AAIB Bulletin No: 6/2005 **Ref: EW/C2004/02/02** **Category: 1.1**

Aircraft Type and Registration:	Falcon 900EX, VP-BMS
No & Type of Engines:	3 Garrett TFE 731-60-1C turbofan engines
Year of Manufacture:	1999
Date & Time (UTC):	9 February 2004 at 0130 hrs
Location:	London (Stansted) Airport, Essex
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - 2
Injuries:	Crew - None Passengers - None
Nature of Damage:	Extensive damage to right wing and landing gear doors
Commander's Licence:	Airline Transport Pilot's Licence (FAA) with Bermudan validation
Commander's Age:	52 years
Commander's Flying Experience:	20,954 hours (of which 700 were on type) Last 90 days - 105 hours Last 28 days - 35 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft departed from Kilimanjaro en route to London (Luton) Airport with a known hydraulic problem. The crew believed, incorrectly, that this was allowed under the terms of the Minimum Equipment List. During the approach at Luton the crew were unable to obtain indications that the gear was down and locked following selections on both the normal and emergency systems. The crew requested a diversion to Stansted and the aircraft was configured for a full flap landing on Runway 05. During the landing roll the right main landing gear partially retracted and the aircraft veered to the right until it finally left the paved surface, crossed the grass, and came to rest about 139 metres to the right of the runway centreline. Four safety recommendations have been made as a result of the investigation.

History of flight

The aircraft departed Kilimanjaro Airport, Tanzania, at 1515 hrs UTC bound for London (Luton) Airport, UK, with the commander as the handling pilot. The planned flight time was nine hours and thirty minutes and on board were two passengers and the crew, consisting of two pilots. All four had arrived in Kilimanjaro on the same aircraft four days earlier and on this inbound flight the crew had experienced an intermittent HYDR#1 PUMP 3 caution light during the final approach. Engineering facilities at Kilimanjaro were limited and since the crew considered the fault still allowed the aircraft to be dispatched under the limitations imposed by the Minimum Equipment List (MEL) they decided to defer the defect and have the problem investigated on their return to Luton.

The crew stated that shortly after departure on the return flight the HYDR#1 PUMP 3 caution light once again began to illuminate intermittently until finally it remained illuminated. The checklist required confirmation that No 1 hydraulic system pressure and quantity were normal but did not call for any specific actions to be taken and the crew continued the flight, monitoring both hydraulic systems. Some time later, between one or two hours into the flight, the crew reported that the hydraulic quantity in the No 1 hydraulic system began to reduce. The rate of loss was irregular until finally, after about twenty minutes, the quantity gauge indicated that the No 1 hydraulic system was empty; however, the crew reported that the hydraulic pressure continued to indicate the normal pressure of 3,000 psi in the No 1 system.

No other warnings were apparent on the flight deck and the crew was unsure whether they had actually lost the No 1 hydraulic system or not. Whilst continuing the flight they referred to the appropriate checklists to identify systems which would be affected following a subsequent loss of the No 1 hydraulic system. As a result they selected the No 2 braking system and reviewed the procedures for emergency slat selection and emergency gear extension. They also added 5 kt to the planned approach speed and an additional 60% to the landing distance required, as indicated in the checklist, before finally confirming that Luton's runway had sufficient landing distance available.

The flight continued without further incident and the aircraft was positioned onto a long base leg for Runway 26 at Luton. The weather at the airport was good with CAVOK conditions and a surface wind from 300° at 6 kt being reported on the ATIS. The aircraft was slowed to 200 kt and the flap selection lever moved to the Flap 7 position. The crew stated that the flap position indicator showed normal slat movement then Flap 7 extension, with the slat indicator light illuminated steady green. However, the red slat indicator light then illuminated and the emergency slat switch was selected, although the crew was unclear of the order in which these last two events occurred. The co-pilot then went into the aircraft cabin and reported that there was sufficient light looking through the window to determine that the outer slats were extended whilst the inner slats were retracted.

Whilst still on base leg the aircraft was slowed to 175 kt and the crew attempted to lower the landing gear using the Landing Gear Control Lever. This resulted in three red but no green gear position indicating lights; these were the expected indications following the loss of the No 1 hydraulic system. Emergency gear extension was then initiated by pulling the Emergency Hydraulic Extension Gear Pull Handle (referred to in the pilot checklist as the Gear Pull Handle). The two Main Gear Manual Release Handles were then pulled; these are positioned either side of the flight deck centre pedestal and each pilot pulled the handle located on his particular side of the flight deck. The commander then instructed the co-pilot to pull the Nose Gear Manual Release Handle. This is located on the commander's side of the central console and the co-pilot had to leave his seat in order to access and pull the handle. The three gear position indicating lights remained red with no green lights illuminated, and at no point did the crew recall hearing the gear lock down.

