounded in the cockpit and half a minute later the points on the emergency checklist were briefly addressed once more in the cockpit. At 20:51:11 UTC, the copilot reported that he had pressed the glideslope inhibit pushbutton and 20 seconds later he reported: *"approach lights in sight"*.

At 20:51:49 UTC, the commander mentioned that he would now be flying the aircraft manually and at the same time the "*five hundred*" call-out sounded in the cockpit. Subsequently the *"four hundred"* and *"three hundred"* call-outs sounded and five seconds later the "*too low, gear*" warning generated by the ground proximity warning system (GPWS) sounded. Again three seconds later, the *"two hundred"* call-out sounded and after another four seconds the "*too low, gear*" warning sounded again.

The aircraft touched down at 20:52:37 UTC and eight seconds later the commander reported that he would now bring the nose down[4]. At 20:52:51 UTC, the noise of the aircraft's nose scraping on the runway was audible. According to the commander's statement, he maintained the aircraft in the runway direction by applying the brakes asymmetrically. The aircraft came to a standstill after 24 seconds.

The first point on the emergency checklist for "Emergency Airplane Evacuation", namely *"parking brake"*, was called out by the copilot and confirmed as performed by the commander. A brief exchange concerning the actions taken fol-

[2] This acoustic warning consists of a sound signal comprising two alternating frequencies.

[3] In the prevailing aircraft configuration, this warning cannot be suppressed because of the design of the system; see chapter 1.6.3.5.

[4] The recordings indicate that after the smooth landing the commander slowly brought the aircraft to an attitude of 0°, maintained this for three seconds, and that the aircraft's nose then touched the ground within 2 seconds.

lowed and the copilot remarked that everything was switched off. The CVR recordings end when the batteries were switched off.

The crew decided to use the main entry door for the evacuation. This was opened by the copilot and the passengers and crew evacuated the aircraft using the onboard stair which was resting on the ground. No-one was injured.

1.2 Injuries to persons

Injuries	Crew	Passengers	Total number of occupants	Third parties
Fatal	---	---	---	---
Serious	---	---	---	---
Slight	---	---	---	---
None	4	5	9	---
Total	4	5	9	---

1.3 Damage to aircraft

There was considerable damage to the aircraft (see Annex 1). The individual items of damage could be reconstructed using the maintenance company's repair report (Work Report W.O. No. BHIMJ067). The listing below is a summary of the damage which occurred.

In order to be able to fly the aircraft to the maintenance company's base in Basle, it was temporarily repaired in Zurich. The work listed below was carried out in Basle.

In order to gain the necessary access to the structure, numerous items of equipment in the cockpit and the lower area of the nose had to be removed and later refitted and tested. In addition, part of the panelling in the nose area had to be removed and refitted.

In the area of fuselage stations FS 44 – FS 145, the lower fuselage sheeting was replaced. In the area of fuselage stations FS 44 – FS 119 a fairly large number of bulkheads, frames and stringers were replaced. In the area of fuselage stations FS 95 – FS 114, stiffeners were installed. This work was performed in accordance with special instructions from the aircraft manufacturer.

On the nose, the radome was replaced.

In addition, various parts in the area of the nose gear were tested using ultrasound techniques.

In the nose gear area, the following parts were replaced:

- *Nose landing gear assembly*
- *Nose landing gear steering unit*
- *Nose landing gear harness (wiring)*
- *Nose landing gear weight on wheel switch*
- *Nose landing gear door open switch*
- *Nose landing gear door control arm and rod*
- *Nose landing gear door hinges, doors and fairings*
- *Nose landing gear door bellcrank*
- *Nose landing gear door actuator*

1.4 Other damage

There was no damage to third parties.

1.5 Personell information

1.5.1 Commander

Person	Swiss citizen, born 1974
Licence	Air transport pilot licence aeroplane (ATPL(A)) according to joint aviation requirements (JAR), first issued by the FOCA on 11.05.2005, valid till 08.05.2012
Ratings	Type rating G-V PIC, valid till 19.04.2008 RTI (VFR/IFR), NIT (A), IR (A)
Instrument flying ratings	Instrument flight aircraft IR(A) Category II instrument approaches with G-V, valid till 19.04.2008
Last proficiency check	Operators' proficiency check (OPC) on 19.04.2007
Medical fitness certificate	Class 1 & 2, without restrictions valid till 19.01.2008
Last medical examination	08.01.2007
Commencement of pilot training	1998

1.5.1.1 Flying experience

Total	4078:00 hours
on the accident type	2300:00 hours
during the last 90 days	178:00 hours
of which on the accident type	178:00 hours
as commander	1537:00 hours

1.5.2 Copilot

Person	German citizen, born 1974
Licence	Commercial pilot licence aeroplane, (CPL(A)), according to joint aviation requirements (JAR), first issued by the FOCA on 26.09.2001, valid till 03.11.2011
Ratings	Type rating G-V COPI, valid till 04.11.2007 RTI (VFR/IFR), NIT (A), IR (A)
Instrument flying ratings	Instrument flight aircraft IR(A) Category II instrument approaches with G-V, valid till 04.11.2007

Last proficiency check	Operators' proficiency check (OPC) on 21.03.2007
Medical fitness certificate	Class 1 & 2, without restrictions valid till 01.04.2008
Last medical examination	20.03.2007
Commencement of pilot training	1999

1.5.2.1 Flying experience

Total	1787:00 hours
on the accident type	1597:00 hours
during the last 90 days	170:00 hours
of which on the accident type	170:00 hours

1.5.3 Crew duty times

Since the two pilots had been working together as crew since 25 May 2007, the same duty times applied to both of them (all times in UTC). The following times were derived from the logbook and duty roster:

Date	*Route*	*ETD/ETA planned*	*ATD/ATA actual*	*Rest time planned*	*Rest time[1)] actual*
30.05.2007	*Halifax (CYHZ)* *Boston (KBOS)*	*12:00* *13:00*	*12:15* *13:30*	*> 24 hours*	*> 24 hours*
31.05.2007	*off duty*				
01.06.2007	*Boston (KBOS)* *Jersey (EGJJ)*	*00:15* *06:30*	*00:15* *06:45*		
	Jersey (EGJJ) *Rotterdam (EHRD)*	*07:00* *08:00*	*07:45* *08:55*	*08:30*	*07:55*
	Rotterdam (EHRD) *Zurich (LSZH)*	*17:30* *18:30*	*17:50* *20:58*		
	Zurich (LSZH) *Mykonos (LGMK)*	*19:00* *21:20*			

[1)] With regard to pre-flight and post-flight duties, rest times take into account the regulations on the operator's OM A (see section 1.17.1.2).

1.6 Aircraft information

1.6.1 General

Aircraft type	Gulfstream G-V
Characteristics	Twin-jet commercial aircraft
Manufacturer	Gulfstream Aerospace Corp.
Year of construction	1997
Serial number	517
Engine	2 BMW Rolls Royce, BR700-710A1-10

Operating hours, airframe	Total hours since manufacture: 11 257:35 hours; Since last periodic check: 44:13 hours
Operating hours, engines	Total hours since manufacture, at the last periodic check on 15 to 18 May 2007: 9690:31 hours and 2346 cycles respectively 8991:01 hours and 2207 cycles
Max. permitted take-off mass	90 500 lbs (41 050 kg)
Mass and centre of gravity	On engine start-up, the aircraft had 25 000 lbs of fuel on board. The aircraft's mass on take-off from Rotterdam was 74 820 lbs. The mass and centre of gravity were within the permitted limits.
Maintenance	The last scheduled maintenance took place from 15 to 18 May 2007 at 11 213:22 hours.
Technical limitations	No outstanding points were entered in the Hold Item List (HIL) of the Flight & Technical Log.
Fuel grade	JET A1 kerosene
Registration certificate	Issued by the FOCA on 20.12.2006 / No. 3, valid till removal from the aircraft register
Airworthiness certificate	Issued by the FOCA on 28.05.1998, valid till revoked
Certification	For passenger transport between 60S and 90N VFR day and night, IFR Cat. I and II Cat. II RVR 300m / DH 100ft LVTO RVR 125m MNPS RVSM RNP 5 / 10

1.6.2 The hydraulic system

1.6.2.1 General

The hydraulic system of the G-V aircraft consists basically of the following four subsystems (see Annex 2):

- left engine driven system
- right engine driven system
- the power transfer unit (PTU)
- the auxiliary hydraulic system

If a fault occurs in one of the four subsystems, this is indicated in the cockpit on the EICAS (Engine Indicating and Crew Alerting System).

1.6.2.2 The left and right hydraulic system

The left and right hydraulic systems constitute the primary source of the aircraft's hydraulic supply. Each engine drives a hydraulic pump. These pumps are each mounted on the front left side of the accessory gearbox and supply hydraulic pressure as soon as the engine begins to run. Each pump delivers 3000 psi hydraulic pressure to operate the tandem actuators of the primary aircraft control

systems and the stall barrier. The primary aircraft control system includes the ailerons, elevators, rudder including yaw damper and air brakes.

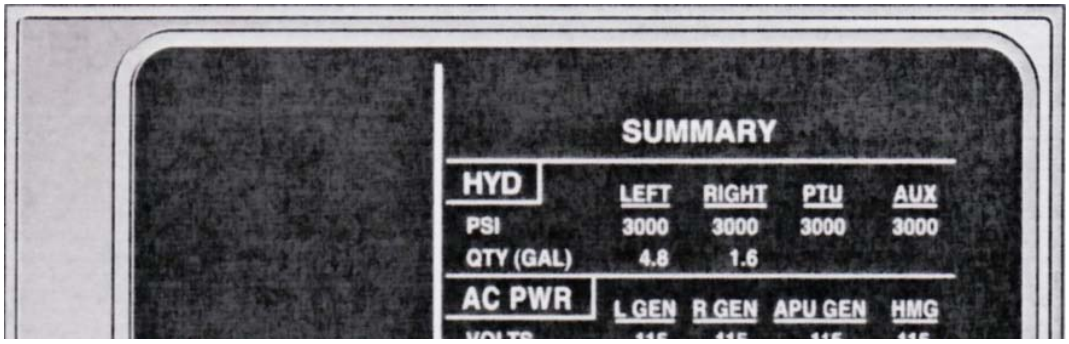
The left system (see Annex 2, green and blue system) also provides hydraulic pressure to drive the hydraulic motor generator (HMG)[5] and to operate the landing flaps, landing gear, nose wheel steering, wheel brakes and the left thrust reverser.

The right system (see Annex 2, red system) additionally provides hydraulic pressure for the right thrust reverser and the power transfer unit (PTU).