At this point the commander notified ATC that they had a problem with the landing gear and he was given permission to orbit whilst attempting to rectify the problem. Meanwhile the co-pilot went back into the cabin to inform the passengers of the situation.

The commander then reported that he side-slipped the aircraft in both directions before accelerating to the gear limiting speed (190 kt) and repeating the manoeuvre. The gear indicating lights continued to indicate that the landing gear remained in an unsafe condition and the crew discussed with ATC options for the most suitable airfield at which to attempt a landing. The crew then requested a diversion to Stansted and the co-pilot went back into the cabin once again to brief the passengers for a possible emergency landing and evacuation. At this point the aircraft had been holding for about thirty minutes and the crew estimated that they had about thirty further minutes flight time remaining with the existing fuel on board.

ATC provided radar vectors to establish the aircraft on an approach to Runway 05 at Stansted and the tower controller suggested to the crew that he turn the runway centreline lights off in an attempt to minimise the risk of fire after touchdown. No emergency was declared by the pilots although they did request full attendance by the emergency services for the landing. The crew decided that on touchdown the co-pilot would turn off the three generators and two batteries to reduce the risk of fire.

The aircraft was configured for a full flap (Flap 40) landing and the commander flew a manual visual approach. Prior to touchdown the co-pilot dumped the cabin pressure to ensure that opening of the cabin door after landing would not be inhibited by any pressure differential. The commander flared the aircraft at the normal height but intentionally selected a slightly higher nose attitude than normal to ensure that if the gear was not down then it would be the rear of the aircraft that would make the initial contact with the ground; however, initially the aircraft seemed to settle onto its landing gear. The co-pilot switched off all the electrics as briefed and the commander applied the brakes; he could

not recall whether he had applied reverse thrust. The aircraft maintained the runway centreline initially, but as its speed reduced the right wing began to drop. At around the runway's mid-point the aircraft began to veer to the right until it finally left the paved surface and crossed the grass, coming to rest about 1,900 metres from the runway threshold and 139 metres to the right of the centreline. The co-pilot immediately left his seat and opened the main passenger door, using this exit to get both the passengers and himself out of the aircraft. The commander meanwhile shut down the engines by selecting all three thrust levers to the idle cut-off position. He then selected the three fuel switches to OFF before vacating the aircraft. The emergency services arrived at the aircraft quickly and were able to put down a protective blanket of foam.

Aircraft information

VP-BMS was a Falcon 900EX, Serial No 042, manufactured in 1999 and registered in Bermuda. It was issued with a Private Category Certificate of Airworthiness on 19 June 2003, valid until 21 June 2004. The last maintenance action was a monthly inspection, carried out on 8 March 2004. The last check was an 'A' check carried out on 21 November 2003. There were no Technical Log entries of relevance.

On-site aircraft examination

The aircraft had come to rest on the grass to the right of the runway. Ground marks indicated that, at the time the aircraft reached the grass, the nose and left main landing gears were extended. Tracks were made in the grass by the nose and both main landing gears, and further on by the right wing tip and flaps, and by the inboard main landing gear doors. There were no evident marks on the runway itself.

When examined by the AAIB the following morning, the aircraft was being prepared for jacking in order to recover it from the grass. The left main landing gear and nose landing gear were both fully extended and locked, however the right main landing gear was partially retracted and the aircraft had come to rest on the right wing tip, causing damage to the right hand flap and outboard slat as well as to the wing tip. There was also damage to the right main landing gear outer door and both inboard main landing gear doors, which were open. There was no obvious damage to the left wing or its flaps or slats. On the flight deck, the Gear Manual Release Handles for all three landing gears were pulled, as was the Emergency Hydraulic Extension Gear Pull Handle, the No 2 brake system was selected, the Emergency Slats switch had been operated and the cockpit voice recorder (CVR) circuit breaker was found in the tripped position. The AAIB inspector was advised that none of these items had been touched after the accident, except to pull the CVR circuit breaker. When the aircraft had been raised, the right main landing gear extended and locked down satisfactorily. The aircraft was recovered from the grass, the flight recorders were removed and the aircraft was then towed to a hangar where it was cleaned and where, subsequently, rectification and testing was carried out in preparation for a ferry flight to Paris (Le Bourget) for permanent repairs.