Each hydraulic system obtains its hydraulic fluid from a reservoir in the tail of the aircraft. The left system reservoir includes a separate auxiliary chamber which supplies hydraulic fluid for the auxiliary hydraulic system. The left reservoir has a capacity of 5.75 gallons and the auxiliary chamber a capacity of 2.0 gallons. Maximum capacity of the left system reseroir when servicing to full mark is 4.8 gallons. The total content of the left system is 20.6 gallons. The right reservoir has a capacity of 1.85 gallons. The maximum capacity when servicing to full mark is 1.5 gallons. The total content of the right system is 7.0 gallons.

If the tank quantity in the left reservoir falls below 2.8 gallons, the following EICAS warning is displayed in the cockpit: “L HYD QTY LOW”. If the tank quantity in the right reservoir falls below 1.2 gallons, the warning “R HYD QTY LOW” appears.

The system pressure and the corresponding tank quantities are displayed as follows on the summary page:



If the hydraulic fluid level falls to zero in the left or right system, the corresponding warning appears on the EICAS: “L HYD SYS FAIL” or “R HYD SYS FAIL” respectively.

The QRH (Quick Reference Handbook) specifies the procedures which must be applied if these warnings appear (see chapter 1.17.2.2).

1.6.2.3 The power transfer unit

The power transfer unit (PTU) delivers substitute pressure for the following systems (see Annex 2, blue system) if the left engine-driven hydraulic pump fails: flaps, landing gear, nose wheel steering, wheel brakes and HMG.

[5] The HMG is a generator which is driven by hydraulic pressure and which supplies AC power to the standby electrical power system when the auxiliary power unit (APU) generator and both main AC power generators are not available.

The PTU includes a hydraulic motor (PTU MOTOR), which is connected via a drive shaft to a hydraulic pump (PTU PUMP). The right system pressure powers the motor and the pump generates pressure in the left system.

The PTU can be operated either in automatic or manual mode. In normal operation the PTU is operated in automatic mode, i.e. the PTU turns on if the system pressure in the left system falls below 1500 psi and it switches off if the quantity in the left system falls below 1 gallon or the hydraulic fluid in the right system exceeds a temperature of 104.4 °C. In manual mode, the switch-off functions can be overridden and the PTU runs as longs as the right system is under pressure.

1.6.2.4 The auxiliary hydraulic system

As soon as the auxiliary hydraulic pump (AUX PUMP) is running, the auxiliary hydraulic system (see Annex 2, brown system) delivers pressure for normal operation of the main entry door and charges the accumulator of the parking and emergency brake (PARK/EMERG BRAKE). The auxiliary hydraulic system also provides back-up pressure to operate the flaps, nose wheel steering and wheel brakes in the eventuality of the left hydraulic system losing pressure.

In the event of a pressure loss in the left and right hydraulic systems in flight, the auxiliary hydraulic system can be used to operate the rudder and the yaw damper.

For servicing, the auxiliary hydraulic system can be used to operate the landing gear by means of the ground service valve.

The auxiliary hydraulic system obtains its hydraulic fluid from a separate, cylindrical auxiliary chamber (AUX), which is located in the left system reservoir. The two fluids of the auxiliary chamber and the left system reservoir are separate. The left system ensures that the auxiliary chamber is always full.

The auxiliary hydraulic system can be operated either in automatic or manual mode. In normal operation, the auxiliary hydraulic system is operated in automatic mode, i.e. it is activated as soon as the left hydraulic system is delivering less than 1500 psi pressure and a brake pedal is depressed more than 10°.

1.6.3 The landing gear

1.6.3.1 General

The Gulfstream G-V aircraft has retractable gear. It consists of the main gear, with one double wheel on each side, and the nose gear with one double wheel. The main gear wheels have individual wheel brakes, connected to an antiskid system. The main gear and nose gear shock struts are equipped with conventional hydraulic-pneumatic shock absorbers. The nose wheel steering torque link can be separated from the system on the ground so that the aircraft can be towed.

1.6.3.2 The nose gear

The nose gear essentially consists of the shock strut, the double wheel and the retraction/extension mechanism. When the nose gear is extended, it is locked on the one hand by a downlock actuator and on the other by a spring-loaded mechanical linkage, which is brought in the overcenter position. If hydraulic pressure is no longer available on the downlock actuator after extension, this rod remains in the overcenter position.

The nose wheel door consists of two halves which are normally opened and closed hydraulically by the door actuator piston. In an emergency, the door actuator piston can be moved by nitrogen pressure in the direction which enables the nose wheel doors to open. The switchover between hydraulic and pneumatic operation takes place by means of a shuttle valve.

1.6.3.3 The main gear

The principle of operation of the main gear is analogous to that of the nose gear.

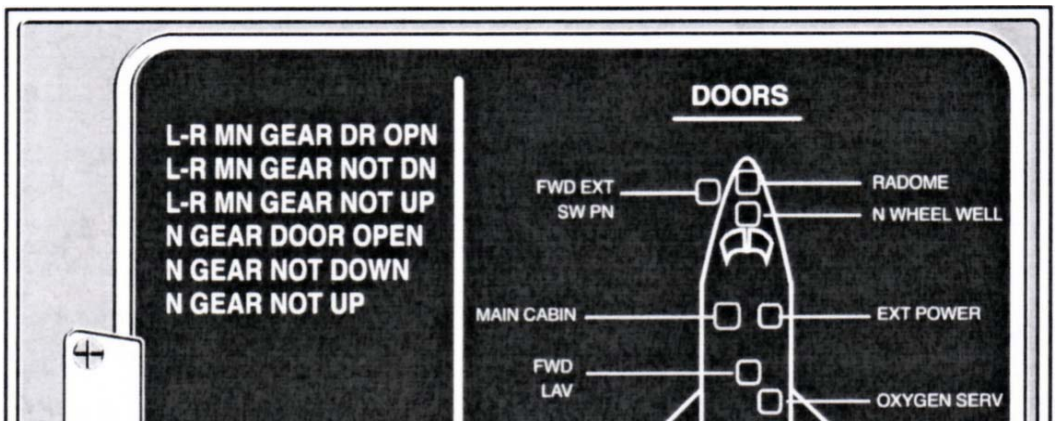
The two main gear doors each consist of a hydraulically operated inboard door and a fairing door, which is fixed to the gear structure. Like the nose wheel door, the main gear doors are activated via a door actuator. The main gear doors can also be opened pneumatically by nitrogen pressure in an emergency.

1.6.3.4 Retraction and extension of the landing gear

The gear is electrically controlled and hydraulically activated. Gear retraction and extension normally take place via the left hydraulic system. If the hydraulic pump driven by the left engine fails, the gear can be retracted and extended normally using pressure from the right hydraulic system via the power transfer unit (PTU).

Three green lights confirm to the crew that the gear is down and locked. In the gear lever itself a red lamp lights up if the lever position does not match that of the gear. When the gear is retracted, this red lamp lights up until all three landing gears are retracted and locked and the gear doors are closed. During extension, it lights up until all three landing gears are down and locked.

In addition, EICAS indicates to the crew if the gear is either not fully extended (down) or fully retracted (up), or if the gear doors are not closed.



1.6.3.5 Acoustic warning relating to gear position

The acoustic gear warning is generated by the fault warning computer (FWC). The FWC monitors height above ground, thrust lever position, flap position and the gear downlock signals.

In flight, the crew are made aware of the following abnormal configurations by the acoustic gear warning:

- The engine power lever position is less than 5°, the flaps are at a position of less than 22° and the gear is not down and locked at an altitude of 350 ft AGL (radio altitude).
- The flap position is over 22° and the gear is not down and locked.

At a flap position of less than 22° the acoustic warning can be suppressed with the HORN SILENCE pushbutton on the landing gear control panel. The amber illuminated pushbutton indicates to the crew that the warning has been suppressed.

At a flap position greater than 22° the acoustic warning can be suppressed only if either the flaps are retracted to 20° or less or the gear is extended.

Since in the accident in question the flaps were set to the 39° position and the gear was only partially extended and locked, the acoustic gear warning was activated and could not be suppressed.

1.6.3.6 Extension of landing gear in an emergency

If it is not possible to extend the gear as a result of a pressure loss in the hydraulic system, it can be extended with the aid of nitrogen pressure (emergency extension) (see Annex 2, violet system).

In order to extend the gear in an emergency, a so-called T-handle must be pulled on the copilot's side. This opens, via a cable, the air release valve, which releases nitrogen (N_2) from two bottles at a pressure of 3100 psi. The three door actuators which open the gear doors are activated via separate pneumatic lines. In addition, the gear is unlocked, extended and locked again in the down position. At the same time, the gear is disconnected from the hydraulic system.

This entire process lasts for approximately six seconds. In the case of emergency extension and locking of the gear, the sequence for closing the gear doors is bypassed and the gear doors remain open.

1.6.4 Findings after the accident

The nose of the aircraft was lifted using a hydraulic crane in order to open the nose wheel door by force and extend the nose gear. When the nose wheel door was opened, and before the nose wheel was released from its uplock, the piston housing of the door actuator shuttle valve fell to the ground.

It was possible to release the nose wheel from its uplock, but it could not be locked in the extended position, as the drag brace had been abraded.

On the door actuator it was evident that the four screw heads securing the end gland on the shuttle valve had ripped off. The end gland was broken and hanging from the hydraulic line (see Annex 3).

1.7 Meteorological information

1.7.1 General

The information in chapters 1.7.2, 1.7.4 and 1.7.5 was provided by MeteoSwiss and that in chapters 1.7.3 and 1.7.6 by skyguide.

1.7.2 General weather situation

A low-pressure area was moving from France to the Mediterranean and brought rainfall, some heavy, to the whole of Switzerland. In the course of the day, the snowline fell to about 2000 metres, and locally to 1500 metres. The high-altitude winds turned from south to north-east towards the evening.

1.7.3 Forecasts and warnings

Short TAF Zurich-Kloten (LSZH) airport for the period of the accident:

TAF LSZH 011800Z 011904 21005KT 4500 RA FEW006 SCT024 BKN030
TEMPO 1904 9999 NSW=

TAF AMD LSZH 012100Z 012207 16005KT 6000 –RA FEW005 SCT010 BKN020
TEMPO 2203 BKN005=

The following AIRMET was broadcast together with the ATIS information:

up to and including ATIS X-RAY at 19:50 UTC

AIRMET 6. VALID BTN 1700 AND 2000.
SWITZERLAND FIR MOD ICING FCST ABV FL 65 STNR INTENSITY NO CHANGE

from ATIS BRAVO at 20:50 UTC

AIRMET 7. VALID BTN 2000 AND 0200.
SWITZERLAND FIR MOD ICING FCST ABV FL 70 STNR INTENSITY NO CHANGE

1.7.4 Measured and observed values

METAR Zurich-Kloten (LSZH) airport for the period before and during the accident:

LSZH 011850Z 20003KT 160V230 7000 RA FEW008 BKN011 BKN021 11/10
Q1017 NOSIG=

LSZH 011920Z 17004KT 7000 RA FEW007 BKN012 BKN022 11/10 Q1017
NOSIG=

LSZH 011950Z 15003KT 100V190 7000 –RA SCT006 BKN012 BKN020 10/09
Q1018 TEMPO BKN006 =

LSZH 012020Z 16008KT 7000 –RA SCT006 BKN012 BKN020 10/09 Q1018
TEMPO BKN006=

LSZH 012050Z 17006KT 120V200 6000 –RA SCT005 BKN011 BKN020 10/09
Q1018 TEMPO BKN006=

1.7.5 Weather at the time of the accident at Zurich airport:

On the basis of the listed information, it is possible to conclude that the weather conditions at the time and location of the accident were as follows:

Cloud	*3/8 at 1900 ft AMSL, 5/8 at 2500 ft AMSL, 7/8 at 3400 ft AMSL*
Weather	*light rain*
Visibility	*6 km*
Wind	*south-south-east 6 kt*
Temperature/dewpoint	*10 °C / 09 °C*
Atmospheric pressure	*QNH LSZH 1018 hPa, LSGG 1019 hPa, LSZA 1013 hPa*
Position of the sun	*Sun below the horizon*
Hazards	*Moderate icing above FL065*

1.7.6 Zurich airport ATIS reports

Before and during the accident, the following ATIS reports were being transmitted:

INFO UNIFORM
LDG RWY 28 ILS APCH
QAM LSZH 1850Z 01.06.2007
220 DEG 4 KT
VIS 7 KM
RAIN
CLOUD FEW 800 FT. BKN 1100 FT. BKN 2100 FT
+11/+10
QNH 1017 ONE SEVEN
QFE THR 14 967
QFE THR 16 967
QFE THR 28 966
NOSIG

INFO WHISKEY
LDG RWY 34 ILS APCH
QAM LSZH 1920Z 01.06.2007
190 DEG 3 KT
VIS 7 KM
RAIN
CLOUD FEW 700 FT. BKN 1200 FT. BKN 2200 FT
+11/+10
QNH 1017 ONE SEVEN
QFE THR 14 967
QFE THR 16 967
QFE THR 28 966
NOSIG

INFO X-RAY
LDG RWY 34 ILS APCH
QAM LSZH 1950Z 01.06.2007
200 DEG 4 KT
VIS 7 KM
LIGHT RAIN
CLOUD SCT 600 FT. BKN 1200 FT. BKN 2000 FT
+10/+09
QNH 1018 ONE EIGHT
QFE THR 14 967
QFE THR 16 968
QFE THR 28 967
TREND TEMPO BKN 600 FT
NOSIG

INFO ALFA
LDG RWY 34 ILS APCH
QAM LSZH 2020Z 01.06.2007
VRB 2 KT
VIS 7 KM

LIGHT RAIN
CLOUD SCT 600 FT. BKN 1200 FT. BKN 2000 FT
+10/+09
QNH 1018 ONE EIGHT
QFE THR 14 968
QFE THR 16 968
QFE THR 28 967
TREND TEMPO BKN 600 FT
NOSIG

INFO BRAVO
LDG RWY 34 ILS APCH
QAM LSZH 2050Z 01.06.2007
200 DEG 5 KT
VIS 6 KM
LIGHT RAIN
CLOUD SCT 500 FT. BKN 1100 FT. BKN 2000 FT
+10/+09
QNH 1018 ONE EIGHT
QFE THR 14 968
QFE THR 16 968
QFE THR 28 967
TREND TEMPO BKN 600 FT
NOSIG

1.8 Aids to navigation

DVOR/DME Kloten (KLO) and ILS DME 14 were being used as navigation aids. The ILS DME 14 system is CAT IIIB capable.

DVOR KLO is an omnidirectional VHF radio range which functions on the Doppler principle. It is equipped with distance measuring equipment (DME).

The stations DVOR/DME KLO and ILS 14 were in normal operation at the time of the accident and were available to the operational services without restriction.

1.9 Communications

Radiocommunication between the crew and the air traffic controllers involved took place without exception in an orderly fashion and without any difficulties.

According to the two pilots' statements, they were optimally supported in all respects by the corresponding air traffic controllers.

1.10 Aerodrome information

1.10.1 General

Zurich Airport is located in north-east Switzerland. The airport reference point (ARP) has coordinates N 47 27.5 / E 008 32.9 and an ELEV of 1384 ft.

The dimensions of Zurich airport runways are as follows:

Runway	Dimensions	Elevation of the runway threshold
16/34	3700 x 60 m	1390/1386 ft AMSL
14/32	3300 x 60 m	1402/1402 ft AMSL
10/28	2500 x 60 m	1391/1416 ft AMSL

1.10.2 Runway equipment

Zurich airport is characterised by a system of three runways, two of which (16 and 28) intersect at the airport reference point. The approach paths of two other runways (16 and 14) intersect approximately 850 metres north-west of the threshold of runway 14. Runways 16 and 14 are equipped with a Category III instrument landing system (ILS), runway 34 with a CAT I system and runway 28 with an "uncategorised" ILS. These runways are therefore suitable for precision approaches.

1.10.3 Operational restrictions

The Alarm 21 was raised at 18:55 UTC and at 19:00 UTC, in accordance with the operating regulations, runway 34 was put in service for landings and runway 32 for take-offs.

According to the Skyguide logbook (LOGOPS), the landing of aircraft HB-IMJ took place at 20:53 UTC on runway 14. The airport was closed as a result of the deployment of the fire brigade. According to LOGOPS, the airport, with the exception of runway 14, was re-opened at 20:57 UTC.

After recovery of the aircraft and the subsequent clean-up works on runway 14, the runway was released again on 2 June 2007 at 02:40 UTC.

1.11 Flight recorders

1.11.1 Flight data recorder

Type	Digital Flight Data Recorder - DFDR
Manufacturer	Penny+Giles Aerospace Incorporation, Kansas, USA
Year of construction	1997
Part Number P/N	91005-0031122
Serial Number S/N	86795

1.11.2 Quick Access Recorder

Type	Quick Access Recorder – QAR, Model QAR200
Manufacturer	L3 communications, Sarasota, Florida, USA
Part Number P/N	QAR200-02-00
STC / PMA	The QAR is approved by the American (FAA) and European (EASA) licensing authority. DOC 905-E3582-05.
Parameters	70 different parameters were recorded.
Recording	The entire flight from take-off at EHRD to landing at LSZH was recorded.

1.11.3 Cockpit voice recorder

Type	Cockpit Voice Recorder - CVR
Manufacturer	Penny+Giles Aerospace Incorporation, Kansas, USA
Year of construction	1997

Part Number P/N	89095-0031
Serial Number S/N	85769
Recording medium	Solid state memory
Duration of recording	30 minutes

1.12 Wreckage and impact information

The aircraft came to a standstill approximately 1900 m after the threshold of runway 14 (see Annex 4). The aircraft was positioned, pointing ten degrees to the right, two to three metres to the left of the runway centreline.

A wide strap was placed around the front part of the fuselage and the nose of the aircraft was lifted with the aid of a hydraulic crane. The intention was to extend the nose gear manually, lock it and tow the aircraft away. When the badly damaged gear door was opened, it was apparent that the drag brace had been considerably abraded (see Annex 1). This meant that the nose gear could no longer be locked.

In order to clear the runway, the aircraft nose was lowered onto a low loader. It was then possible to tow the aircraft off the runway on its main gear, with the nose on the low loader.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Fire did not break out.

1.15 Survival aspects

There was no direct danger to the crew and passengers, because the airframe remained intact, the aircraft did not leave the runway and the rescue services were standing by.

1.16 Test and research

1.16.1 Examination of the shuttle valve end gland

Fractographic examination of the end gland showed that the fracture occurred on the inner radius at the transition from the lug to the flange. At the origin point of the fracture, impressions could be detected on the surface of the inner radius, which were very probably caused by a washer. Other incipient cracks were present over virtually the entire extent of the inner radius (see Annex 5, figure 1 and 2).

An incipient crack was also present on the opposite side of the flange over the entire extent of the inner radius.

Part of the surface of the fracture was mechanically damaged (secondary damage). Macrofractographically, the origin of the fracture was located in the area of the indentation point of the washer.

The other incipient cracks were opened up in the laboratory. The incipient cracks also run out from the inner radius and the image of the laboratory fracture hardly differs from the primary fracture surface.

The primary fracture surface and the laboratory fracture surfaces were examined under the scanning electron microscope. In the area of the origin of the fracture there were numerous steps which are in the direction of the machining traces (rotary scoring). The fatigue fracture is delimited from the ductile forceful fracture surface by a surface which is a half-ellipse in shape. A comparable picture emerged from the laboratory fractures.

The chemical composition of the end gland was then established by means of optical emission spectrometry. The analysis showed that the actual composition corresponds to the alloy type 7075. According Gulfstream's drawing No. 1159HM20151 this material was approved as an alternative.

1.16.2 Investigation of the end gland retaining screws

Fractographic examination of the retaining screws indicated the typical characteristics of a fatigue fracture. With approximately 85%, screw 1 exhibits the highest fatigue fracture area (see Annex 6, figure 1 and 2). Screws 2, 3 and 4 show fatigue fracture area of approximately 70%. There are numerous steps, which indicate a high level of notch effect. The residual surfaces of the forceful fracture show the typical characteristics of a ductile fracture (honeycombs). No abrasion is evident on the thread flanks, as is normally present when adequate tension force is applied to screws.

A metallographic cross-section was then produced in the axial direction on screw 1. The screw is coated; the coating is undamaged along the thread flanks. Incipient cracks, presumably caused during manufacture, were present over virtually the entire length of the screw on the thread flanks. In the groove of the further threads, fine incipient cracks were also present (see Annex 6, figure 3).

Since all four screws exhibited a relatively high fatigue fracture component and the surfaces in the area of the fracture exhibited hardly any mechanical damage, it can be assumed that all four screws were ripped out simultaneously.

1.16.3 Examination of the shuttle valve piston housing

The two O-ring seals on the piston housing were removed. The O-ring on the manually engraved side of the piston housing was abraded over virtually the entire circumference.

Filings and solid particles were taken from the front face, the lateral surface and the internal areas of the piston housing, separated and analysed by means of energy-dispersive X-ray analysis. Basically there is a mixture of multiple different particles at the sampling points. On the one hand there are aluminium particles with a composition comparable to that of the shuttle valve end gland, and on the other there are coating particles. It was also possible to analyse small steel filings with high Cr and Ni contents, presumably originating from the piston housing itself.

1.16.4 Impact point on the door bell crank

The door bell crank located approximately 60 cm from and at the same level as the shuttle valve, exhibited an impact point. At the base of the impact point, machining traces of the impacting component were impressed; these were compared with the machining traces on the front face of the shuttle valve piston housing. There is a good match between the machining radii. The traces permit

the conclusion that the piston housing hit the door bell crank at high speed, comparable to that of a bullet.