Flight recorders

The aircraft was equipped with a 25-hour duration, solid state flight data recorder (FDR) and a 30 minute duration, solid state CVR. Both flight and audio data was successfully recovered from the FDR and CVR. The FDR recording contained the time history of the flight from Kilimanjaro to Stansted, as well as the preceding approach and landing at Kilimanjaro. The CVR contained the audio recording for the approach and landing phase only of the flight into Stansted.

Twenty minutes prior to landing on the flight into Kilimanjaro the low-pressure warning parameter for the No 3 hydraulic pump, recorded on the FDR, began to alternate between the normal and the warning state: the warning state was recorded on the FDR when the hydraulic pressure dropped below 97 bar (1,400 psi). The landing gear, slats and flaps were in the retracted position when the hydraulic system low-pressure warning was initially recorded. The No 3 hydraulic pump low-pressure warning parameter then alternated between the normal and the warning state on numerous occasions prior to landing. This parameter then remained in a steady warning state for the final three minutes before engine No 3 was shutdown. All other recorded parameters indicated normal aircraft operation.

On the return flight to Luton, the No 3 hydraulic pump low pressure warning parameter was recorded in the warning state for 37 seconds after the No 3 engine was started. This parameter then recommenced alternating between the normal and the warning state. The No 3 hydraulic pump low pressure warning then entered a steady warning state as the aircraft reached FL120, 15 minutes after the No 3 engine had been started, and remained in this state for the rest of the flight. No other warnings were indicated at this time; however, information concerning hydraulic contents, quantity or system pressure, other than pump discrete warnings, were not recorded on the FDR.

On the initial approach to Luton, at 2,500 feet and 185 KIAS and with the autopilot engaged, the flaps were selected to the Flap 7 position. The outboard slats extended first followed seven seconds later by the inboard slats: this was the normal sequence of operation. The FDR inboard and outboard slat parameters indicated that both slats reached the fully extended position.

Nineteen seconds after the inboard slats were indicated to be in the extended position the No 1 hydraulic pump warning was recorded, thereby rendering the No 1 hydraulic system unserviceable, five seconds later the emergency slat system was selected. After a further two seconds the inboard slats extended parameter altered state to indicate that the inboard slats were no longer in the fully extended position.

Following the loss of No 1 hydraulic system the aircraft remained at 2,500 feet and over the next three minutes the airspeed reduced from 176 KIAS to 164 KIAS. During this period various rudder

deflections were recorded by the FDR. These occurred in both directions and varied in magnitude and duration. The largest recorded input was a deflection to the left of 6.5 degrees and the longest duration for a sustained rudder deflection was nine seconds.

The CVR indicates that 12 minutes after the loss of the No 1 hydraulic system the crew advised Luton ATC that the landing gear could not be lowered and that the aircraft had 30 minutes of fuel remaining. The commander subsequently requested radar vectors to Stansted and the aircraft touched down 13 minutes 30 seconds later.

Conversation between the two pilots recorded on the CVR indicates that there was concern that the Gear Manual Release Handles were not operating properly and that the gear had not deployed despite the handles being pulled. Three minutes and thirty seconds prior to landing a "GEAR…GEAR" audio warning was recorded on the CVR, this continued until touchdown. Fifty seconds prior to touchdown, at a radio height of 560 feet, an audio warning "TOO LOW GEAR" was recorded on the CVR, this warning also continued until touchdown. Eight seconds prior to touchdown the audio warning "SINK RATE….SINK RATE" was recorded on the CVR, at a radio height of 50 feet and airspeed of 113 KIAS.

The touchdown, as indicated by the transition of the left weight on wheel parameter, occurred at 106 KIAS. The CVR and FDR recordings ended one second after the left gear weight on wheel parameter had activated coincident with recorded switch movements and it is believed that this was the removal of aircraft electrical power from both the FDR and CVR at touchdown.

Hydraulic system description

The aircraft was equipped with two independent main hydraulic systems. The No 1 hydraulic system was normally pressurised by either of two mechanical pumps: No 1 pump driven by No 1 engine and No 3 pump driven by No 3 engine. The No 2 hydraulic system was pressurised by the No 2 engine driven pump and could also be powered by an electric pump. Both hydraulic systems were equipped with accumulators to minimise pressure fluctuations within the system.

The No 1 hydraulic system provided hydraulic power to the three landing gears and landing gear doors, normal brakes, primary flight controls and also powered the leading edge slats. No 2 hydraulic system provided hydraulic power to the flaps, airbrakes, emergency brakes, and primary flight controls, and provided power for the outboard slats when the Emergency Slat Extension was selected.

Hydraulic system examination

Following the accident the system was checked and fluid was observed running from the No 1 hydraulic pump drain: this leak had caused the loss of the No 1 system contents.

At the AAIB's request, the aircraft manufacturer initiated an investigation of both the No 1 and the No 3 hydraulic pumps and returned the pumps to the original equipment manufacturer for analysis. Unfortunately the pumps were repaired rather than subjected to any failure analysis, as requested. As a result further work was carried out to try and establish their condition before rectification, but little additional information was available. It was, however, possible to establish that the general state of the pumps did not reveal any evidence of abnormal wear or mechanical anomaly.

Pumps 1 and 3 operate independently in the No 1 hydraulic system, drawing from the same hydraulic reservoir. A functional pump will deliver the correct output pressure as long as there is hydraulic fluid available from the reservoir. The aircraft manufacturer concluded that the No 3 hydraulic pump might have had either a sticking of its internal mechanism, or a slight offset of its regulation, resulting in reduced delivery pressure. The unrelated leak in the No 1 hydraulic pump was suspected to have been due to damage to a seal or loss of effectiveness of an associated spring washer.

Landing gear description

The landing gear was a conventional retractable tricycle arrangement. Power for gear retraction and normal extension was provided from No 1 hydraulic system. In the event of loss of No 1 hydraulic system pressure or contents, each landing gear had an independent gravity free-fall system.

In normal operation the gear was extended by selecting the Landing Gear Control Lever to the down position. Operation of this lever energised the landing gear and landing gear door solenoid selector valves and initiated the full sequencing of the opening of the doors, uplock release, extension and downlocking of the landing gears and closing of the inboard main landing gear doors.

In the event of failure of the electrical subsystem the landing gear could be extended by manual operation of the Emergency Hydraulic Extension Gear Pull Handle, located on the co-pilot's instrument panel. Operation of this handle positioned the normal/emergency selector valve to the emergency position. It simultaneously unlocked and opened the main landing gear inboard doors and unlocked, lowered and locked down all three landing gears using hydraulic power. In this configuration the main landing gear inboard doors remained open.

If hydraulic power was lost, the Emergency Hydraulic Extension Gear Pull Handle must be operated as above in order to position the normal/emergency selector valve to the emergency position.

However, without hydraulic power the gears and doors would not be released from their uplocks at this stage. To achieve this each landing gear had a Gear Manual Release Handle fitted at the flight deck floor, which must be pulled. Each handle operated its landing gear independently, mechanically releasing the uplock for the associated landing gear and, in the case of the main landing gears, also releasing the inboard door uplocks. When the handles had been pulled the doors would open and each landing gear would extend by gravity, but would not lock down. In order to achieve engagement of the mechanical downlocks it was necessary to apply a sufficient and sustained aerodynamic force to each landing gear. This was achieved for the main landing gears by sustained sideslip until the gear locked down indications were obtained, and for the nose gear by accelerating until its locked down indication was obtained.

Landing gear examination

Tests were conducted on the right main landing gear to establish whether it had failed to lock down as a result of a malfunction. It was not possible to pressurise the whole of the No 1 hydraulic system because of the failure of both the No 1 and No 3 hydraulic pumps, so a hand pump was used to retract the right main landing gear alone. During the initial testing checks were made for any interference or restriction which might have affected normal operation. No such interference or restriction was found.

With the gear retracted and the inboard door open, but with a load simulated on its uplock, the free fall mechanism was operated. The force required to pull the Mechanical Extension Control Handle was measured as 13 DecaNewton (DaN), about 30 lbf, which was less than the allowable maximum of 16 DaN. The gear fell normally, but came to rest a few degrees short of the downlocked position. A sustained force of 62 DaN was required to engage the downlock. The manufacturer provided limits of 60 DaN, +/- 5DaN. Therefore the free-fall operation of the right main landing gear was found to be normal and within production limitations. In addition, the nose landing gear should require 130DaN, +/- 15DaN, to achieve a downlock. The manufacturer was provided with data from the FDR and asked to evaluate the aerodynamic loads generated on the landing gear during the relevant part of the descent and approach. Their investigation concluded that the lateral forces generated on the main landing gears were about 36 DaN, and the drag force on the nose landing gear reached about 127 DaN.