1.16.5 Examination of the hydraulic fluid

The hydraulic fluid used was Skydrol LD-4. Visual examination of the hydraulic fluid indicated a clear, brownish-red/black fluid with little contamination by solids. Analysis of the hydraulic fluid shows that it no longer complied with the specification for Skydrol LD-4 in terms of viscosity at 38 °C and 99 °C as defined by the manufacturer in its Technical Bulletin Pub. No. 7249153C.

In the case of the trace elements, the relatively high calcium and potassium warranted attention; however, the examined parameters still comply with the limits as published in the manufacturer's Technical Bulletin.

1.16.6 Investigation of the drag brace

The formation of bubbles in the coating was simulated by annealing tests on a piece cut off from the drag brace which was examined. The tests were aborted at a temperature of 300 °C without any bubbling occurring. From this it is possible to make the qualitative statement that the temperatures reached at the abrasion point of the brace were distinctly above 300 °C (see Annex 1).

1.16.7 Functionality of the door actuator

Two new 0-ring seals were fitted to the shuttle valve piston housing and the new end gland supplied by the manufacturer (P/N 1159HM20151-1) was mounted on the door actuator shuttle valve using the new screws also supplied (P/N NAS1101E3H8).

The door actuator was tested for functionality on a hydraulic test bench. The basis for this function test was the test specification provided by the aircraft manufacturer, document No. 1159-MS-09 *(GULFSTREAM HYDRAULIC TEST SPECIFICATION 1159-MS-09 ACTUATORS, DOUBLE ACTING-INTEGRAL SHUTTLE 3000 PSI SYSTEM)*.

Among other things, this test specification states that the pressure required to set the door actuator piston in motion must be between 25 and 100 psi. The test showed that the piston was set in motion in both directions at approximately 52 psi and moved as far as the stop.

The functionality of the shuttle valve was tested by connecting the nitrogen inlet to the hydraulic pressure line. The shuttle valve piston moved even at a pressure of 11.5 psi and the door actuator piston functioned similarly to the first test.

In addition, 3000 psi pressure was applied to the door actuator on each side for one minute. It was apparent that the door actuator was internally and externally tight.

The test showed that the door actuator functioned perfectly once the broken parts had been replaced.

The failure of the door actuator during the flight involved in the accident is attributable to the fracture of the four retaining screws and the shuttle valve end gland. Consequently, it was not possible to build up either hydraulic or pneumatic pressure in the door actuator.

1.17 Organizational and management information

1.17.1 The G5 Executive AG company

1.17.1.1 General

The owners and managers of G5 Executive AG founded their first air transport company for business travellers in Germany in 1983. In 1997 it was registered in the cantonal commercial register of Zug as a public limited company with a registered office in the city of Zug and in 1998 offered for the first time a worldwide long-haul operation using the Gulfstream G-V.

The air transport company is certificated by the Federal Office of Civil Aviation under AOC (Air Operator Certificate) number 1009 and is authorised to make worldwide flights, including ETOPS (Extended-range Twin-engine Operation Performance Standards) of up to 180 minutes, under JAR/OPS. The American FAA 129 certificate additionally permits the air transport company to carry out unlimited operations in the United States of America.

In 2002 the air transport company extended its fleet with the first “Embraer Legacy” executive aircraft and in the following year the first type G550 executive aircraft was brought into service.

The first type G450 executive aircraft was brought into service by the air transport company in 2006 and an additional type G550 aircraft was integrated into the fleet. At this time the company had completed more than 10 000 flying hours with its first Gulfstream G-V type aircraft, HB-IMJ, and therefore had the most flying hours on this aircraft type.

At the time of the accident, the air transport company was operating a fleet of five aircraft. One aircraft respectively of the following types: EMB-135BJ (LEGACY 600), Gulfstream G-V and G-450 and two aircraft of the Gulfstream G-550 type.

1.17.1.2 Rest time procedures

The procedures regarding duty times and rest times are laid down in the operator’s Operations Manual A (OM A). Chapter 7.1.2 “Definitions”, among other things, states the following under “duty time”:

The total time between the duty start of the crewmember after a rest time and the time at which the crewmember has terminated the leg or the flight and has accomplished all tasks, which are connected with it.

For pre-flight and post-flight duties one hour before and one half hour after the flight have to be taken into consideration as duty time. If aircraft preparation (e.g. fuelling, catering, etc.) is accomplished by ground personnel pre-flight duty time can be reduced to half an hour, if required.

Additional work of crewmembers (i.e. administration) for and on behalf of G5 Executive also counts towards the duty time.

According to the statement of the commander of the crew of flight EXH 152, the aircraft was fuelled on arrival in Rotterdam and catering was provided by the cabin crew, who had already arrived in Rotterdam the previous evening. Thus the pre-flight duty time was reduced to 30 minutes (see above).

With regard to rest times, chapter 7.1.9 "Rest Time" states the following, among other things:

Between duty time periods each crewmember has to be allowed sufficient rest time as follows:

Duration of duty time in hours	*Minimum duration of rest period in hours*
up to 12	*8*
12 to 14	*10*
14 to 20	*12*
More than 20 (mode "B")	*14*

1.17.1.3 Procedures

The air transport company works according to the aircraft manufacturer's QRH (see also chapter 1.17.2).

According to information from the crew, they had contact with the aircraft manufacturer's help line and were able to obtain additional advice from test pilots on various flight manoeuvres and the impending emergency landing.

1.17.2 The aircraft manufacturer Gulfstream

1.17.2.1 General

Gulfstream Aerospace Corporation was founded in 1978 as a successor in interest to Grumman American Aircraft Company and is currently a fully owned subsidiary of General Dynamics. By the time of the accident, the aircraft manufacturer had built more than 1500 aircraft for clients in the private, business, state and military domains.

Gulfstream launched the Gulfstream G-V aircraft in 1997 and in so doing brought the first ultra-long-range business jet onto the market. Powered by two Rolls-Royce BR 710 engines, the G-V was able to make non-stop flights at a speed of mach 0.885 over a distance of 6500 nautical miles. Gulfstream G-V production ended with the construction of the 193rd aircraft in December 2002 and the production line was switched to the G-500 and G-550.

1.17.2.2 Procedures in the event of hydraulic failures

According to the statement of the crew of flight EXH 152, after the first go-around they consulted the checklist for the fault message L HYD QTY LOW under MESSAGES AND ANNUNCIATIONS in the aircraft manufacturer's Quick Reference Handbook (QRH). This checklist indicates how the crew are to proceed if the loss of hydraulic fluid is evident:

"If leak is evident, expect system to fail. See appropriate procedure in the Fuel / Hydraulics Index, page EE-1".

The Fuel / Hydraulics Index, page EE-1, refers to the following checklist in the event of failure of the left hydraulic system:

Left Hydraulic System (L SYS) Failure .....EE-7 (see Annex 7)

1.17.2.3 Procedures for abnormal gear conditions

In the QRH, the procedures for abnormal gear conditions are specified under ABNORMAL / EMERGENCY PROCEDURES in the "Abnormal Gear Condition - Emergency Landing" checklist. Procedures for the following four gear conditions are included in this checklist:

- *Nose Gear Retracted, Both Main Gear Down And Locked*
- *One Main Gear And Nose Gear Down And Locked, Opposite Main Gear Retracted*
- *One Main Gear Only Down And Locked*
- *Both Main Gear Retracted, Nose Gear Down And Locked*

In the present accident, the first procedure was applicable (see Annex 8).

1.17.2.4 Procedures for emergency evacuation

The manufacturer has specified the procedure for an emergency evacuation in the QRH under ABNORMAL / EMERGENCY PROCEDURES on page EI 5 as follows:

Emergency Airplane Evacuation AFM 4-19-50

1. Parking Brake ..... SET
2. L/R FUEL CONTROL ..... OFF
3. APU MASTER ..... OFF
4. L/R FIRE HANDLES ..... PULL
5. L/R FIRE HANDLES ..... ROTATE FULLY TO DISCH 1 / DISCH 2
6. CABIN PRESSURE CONTROL ..... MANUAL
7. OUTFLOW Valve ..... FULL OPEN
8. LEFT / RIGHT MAIN BATTERIES ..... OFF
9. Passengers/Crew ..... EVACUATE IMMEDIATELY

END

Point 5 specifies explicitly that the two fire handles must be rotated.

1.18 Additional information

According to information from the Gulfstream aircraft manufacturer, a modification was made in December 1980 because of damage to the end gland of an uplock actuator for the main gear. The thickness of the material for the end gland flange was increased from 0.125” to 0.375”. This modification was made to the door actuators and the uplock actuators of the main gear and to the nose gear retract actuator. This modification was not implemented on the nose gear door actuator and uplock actuator.

In November 1996 screws on the hydraulic reservoir of GIV type aircraft had caused problems. These screws were of the same type as the retaining screws on the end gland of the nose gear door actuator shuttle valve on the aircraft involved in the accident. As a measure, the aircraft manufacturer immediately published customer bulletins (CB) for operators of aircraft types GII, GIII and GIV. This CB required tightening of these screws within 150 hours and replacement of the type AN502 retaining screws by type AN3CH retaining screws within 300 hours.

On 22 June 2007 there was an incident which had the same cause as the present accident. According to a report to the FAA, the aircraft, also a Gulfstream G-V, was on a military training flight. A crew member in the rear of the aircraft noticed hydraulic fluid traces on a cabin window. He immediately informed the flight crew and the latter established that hydraulic fluid was leaking and that hydraulic pressure was falling. The flight crew decided to return to base immediately. They were able to extend the gear normally and land without incident.

The aircraft manufacturer's investigations after the incident showed that a retaining screw for the end gland of the nose landing gear door actuator shuttle valve had ripped off and that parts of the gland had broken off (see Annex 9).

1.19 Useful or effective investigation techniques

Not applicable.

2 Analysis

2.1 Technical aspects

The primary fracture of the end gland was initiated by a fatigue fracture, starting from the inner radius at the transition from the flange to the lug. The fracture starts in the area of a nick which was presumably caused by the impression of the washer lying on it. The question arises whether the choice of diameter of the washer was appropriate.

In 1980 a modification was made because of damage to the end gland of an uplock actuator for the main gear. The thickness of the material for the end gland flange was increased from 0.125" to 0.375". This modification was made to the door actuators and the uplock actuators of the main gear and to the nose gear retract actuator. The question of why this modification was not made to the door actuator and uplock actuator of the nose gear was answered by the manufacturer as follows:

"An end gland modification made to a different component of the aircraft performing a similar function was not viewed by the OEM as being relevant to the part that caused this event. The end glands which were changed in 1980 have a 90° angle in the hydraulic port versus a straight port on the NLG door actuator end gland. There were no reported problems with the NLG door actuator end gland design, thus a change was not deemed to be necessary. Furthermore, the stress analysis of the NLG door actuator end gland showed positive static and fatigue margins."