The manufacturer noted that the degree of rudder used to generate sideslip, as observed on the FDR, was insufficient to generate the necessary aerodynamic forces required to engage the main landing gear downlocks. The manufacturer analysed the data with regard to the rudder deflection and believed the deflection was a yaw damper input reacting to the yaw generated by each landing gear door and gear leg whilst extending under gravity.

Previous landing gear gravity extensions

The manufacturer advised that for the entire Falcon aircraft fleet and for the last ten years (1 January 1994 to 1 January 2004), there had been 23 events in which the landing gear gravity extension procedure was carried out, following hydraulic failure or abnormal gear behaviour. It had been successful on 20 occasions and unsuccessful three times, twice because an internal mechanical jam had occurred and once because of a jam caused by a foreign object.

Slat system description

The slat system consisted of inboard and outboard sections on each wing, which were normally powered by the No 1 hydraulic system. In the event of No 1 hydraulic system failure it was possible to select Emergency Slat by operating a guarded switch on the flight deck. When so selected hydraulic power from the No 2 hydraulic system was supplied to the outboard slat sections only and the inboard slats, if extended, would be returned to the stowed position by the aerodynamic loads.

Slat position was normally signalled from sensors which indicated full extension. While the slats were in transit, the red arrow 'slats in transit' indication would be shown. Successful normal deployment would illuminate a single steady green lamp on the flap/slat indicator.

The indications from a normally functioning slat system may be summarised as follows:

- SLATS + FLAPS handle on SLATS (EMERGENCY SLATS switch OFF):
  - Slats in transit:
    Red arrow
  - Outboard and inboard slats extended:
    Steady green slats indicator

- EMERGENCY SLATS switch ON (SLATS + FLAPS handle on CLEAN:
  - Slats in transit:
    Red arrow
  - Outboard slats extended:
    Flashing green indicator

- EMERGENCY SLATS switch ON and SLATS + FLAPS handle on SLATS, with inboard slats not extended (hydraulic #1 failure):
  - Outboard slats extended:

    Red arrow

Slat system operation during the flight

The FDR data indicate that the flaps were selected to the Flap 7 position. The outboard slats extended first followed seven seconds later by the inboard slats: this was the normal sequence of operation. The FDR indicated that both slats reached the fully extended position. Nineteen seconds after the inboard slats were indicated to be in the extended position the No 1 hydraulic system was rendered inoperative by the loss of pressure from the No 1 pump, five seconds later the emergency slat system was selected. Two seconds later the inboard slats extended parameter altered state to indicate that the inboard slats were no longer in the fully extended position and were correctly returning to the stowed position.

The initial indications on the flight deck following normal slat selection should have been a red arrow 'slats in transit' indication. This red light would have extinguished when the slats reached the fully extended position and would then have been replaced by a single steady green light. Extension of the slats would have ended a residual circulation of fluid in the No 1 hydraulic system and caused the loss of pressure from the No 1 hydraulic pump. This resulted in the loss of the No 1 hydraulic system since the No 3 pump had already failed. Hydraulic power would now have been removed from the slats allowing them to be forced back by aerodynamic forces. As soon as one full extension switch was no longer active the red arrow would have appeared prompting the crew to select emergency slats. If the SLAT + FLAP handle were also returned to the CLEAN position, a flashing green indication would then have been expected indicating that the outboard slats were in the extended position. If, however, it was left in the SLATS position, the steady red light should have illuminated.

The crew reported that the flap position indicator showed normal slat movement then Flap 7 extension, with the slat indicator light illuminated steady green. However, the red arrow then illuminated and the emergency slat switch was selected, although the crew was unclear of the order in which these two events occurred. The crew could not recall any flashing green light on the flap position indicator. The co-pilot then went into the aircraft cabin and reported that the outer slats were extended whilst the inner slats were retracted.

The checklist used by the flight crew covered two cases including one where the Slat/Flap handle was at 7° and the red transit light was illuminated, with no green steady or flashing light; these were the indications reported by the crew. This case required selection of the Emergency Slat switch to ON and then describes three further possibilities. One of these is that the outboard slats are extended, the inboard slats are retracted, the red transit light is on and the Flaps are at 7°: again, this was the situation reported by the crew.

Checklists and training

In dealing with the failure of the No 1 hydraulic system, and the subsequent gear and slat problems, the crew referred to a set of checklists produced by their training organisation entitled: "FALCON 900EX EMERGENCY /ABNORMAL PROCEDURES PILOT CHECKLIST Revision 4". The crew reported that they found this easier to use than the approved Flight Manual published by the manufacturer. The approved Flight Manual (AFM) was on board the aircraft, but was not used by the crew.