In view of the results of the investigation it must be assumed that the primary cause of the accident must be sought in the retaining screws of the end gland on the nose gear door actuator shuttle valve. The cracks in, and fracture of, the end gland must therefore be classified as secondary damage.

All four retaining screws exhibited a high area of fatigue fracture (pulsating/flexural loading), finally leading to failure (forceful fracture). Numerous production-related incipient cracks were present on the thread flanks of the retaining screws. The applied coating is virtually undamaged, indicating that the screws were insufficiently tightened.

It is highly probable that the accident would not have occurred if the shuttle valve of the nose gear door actuator had been equipped with a modified end gland (0.375") and with more appropriate screws than the AN502 type.

2.2 Human and operational aspects

2.2.1 Flight crew

2.2.1.1 Application of various checklists

According to the commander's statement, after the first go-around, in AMIKI holding, the crew dealt with the checklist for the fault message L HYD QTY LOW, which states that in the event of an evident loss of hydraulic fluid, as mentioned in the "Fuel / Hydraulics Index", page EE-1, the following procedure shall be applied:

Left Hydraulic System (L SYS) Failure .....EE-7 (see Annex 7)

The commander confirmed that the loss of hydraulic fluid was indeed evident but that the L HYD SYS FAIL warning was not yet being displayed.

The subsequent discussions in the cockpit regarding the flap position for the approach leave open the question of whether the checklist for the "Left Hydraulic System (L SYS) Failure" was processed in full. This checklist mentions the following for the condition which was apparent in the flight involved in the accident: *If loss of only L SYS fluid has occurred, perform Steps 3 through 20* (see Annex 7). There it is mentioned that a flap position of 20° should be used for landing.

During the second approach, after extending the gear, the same situation applied as for the first approach. Main gear down and locked, nose gear not extended. As a result, the crew applied the "Landing Gear Failure To Extend" procedure. Application of this procedure was a logical consequence and appropriate. However, this procedure also produced no effect.

The decision to fly a low pass over runway 14 to have ground units verify whether the nose gear was extended was appropriate.

Making telephone contact with the aircraft manufacturer in AMIKI holding made sense. However, the instructions given by the aircraft manufacturer to release any possible mechanical jamming of the nose gear by flying manoeuvres with positive g-load had no effect.

After the unsuccessful flying manoeuvres, the crew turned their attention to the impending emergency landing. To this end they consulted the "Abnormal Gear Condition - Emergency Landing" checklist (see Annex 8). The procedure in this checklist for the case of "Nose Gear Retracted, Both Main Gear Down & Locked" begins with a *NOTE* which mentions the flying manoeuvres advised by the aircraft manufacturer over the telephone. The instruction states that the manoeuvres must be carried out with flaps retracted and that the g-load must not exceed a value of 2.5g.

The recordings show that the flying manoeuvres were carried out at a 20° flap setting. It is not know whether this configuration was discussed with the aircraft manufacturer. Since the auxiliary hydraulic system was operational, it would have been possible to retract the flaps.

After declaring an emergency, the crew discussed the evacuation of the aircraft in accordance with the “Emergency Airplane Evacuation” checklist (see chapter 1.17.2.4). The copilot read out the checklist item by item. Contrary to the checklist, the commander decided only to pull the fire handles of both engines but not to turn them. He expressed the opinion that this only had to be performed if it were necessary. This decision led to a brief period of uncertainty in the cockpit. The question must remain open as to how appropriate it is to deviate without pressing reasons in an actual emergency situation from specified emergency procedures which had been trained for.

The copilot’s question as to whether he should shut down the engines already during the landing roll on the runway was answered in the negative by the commander with the comment that this would be “too wild a procedure”. The commander’s decision must be supported.

In the discussion on the emergency landing, based on the “Abnormal Gear Condition – Emergency Landing” checklist, the commander mentioned to the copilot, among other things, that after landing he wanted to keep the aircraft’s nose up as long as possible using the thrust reverser, before setting it down on the runway.

The checklist states:

5. Thrust Reverser……USE MAXIMUM (BOTH ENGINES) TO REDUCE LOAD ON NOSE

The absence of thrust reversal on the left engine due to the hydraulic fault was not addressed.

The next point in the checklist is:

6. Nose……FLY ONTO RUNWAY

The commander's intention to keep the aircraft's nose up as long as possible is not in line with this instruction.

After further telephone contact with the aircraft manufacturer's test pilot it was decided not to use the thrust reversers and not to keep the aircraft's nose up for too long.

The acoustic gear warning sounded after the flaps were extended beyond the 22° position (see chapter 1.6.3.5). As the CVR recordings show, this acoustic warning was perceived as very intrusive by the crew throughout the final approach. Until just before the landing, they therefore tried to cancel the warning by pressing various pushbuttons. All these attempts were unsuccessful. The question must remain open whether a lack of systems knowledge or intense mental pressure meant that the crew did not realise that the warning could have been stopped by retracting the flaps.

If the crew had acted in accordance with the checklist for "Left Hydraulic System (L SYS) Failure", the flaps would have remained in the 20° position for the approach and the warning would not have been triggered.

In the present accident, there arose two different problems which had a common cause. There exists a checklist for each individual problem which is orientated specifically to the respective problem. If multiple problems arise, the crew must set priorities, giving appropriate consideration to the individual problems.

In the present case there was an impression that the crew was focused on the failure of the nose gear to extend and therefore did not pay the necessary attention to the consequences of the hydraulic failure.

2.2.1.2 Cooperation in the cockpit

According to the statement of the commander who was pilot flying (PF) on this flight, control was handed over to the copilot on various occasions. These handovers took place in connection with the problems which arose and were appropriate.

The recordings in the CVR, which covered only the last 30 minutes of the flight, gave an indication of the cooperation inside the cockpit. It is conspicuous that very much was discussed. These discussions about procedures and sequences of events took place virtually without interruption until the aircraft came to a standstill on runway 14.

A clear issuing of commands for individual activities in the cockpit was not discernible. Also, there was often a lack of clear information about actions which were taken. This may be related to the fact that the two pilots, as is usual in smaller air transport companies, flew together very often and knew each other well.

The repetition, several times, of procedures for the approach and emergency landing which had already been discussed, constantly disturbed by the acoustic gear warning, gives the impression of a degree of agitation in the cockpit.

The recordings show that the touch-down on runway 14 was soft and that the commander maintained the aircraft on the centreline very well and under good control.

Evacuation of the aircraft was appropriate to the situation.

2.2.1.3 Aircraft manufacturer's checklists

Some of the checklists published in the aircraft manufacturer's QRH (Quick Reference Handbook) are voluminous and very challenging for crews. Thus, for example, the procedure for a "Left Hydraulic System (L SYS) Failure" (see Annex 7) is dealt with over four pages.

In this procedure, item 5 requires the flaps to be set to the 20° position. Immediately afterwards, a *NOTE* points out that it may take up to two minutes for the flaps to extend from the 0° position to the 39° position. This might implicitly give the impression that in the subsequent implementation of the procedure the 39° position is required. It cannot be judged whether this *NOTE* influenced the crew in their decision to set the flaps to the 39° position.

Then, in item 5, this checklist indicates how to proceed if there is an assumed leak of hydraulic fluid in the flap system. However, there is no clue on where to proceed within the checklist if this is not the case.

It is basically difficult for the crew to see where in the "Left Hydraulic System (L SYS) Failure" checklist the procedures for different system conditions begin and where they end.

In this regard, the checklist must be deemed to be not very user-friendly.

In the "Abnormal Gear Condition - Emergency Landing" procedure (see Annex 8), a *NOTE* describes flying manoeuvres whose aim is to free up a jammed nose gear. It is mentioned that a positive g-load of 2.5g must not be exceeded. Compliance with such a limit is, in the absence of a corresponding indication, not possible for pilots.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The aircraft was licensed for VFR/IFR transport.
- The mass and centre of gravity of the aircraft were within the permitted limits at the time of the accident.
- The last scheduled maintenance took place from 15 to 18 May 2007 at 11 213:22 airframe hours.
- It was possible to extend and lock the main gear, but the nose gear could not be extended.
- All four retaining screws on the end gland of the nose gear door actuator shuttle valve were broken. They exhibited a high fatigue fracture component over their surface.
- The typical characteristics of screws which have been tightened could not be established by metallographic inspection.
- The end gland broke and was separated from the shuttle valve.
- The left system's hydraulic fluid gradually leaked out.
- During the attempt to extend the nose gear using nitrogen pressure, the shuttle valve piston housing was expelled.
- Pressure could no longer be built up in the nose gear door actuator and the nose gear door remained closed.

3.1.2 Crew

- The pilots were in possession of the necessary licences for the flight.
- The decisions taken by the crew regarding the flight after the unsuccessful extension of the nose gear were appropriate to the situation.
- The procedures laid down in the aircraft manufacturer's checklists were not implemented consistently by the crew.
- Procedures and sequences of events were discussed virtually without interruption. This discussion was not brought to an end by a structured briefing.

3.1.3 History of the flight

- After an uneventful flight, an approach was made on runway 14 in Zurich.
- When extending the landing gear, the crew established that the nose gear was showing as not extended.
- During the subsequent go-around, the crew established that the indication for the hydraulic fluid quatity in the left-hand system began to fall.
- On a repeated approach, the crew were faced with the same situation: main gear down and locked, nose gear not extended.

- Application of the emergency procedure to extend the gear was not successful.
- To allow observation of the gear configuration from outside, the crew flew a low pass over the runway.
- It was confirmed that the nose gear was not extended.
- In order to release possible jamming of the nose gear, the crew carried out flying manoeuvres with a high g-load.
- These manoeuvres did not achieve the desired result.
- The crew declared an emergency.
- The emergency landing was soft and it was possible to keep the aircraft on the runway centreline until it came to a standstill.
- The emergency evacuation took place via the main entry door.

3.1.4 General conditions

- In the present accident, there arose two different problems which had a common cause. In such a situation, one-sided focussing may occur.
- The “Left Hydraulic System (L SYS) Failure” checklist is not appropriately structured and may hamper the work of the crew, especially under difficult conditions.
- The weather conditions had no influence on the accident.

3.2 Causes

The accident is attributable to the fact that on the nose gear door actuator all four shuttle valve end gland retaining screws ripped off and the end gland broke. As a result, it was not possible to extend the nose gear.

The following factors contributed to the accident:

- failure of the emergency system due to a leak caused by the separated shuttle valve end gland
- inappropriate and insufficiently tightened retaining screws on the shuttle valve end gland
- marginal material thickness of the end gland flange

4 Safety recommendations and measures taken since the accident

4.1 Safety recommendations

In view of the measures already taken by the aircraft manufacturer after the accident, no safety recommendations are being issued.

4.2 Measures taken since the accident

On 2 June 2007, a day after the accident, the aircraft manufacturer informed its customers about the accident via the "MAINTENANCE AND OPERATIONS LETTER" (ALL-MOL-07-0007) as follows, among other things:

On June 1, 2007, a Gulfstream V performed a nose-gear-up landing in Zurich, Switzerland. Passengers were on board the aircraft at the time of the incident and no injuries to the crew or passengers were reported. The event is being investigated and any required fleet action will be communicated.

A second letter followed on 12 June 2007 (ALL-MOL-07-0008). Amongst other things, this ALL-MOL stated:

Gulfstream released Maintenance and Operations Letter (MOL) ALL-MOL-07-0007, on June 2, 2007, communicating a Gulfstream V nose-gear-up landing incident in Zurich, Switzerland. The ongoing investigation of this event is currently focusing on the Nose Landing gear (NLG) door actuator shuttle valve end cap.

Gulfstream has inspected more than 40 aircraft and has found no discrepancies. Investigation into the event continues and further updates will be provided when available.

Another incident on a Gulfstream G-V occurred on 22 June 2007 (see chapter 1.18). The aircraft manufacturer subsequently arranged for the replacement of the type AN502-10-8 retaining screws which were in use.

On 22 June 2007, the aircraft manufacturer also published the "MAINTENANCE AND OPERATIONS LETTER" (GV-MOL-07-0018), in which it informed its customers as follows, among other things:

SUBJECT: *Landing Gear (ATA 32) – Alert Customer Bulletin (ACB) to Inspect Nose Landing Gear Door Actuator Shuttle Valve End Cap.*

On June 2, 2007, Gulfstream issued Maintenance and Operations Letter (MOL) ALL-MOL-07-0007 communicating an incident where a Gulfstream V performed a nose-gear-up landing. Follow-on investigation has concentrated on the nose landing gear door actuator shuttle valve end cap. Gulfstream is developing an Alert Customer Bulletin to provide instructions for inspection of the end cap and attaching fasteners. The anticipated release date of the ACB is today, June 22, 2007.

The above-mentioned ACB (Alert Customer Bulletin No. 27) describes the incident in greater detail and requires one-time action which must be taken within 20 landings but not later than 30 days. Among other things, the ACB states:

B. Reason:

A nose landing gear door actuator shuttle valve end cap separated from the shuttle valve housing, resulting in a loss of hydraulic system fluid. Subsequent efforts to blow down the nose landing gear forced the shuttle valve out of its housing

and allowed the nitrogen to discharge overboard. Investigation determined failure of the shuttle valve end cap and retaining hardware as the cause.

C. Description:

This alert customer bulletin is a one-time action to inspect the nose landing gear door actuator shuttle valve end cap for evidence of cracks, security and condition of retaining hardware

D. Compliance:

Compliance with this alert customer bulletin is to be accomplished within 20 landings, not to exceed 30 days.

E. Approval:

This alert customer bulletin contains no modification information that revises the configuration and therefore does not require regulatory agency approval.

On 25 June 2007 the aircraft manufacturer informed the FAA of the measures taken to date and announced that it had scheduled replacement of the retaining screws under project number TD09991AT-T.

On 29 June 2007 the aircraft manufacturer issued "Alert Customer Bulletin Number 28", in which it required another one-time action under the heading *"Landing Gear (ATA 32), Inspection – Nose Landing Gear Door Actuator Shuttle Valve End Gland (Non-Destructive Testing)"*. Among other things, this was described as follows:

B. Reason:

... Alert Customer Bulletin 27 was issued on June 22, 2007, which directed a visual inspection of the shuttle valve end gland and hardware for condition and security. In addition to a visual inspection, Gulfstream Engineering has determined that non-destructive testing (NDT) of the end gland and installation of improved retaining hardware will reduce the potential for failures of this nature.

C. Description:

This Customer Bulletin is a one-time action to inspect the nose landing gear door actuator shuttle valve end gland using non-destructive testing (NDT) methods and to replace the end gland retaining hardware.

D. Compliance:

For aircraft with NLG door actuators having 2000 cycles or more, compliance with this customer bulletin is to be accomplished within the next 30 days.

For aircraft with NLG door actuators having less than 2000 cycles, compliance with this customer bulletin is to be accomplished within the next 60 days.

E. Approval:

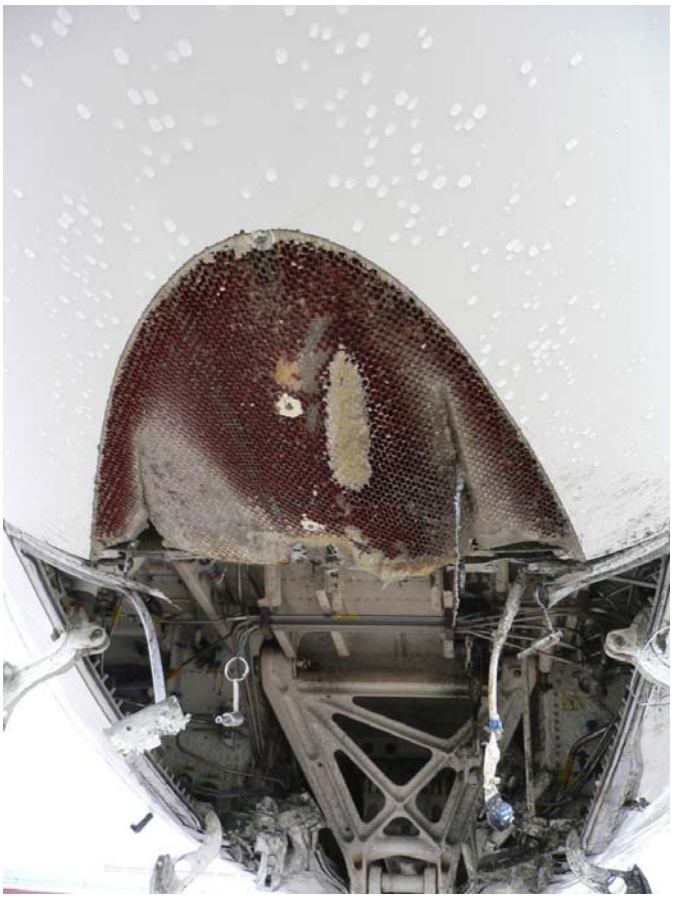
This modification is classified as Minor, and is approved by the Federal Aviation Administration (FAA) and accepted by the European Aviation Safety Agency (EASA) reference, Decision No. 2004/04/CF of the Executive Director of the Agency, dated 10 December 2004.

The work to be performed was scheduled with an inspection time of 8 hours, plus 2 hours if the end gland had to be replaced. It was a requirement that the retaining screws be temporarily removed, one after another, in order to be able to check the end gland flange as well as the drilled holes for the retaining screws for damage. In the process, the retaining screws were replaced by a different type, tightened with a torque wrench and secured.