The checklist used by the flight crew contained the following statement:

> *"These are suggested training procedures only and in no way supersede current procedures outlined in the FAA-approved Flight Manual. In case of conflict, the Flight Manual takes precedence. Checklist procedures represented for USA registered aircraft only. For non-USA registered aircraft, consult AFM for alternate procedures."*

In addition the bottom of each page was marked "FOR TRAINING PURPOSES ONLY".

Study of both the checklist provided by the training organisation and the approved Flight Manual published by the manufacturer revealed several notable differences.

Hydraulics

The checklist used by the crew and the approved Flight Manual had similar procedures for a failure of the No 1 or the No 3 hydraulic pump and a subsequent failure of the No 1 hydraulic system. The checklist stated that failure of a single pump in the No 1 hydraulic system will be indicated by a HYDR#1 PUMP 1 or HYDR#1 PUMP 3 caption (with a master warning and audio warning). Failure of the No 1 hydraulic system, in addition to the above warnings for both pumps, will possibly also result in a PITCH FEEL caption. In addition, the approved Flight Manual also stated that there would be a pressure drop in the No 1 system, and that the fluid quantity indicator may read zero, whereas the checklist simply stated 'Hydraulic pressure and quantity….CHECKED', without providing any guidance on the expected indications.

Landing gear

The checklist for Emergency Gear Extension instructed the pilot to sideslip the aircraft after manually lowering the main gear and stated that the downlock light should illuminate *within* thirty seconds whilst the AFM stated that it will not illuminate until *after at least 30 seconds*. This difference in wording is small but crucial in ensuring sufficient aerodynamic force is applied to the main gear to engage the downlock.

Whilst this difference is noteworthy it did not affect the outcome in this instance as the pilots both stated that they had not referred to this checklist. This is because the procedure for the Loss of No 1 Hydraulic System incorporated a subsidiary procedure for Emergency Gear Extension. This made no reference at all to any time limits associated with sideslipping the aircraft to engage the main gear downlocks. It also failed to direct the user on to study the specific Emergency Gear Extension procedure contained elsewhere in the checklist.

Both the Emergency Gear Extension procedure used by the crew (Revision 4) and that contained within the AFM state that the main gear should be extended first, via the Gear Manual Release Handle, and then locked down with sideslip. Only then should the nose gear be released.

Finally, both pilots reported that when they had conducted training exercises in the flight simulator manually deploying the landing gear only required a minimal use of the rudder pedals to provide sufficient sideslip to lock the main gear. They reported that indications that the main gear was down and locked were virtually instantaneous on applying rudder.

Minimum Equipment List

The aircraft manufacturer supplies a Master Minimum Equipment List (MMEL) from which a Minimum Equipment List (MEL) is derived by the aircraft operator. The item of interest, in this instance, is the section dealing with Hydraulic Power, Section 29. A copy of the first page of this section of the MEL is presented at Figure 1. Identification of the relevant item, the hydraulic pump caution light (Section 29.1) is identical in both the MMEL and the MEL. The format of the MMEL, as an approved document, conforms to the conventions generally used by aircraft manufacturers. In particular capital letters are used throughout the MMEL to emphasise the captions on lights, and the operator's MEL uses the same convention.

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SYSTEM & SEQUENCE NUMBERS	ITEM (1)		2 NUMBER INSTALLED	3 NUMBER REQUIRED FOR DISPATCH	4 REMARKS OR EXCEPTIONS	
29	HYDRAULIC POWER					
1.	HYDR#1 PUMP 1, HYDR#2 PUMP 2, HYDR#1 PUMP 3 Caution Lights	C	3	2	(O)	One may be inoperative provided: a) Associated hydraulic system pressure indicator operators normally and is monitored during flight, and b) Standby hydraulic pump is verified to operate normally before engine start. Refer to PM 29-1A for (O).
2.	#1 System Hydraulic Pressure Indicator	C	1	0		May be inoperative provided HYDR#1 PUMP 1 and HYDR#1 PUMP 3 caution lights operate normally.
3.	#2 System Hydraulic Pressure Indicator	C	1	0	(M)	May be inoperative provided: a) HYDR#2 PUMP 2 caution light operates normally, and b) Standby pump is verified to operate normally prior to engine start. Refer to PM 29-3A for (M).
4.	No. 1 or No. 2 Hydraulic Quantity Indications (EID)	C	2	1	(M)	One may be inoperative provided associated reservoir fluid quantity is verified to be adequate prior to departure. Refer to PM 29-4A for (M).

Figure 1 - Minimum Equipment List - Section 29, Hydraulic Power

Having arrived in Kilimanjaro with indications of an intermittent fault to the No 3 hydraulic pump the crew made the decision not to have the fault investigated and repaired at the time since they believed, incorrectly, that the MEL allowed dispatch with only two of the three engine driven hydraulic pumps operating.

Discussion

The crew arrived in Kilimanjaro aware of an indication of an intermittent fault to the No 3 hydraulic pump. They consulted the MEL and believed, incorrectly, they could depart with this pump unserviceable. This, combined with the limited repair facilities available, persuaded them to defer this defect until their return to London (Luton) Airport.

The crew had misinterpreted their MEL. Section 29.1 of the MEL allows dispatch with two of the three caution lights serviceable and not two of the three hydraulic pumps as the crew believed. The MEL also requires that two operational provisions are addressed and these, when read in conjunction with their associated procedures, make it quite clear that this section of the MEL concerns the caution lights. However, the crew appear to have been deceived by the relative unimportance of the term 'Caution Lights' which was printed in lower case and appeared after the listing of the three hydraulic pumps which were printed in capital letters. If the term 'Caution Light' had appeared after each caption ie 'HYDR#1 Pump 1 Caution Light' there would have been less room for misunderstanding. Any MEL must be read in a thorough manner since partial reading of any item can easily lead to misinterpretation. However, the MEL is not a document that is used frequently and should therefore be presented in the most clear and unambiguous manner available.

On their departure four days later the No 3 hydraulic pump continued to indicate an intermittent fault until 15 minutes after engine start when it then failed completely. Loss of this pump should have had minimal impact on the operation of the aircraft; however, there was also a continuing loss of hydraulic fluid, through a leak in the No 1 hydraulic pump although the time at which this leak commenced is unclear. This leak and the failure to the No 3 hydraulic pump were probably independent. Even though it is not known precisely when the leak developed loss of fluid was observed by the crew after a flight time of between one and two hours. The leak resulted in the hydraulic quantity indication reducing to zero during the flight. The zero level in the hydraulic reservoir may have been slightly offset, so that a sufficient minimum quantity of fluid was circulating in the No 1 hydraulic system, thus explaining the normal pressure in the system and the absence of a HYDR#1 PUMP 1 caution light. In cruise conditions, with low requirements for hydraulic power, the duration of this condition would depend on the rate of fluid loss. At the time of flap and slat extension, the increased requirement caused the final loss of the No 1 hydraulic system.

The crew expected that indications of the loss of the No 1 hydraulic system would include a reduction in pressure; however, since this did not occur the crew did not believe that they had lost the system. As a precaution, however, they considered what they would do if the system subsequently failed when configuring the aircraft for landing. This would require lowering the landing gear using the free-fall system, and would deny them the use of normal braking and normal slat extension. They also considered the required adjustments to the planned approach speed and the landing distance required before finally confirming that Luton's runway had sufficient landing distance available. However, during the remainder of the flight to Luton the crew did not consult the AFM but relied on their 'training' checklist.

The complete failure of the No 1 hydraulic system became apparent to the crew when they selected the slats on approach to Luton Airport. The emergency slat system worked correctly although the crew failed to receive the flashing green indication they were expecting; however, this condition was allowed for in the procedure that they were using.

The initial attempt to lower the landing gear resulted in three red but no green gear position indicating lights; these were the expected indications following the loss of the No 1 hydraulic system. When conducting the subsequent Emergency Gear Extension procedure the crew operated both Main Gear Manual Release Handles then the Nose Gear Manual Release Handle and each element of the gear deployed but, as expected, none of them achieved a downlock indication. This sequence was at variance with the Emergency Gear Extension procedure which required that each main gear is locked down, through the application of sustained sideslip, before the Nose Gear Manual Release Handle is pulled. Furthermore, evidence from the FDR indicates that the flight crew did not sideslip the aircraft to a sufficient degree and for sufficient time to provide the necessary aerodynamic loads on the main gear and did not accelerate sufficiently to provide the required aerodynamic loads on the nose gear. The reason for not doing so can be ascribed to the checklist they were using, which failed to clearly define the parameters required to lock the gear. In addition, the training that the crew had experienced in the flight simulator led them to believe that when manually deploying the landing gear only the minimal use of the rudder was required to provide sufficient sideslip to lock the main gear down. Moreover, evidence from the CVR indicates that the crew was concerned by the apparent failure of the emergency deployment handles, which they incorrectly believed was the cause of the gear failing to lower and lock.