Berne, 22 April 2008 Aircraft Accident Investigation Bureau

Annexes

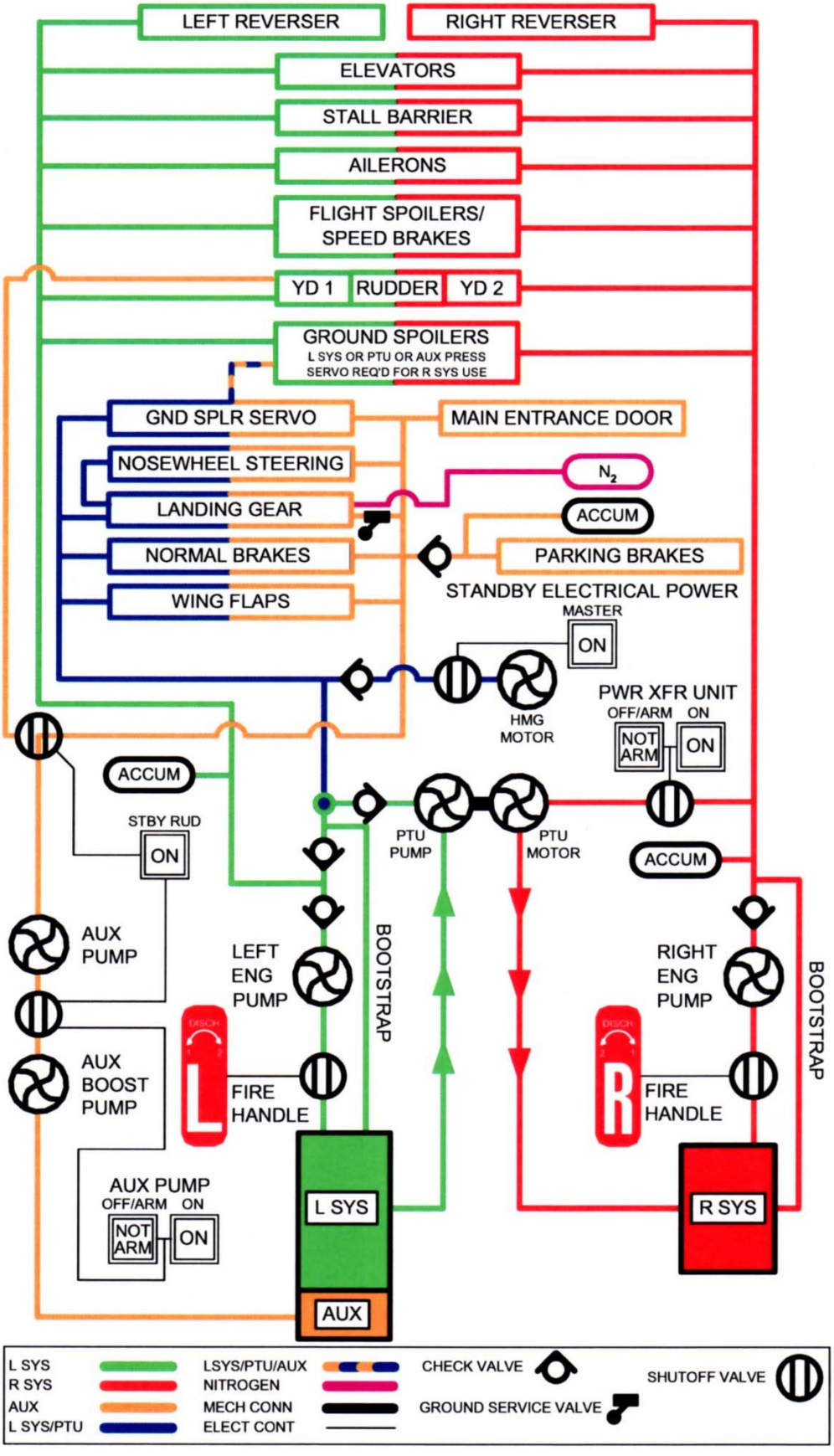
Annex 1: Damage to the aircraft



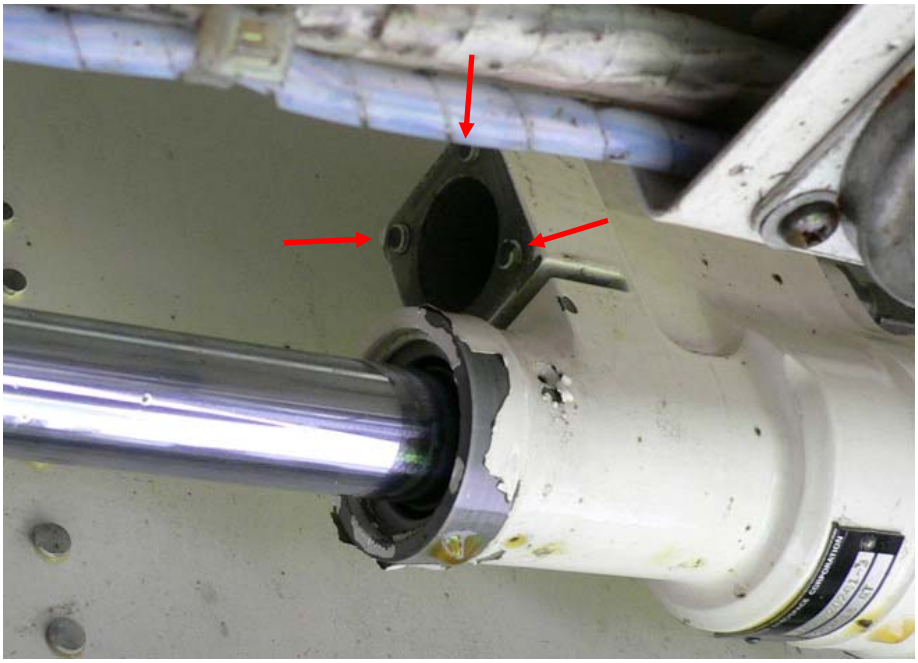
Damaged radome and nose gear bay

Drag brace

Annex 2: Schematic diagram of the hydraulic system

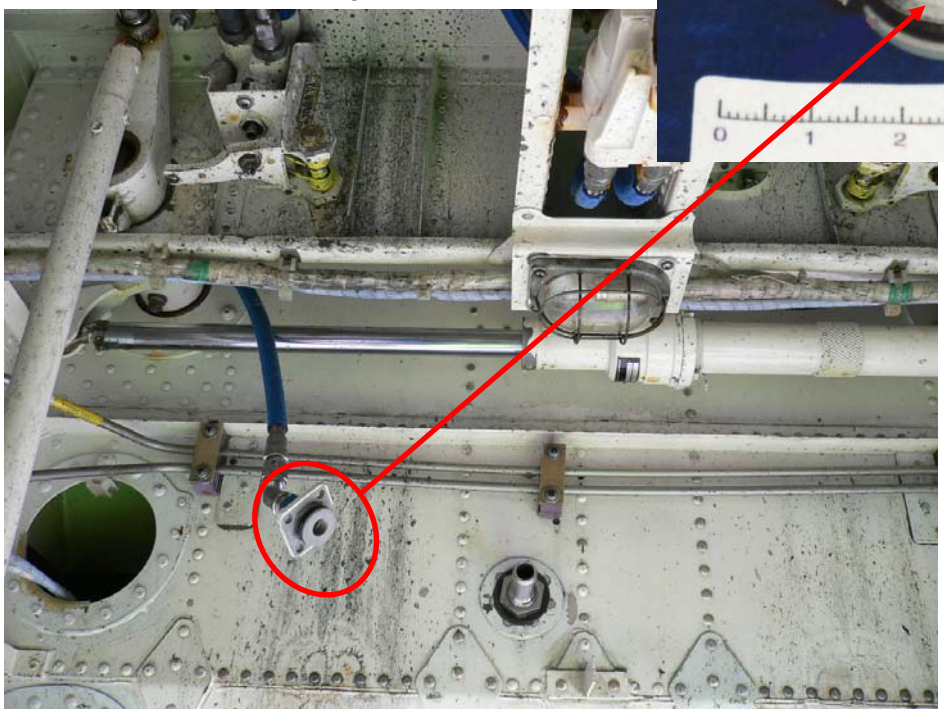


Annex 3: Findings after the accident



Ripped off end gland retaining screws (arrows)

Broken-off shuttle valve end gland



Annex 4: The aircraft after it came to a standstill

Annex 5: Fractographic examination of the end gland

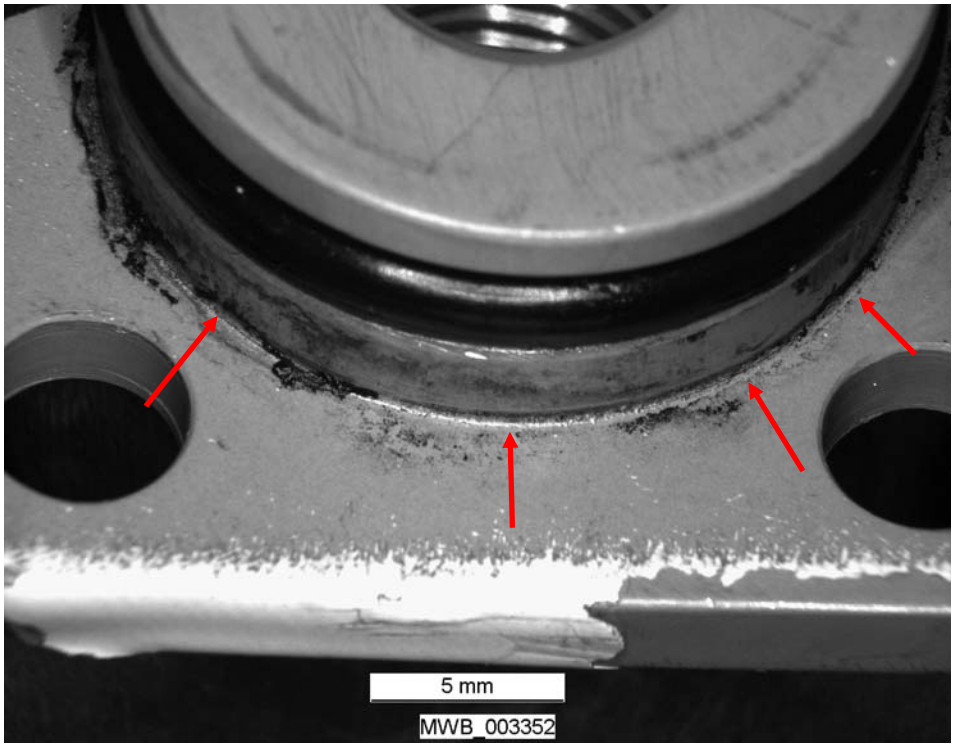


Figure 1:
Incipient crack along inner radius on the opposite side of the flange

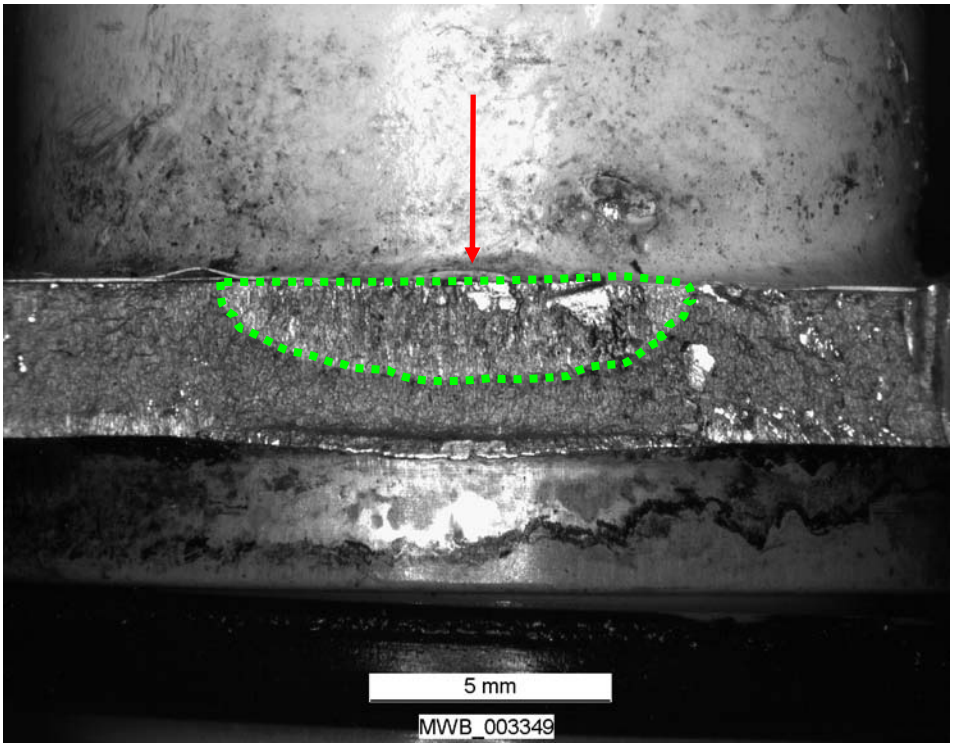


Figure 2:
Fracture surface with secondary damage (shiny). Origin of fracture (arrow) at flange/lug transition. Edged in green: fatigue fracture surface