It seems most probable that all three gears were just short of entering the downlocks before touchdown. Whilst on the runway, any sideways movement would have had the effect of locking one main gear and retracting the other, and this is consistent with the effect of the slight crosswind reported, causing the left gear to lock. The nose landing gear was probably locked down by the initial drag force whilst making contact, wheel spin-up at first contact or possibly by the slight shock of main landing gear first

contact. The point at which the aircraft touched down and two of the gears became locked might well have generated two green indications, however, these would not have been observed as the electrical power had been deliberately removed immediately after the touchdown.

The crew were dealing with a hydraulic failure and were unable to lower the landing gear. They made the decision to divert and were properly guided in their choice of alternate airfield by ATC. Stansted fulfilled their requirements in that it had a long runway, benign weather conditions and, crucially at that time of night, was open. In addition, appropriate emergency services were at hand.

The checklist that the pilots used was clearly marked as being "FOR TRAINING PURPOSES ONLY", moreover, a further caveat noted that the checklist procedures were *"for USA registered aircraft only. For non-USA registered aircraft, consult AFM for alternate procedures"*. The approved Flight Manual was on board the aircraft, but was not used by the crew. The crew reported that they found their 'training' checklist easier to use than the AFM published by the manufacturer. It is clearly the operator's responsibility to ensure that each member of the flight crew has access to approved documentation that is up to date; this was provided in the form of the AFM which was on board the aircraft. However, if the manufacturer's publications are considered by the flight crew to be unclear then the operator should discuss suitable amendments with the manufacturer, since these publications are approved documents. Training Organisations will often provide their own documentation "FOR TRAINING PURPOSES ONLY" in an attempt to provide simplified, structured guidance to pilots during training. However, they have an obligation to ensure that this training documentation accurately reflects the information provided in the manufacturer's operations manual. Additionally, the pilots should not have been using a checklist that was clearly identified as inappropriate. The use of such checklists is of particular relevance to this type of operation where pilots may often be from a variety of training backgrounds.

Recommendations

Safety Recommendation 2005-023

After landing at Kilimanjaro with indications of an intermittent fault to the No 3 hydraulic pump the crew consulted the Minimum Equipment List and concluded, incorrectly, that they could depart with an unserviceable hydraulic pump. Whilst it is clear that a Minimum Equipment List must be read in a thorough manner the crew appear to have been deceived by the presentation of the information in this instance. The MEL is not a document that is used frequently, which makes it particularly important that it should be presented in the most clear and unambiguous manner available.

It is therefore recommended that Dassault Aviation should review Section 29, Part 1 of the Master Minimum Equipment List to make it clear that this refers to the pump caution lights and not the pumps.

Safety Recommendation 2005-024

During the flight to London (Luton) Airport, following a failure of the No 3 hydraulic pump, there was a continuing loss of hydraulic fluid through a leak in the No 1 hydraulic pump which resulted in an indication of zero contents in the No 1 hydraulic system. The crew, however, was confused by the fact that the system indicated normal hydraulic pressure despite the apparent total loss of fluid.

It is therefore recommended that Dassault Aviation review the indications likely to be seen following a failure of either hydraulic system and, if necessary, amend the checklist accordingly.

Safety Recommendation 2005-025

Training Organisations will often provide their own documentation "FOR TRAINING PURPOSES ONLY" in an attempt to provide simplified, structured guidance to pilots during training. However, whilst providing clarity they also have an obligation to ensure that this training documentation accurately and thoroughly reflects the information provided in the manufacturer's operations manual. Moreover, the documentation and procedures promoted during training should be those that the flight crew will use in the aircraft.

It is therefore recommended that FlightSafety International should review their process for ensuring the accuracy of the documents used in training and should promote the same procedures used in training that will be used when flying the aircraft.

Safety Recommendation 2005-026

The fidelity of modern flight simulators is such that non-normal training can now be conducted in the flight simulator and need not be completed on the aircraft; indeed, some non-normal drills such as manually lowering the landing gear following the loss of the No 1 hydraulic system can only be safely conducted in the simulator. Notwithstanding the required level of fidelity for the qualification standard of the simulator it is clear that in this case the forces required to lock down each element of the landing gear were not representative of those necessary in the aircraft.

It is therefore recommended that FlightSafety International, in coordination with Dassault Aviation, should review their flight simulators used for Falcon 900 training to ensure they represent with acceptable realism the correct pilot input, as defined in the operations manual, to successfully lock down the landing gear during emergency gear extension.