Annex 6: Fractographic examinations of the retaining screws

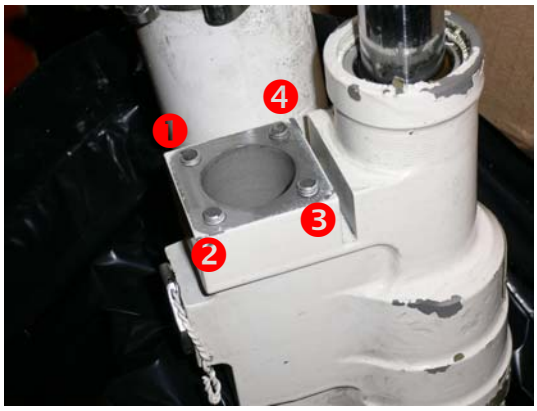


Figure 1: Broken-off end gland retaining screw

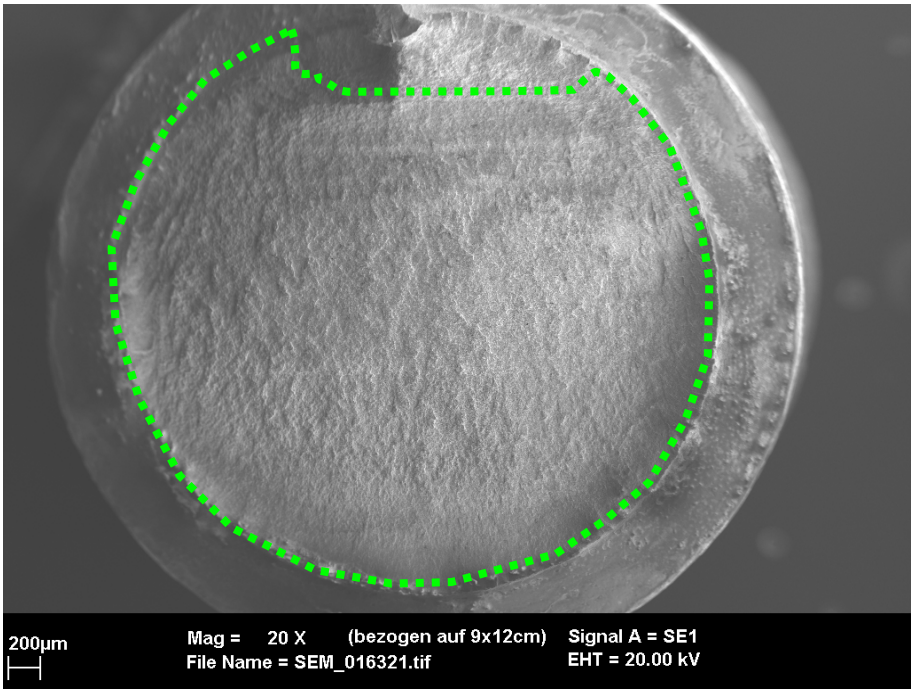


Figure 2: Fracture surface of screw No. 1. Fatigue fracture area edged in green. Numerous steps along the thread base.

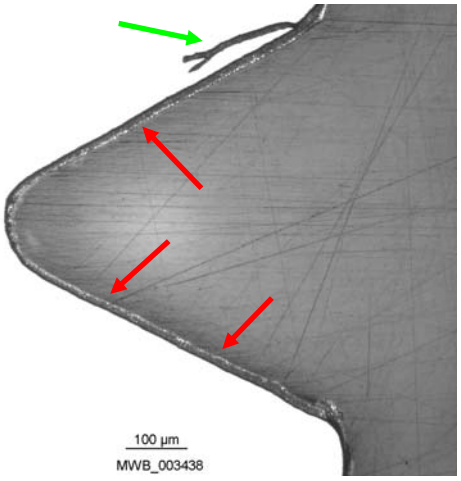


Figure 3: Undamaged coating (red arrows) and incipient cracks (green arrow) on the thread flanks.

Annex 7: Procedure in the event of loss of the left hydraulic system

Left Hydraulic System (L SYS) and Auxiliary Hydraulic System (AUX) Loss Of Fluid, ctd... AFM 4-15-20

14. Speed Brakes ..... EXTEND
15. Right Thrust Reverser ..... DEPLOY / AS REQUIRED

CAUTION: IT IS NORMAL FOR DECELERATION TO INCREASE AS THE STOP PROGRESSES. THIS MAY RESULT IN LOCKED WHEELS AND BLOWN TIRES. REDUCE PRESSURE AS REQUIRED TO MAINTAIN CONSTANT DECELERATION. THERE WILL BE A SIGNIFICANT INCREASE IN LANDING DISTANCE WITH ANTI-SKID INOPERATIVE.

16. Park / Emergency Brake ...AS REQUIRED TO MAINTAIN 400 PSI

Slowly apply park/emergency brake, increasing pressure to 400 PSI. However, it may be necessary to exceed this pressure in order to stop the airplane on the runway. The pilot should devote his attention to airplane control and brake application, while the copilot should monitor applied brake pressure advising the pilot of corrections required to maintain optimum brake pressure.

After Landing:

17. Landing Gear Safety Pins ..... INSTALL

CAUTION: GEAR PINS SHALL BE INSTALLED PRIOR TO RESETTING DUMP VALVE.

END

Left Hydraulic System (L SYS) Failure AFM 3-15-30

1. FGC Selection ..... FGC 2
2. Fluid Quantity ..... CHECK

If loss of L SYS fluid and AUX SYS fluid is suspected or has occurred, see Left (L SYS) and Auxiliary Hydraulic System (AUX) Loss Of Fluid, page EE-6.

If loss of only L SYS fluid has occurred, perform Steps 3 through 20.

If loss of L SYS fluid has not occurred, perform Steps 21 through 30.

Continued on next page →

Left Hydraulic System (L SYS) Failure, ctd... AFM 3-15-30

3. PTU ..... NOT ARM

CAUTION: IF LOSS OF L SYS FLUID IS SUSPECTED OR HAS OCCURRED, 20° FLAPS SHOULD BE PLANNED FOR APPROACH AND LANDING.

For approach and landing:

4. AUX Pump ..... ON
5. Flap Handle ..... 20°

NOTE: Flap extension from UP (0°) to DOWN (39°) may take up to two (2) minutes. An amber **AUX HYD FAIL** message will be displayed on CAS during flap movement.

CAUTION: IF THE AUX HYDRAULIC SYSTEM PRESSURE READS ZERO IMMEDIATELY AFTER SELECTING FLAPS, A HYDRAULIC LEAK IN THE FLAPS SYSTEM SHOULD BE SUSPECTED.

If a hydraulic leak in the flaps system is suspected:

6. AUX Pump ..... OFF
7. FLAP/STAB (LEFT and RIGHT) DC CBs ..... PULL
   FLAP/STAB LEFT DC: POP, C-6 FLAP/STAB RIGHT DC: CPOP, C-6
8. GPWS/GND SPLR FLAP ORIDE ..... ON

NOTE: See **Partial Or Jammed Flaps Landing**, page ED-18.

9. Landing Gear Handle ..... DOWN
10. Airspeed ..... 175 KCAS MAXIMUM
11. Landing Gear ..... EXTEND USING ALTERNATE OPERATION

NOTE: See **Landing Gear Failure To Extend**, page EG-4.

CAUTION: DO NOT RESET EMERG LDG GEAR HANDLE OR DUMP VALVE PRIOR TO LANDING.

12. Landing Gear ..... DOWN / 3 GREEN
13. Flap Position ..... VERIFY 20°

To clear STEER BY WIRE FAIL message:

14. AUX Pump ..... ON
15. NOSE WHEEL STEERING POWER ..... CYCLE OFF THEN ON

Continued on next page →

Left Hydraulic System (L SYS) Failure, ctd... AFM 3-15-30

Prior to touchdown:

CAUTION: ENSURE THAT THE FLAPS HAVE REACHED THE 20 DEGREE POSITION PRIOR TO TOUCHDOWN. IF FLAPS ARE STILL IN TRANSIT, DELAY THE LANDING UNTIL THE FLAP MOVEMENT HAS STOPPED. IF UNABLE TO DELAY THE LANDING, PULL THE FLAP/STAB LEFT DC (POP, C-6) AND FLAP/STAB RIGHT DC (CPOP, C-6) CIRCUIT BREAKERS TO STOP FLAP MOVEMENT. LANDING WITH THE FLAPS IN MOTION DRIVEN BY THE AUXILIARY HYDRAULIC PUMP WILL CAUSE A LOSS OF BRAKES DURING LANDING ROLLOUT.

16. GND SPLR ..... ARMED
17. GPWS/GND SPLR FLAP ORIDE ..... ON

    Select the ORIDE switch to ON if landing with flaps less than 22 degrees. This prevents the nuisance "TOO LOW FLAPS" aural alerts and provides backup capability to deploy the ground spoilers with wheel spin-up.

After landing:

18. Speed Brakes ..... DEPLOY MANUALLY
19. Brakes / Steering ..... AS REQUIRED TO MAINTAIN DIRECTIONAL CONTROL
20. Right Thrust Reverser ..... AS REQUIRED

NOTE: The Left Thrust Reverser will not deploy.

CAUTION: GEAR PINS SHALL BE INSTALLED PRIOR TO RESETTING DUMP VALVE.

If L SYS has failed but L SYS fluid is still available:

While enroute:

21. FGC Selection ..... FGC 2
22. PTU ..... NOT ARM

For approach and landing:

23. PTU ..... ON

    NOTE: For gear and flap operation after takeoff or during approach, operate one system at a time, allowing completion of cycle before operating next system, e.g.,:

    a. After takeoff, raise gear first, then retract flaps after gear is up.
    b. For approach and landing, allow flaps to reach 20° before lowering gear.

Continued on next page →

Left Hydraulic System (L SYS) Failure, ctd... AFM 3-15-30

24. AUX Pump ..... ON
25. Flaps ..... 20°
26. Landing Gear ..... DOWN / 3 GREEN
27. Flaps ..... DOWN (39°)

Prior to touchdown:

28. Ground Spoilers ..... ARMED

After landing:

29. Brakes / Steering ..... AS REQUIRED TO MAINTAIN DIRECTIONAL CONTROL
30. Right Thrust Reverser ..... AS REQUIRED

NOTE: The Left Thrust Reverser will not deploy.

END

Annex 8: Procedure for landing with abnormal gear conditions

GULFSTREAM V *Quick Reference Handbook*

Abnormal Gear Condition - Emergency Landing

AFM 4-18-90

This procedure is divided into the following four scenarios:

- Nose Gear Retracted, Both Main Gear Down And Locked
- One Main Gear And Nose Gear Down And Locked, Opposite Main Gear Retracted
- One Main Gear Only Down And Locked
- Both Main Gear Retracted, Nose Gear Down And Locked

Each scenario title is shown in **bold blue**.

Nose Gear Retracted, Both Main Gear Down & Locked

NOTE: If contamination of the uplocks due to ice and snow is suspected, consider flying to an area where melting can occur. If fully retracted, attempt to release from uplocks by applying positive "g" loading not to exceed 2.5g with flaps UP (0°). If partially extended but not locked down, perform a normal approach and firmly bump the main wheels on the runway in an attempt to shake the nose gear down and locked. Execute go-around. Consideration should be given to flying faster than normal in order to increase elevator effectiveness and the nose falling through on touchdown.

Landing procedure:

1. GPWS / GND SPLR FLAP ORIDE.....ON
2. Touchdown .....RUNWAY CENTERLINE
3. Speed Brakes .....EXTENDED AS NECESSARY
4. Thrust Reversers .....USE MAXIMUM (BOTH ENGINES) TO REDUCE LOAD ON NOSE
5. Wheel Brakes .....USE MINIMUM
6. Nose .....FLY ONTO RUNWAY
   NOTE: Relieve weight with elevator after runway contact.
7. Brakes.....AS NECESSARY FOR DIRECTIONAL CONTROL AND STOPPING

Continued on next page →

Annex 9: Evidence of damage in another incident