Federal Public Service
Mobility and Transport
Air Accident Investigation Unit

Air Accident Investigation Unit
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Safety Investigation Report

SERIOUS INCIDENT
SOCATA TBM 700 A
AT AERODROME GENK / ZWARTBERG
ON 17 DECEMBER 2015

Ref.:
AAIU-2015-16

Issue date:
20 September 2017

Status:
Final

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FOREWORD

This report is a technical document that reflects the views of the investigation team on the circumstances that led to the serious incident.

In accordance with Annex 13 of the Convention on International Civil Aviation and EU Regulation 996/2010, it is not the purpose of aircraft accident investigation to apportion blame or liability. The sole objective of the investigation and the Final Report is the determination of the causes, and to define recommendations in order to prevent future accidents and incidents.

In particular, Article 17-3 of the EU regulation EU 996/2010 stipulates that the safety recommendations made in this report do not constitute any suspicion of guilt or responsibility in the accident.

The investigation was conducted by the AAIU(Be) with the support of the French Safety Investigation Authority (BEA), the aircraft manufacturer Daher-Socata and the equipment manufacturer Hydro-Leduc.

The report was compiled by Henri Metillon and was published under the authority of the Chief Investigator Luc Blendeman.

SYMBOLS AND ABBREVIATIONS

’	Minute
°C	Degrees centigrade
AAIB-UK	Air Accidents Investigation Branch – UK
AAIU(Be)	Air Accident Investigation Unit (Belgium)
A/C	Aircraft
AccRep	Accredited Representative of a State Investigation Unit
AD	Airworthiness Directive
ARC	Airworthiness Review Certificate
ATC	Air Traffic Control
BCAA	Belgian Civil Aviation Authority
BEA	Bureau d’Enquêtes et d’Analyses (France)
BEAD-Air	Bureau enquêtes accidents défense – air (France)
BFU	German Federal Bureau of Aircraft Accident Investigation
CAMO	Continuing Airworthiness Management Organisation
CMM	Component Maintenance Manual
CAVOK	Ceiling and Visibility OK
EASA	European Aviation Safety Agency
EBLG	Liège airport
EBZW	Zwartberg airfield
EU	European Union
FH	Flight hour(s)
ft	Foot (Feet)
kt	Knot(s)
lbs	Pounds
LGCP	Landing Gear Control Panel
m	Metre(s)
Hz	Hertz
MHz	Megahertz
MLG	Main Landing Gear
MSN	Manufacture’s serial Number
NLG	Nose Landing Gear
NTSB	National Transportation Safety Board (US)
O/H	Overhaul
PIC	Pilot in Command
PN	Part number
POH	Pilot’s Operating Handbook
PPL	Private Pilot Licence
psi	Pound per square inch
QNH	Pressure setting to indicate elevation above mean sea level
RH	Right hand
SL	Service Letter
SN	Serial Number
TSO	Time Since Overhaul
TT	Total Time
UTC[1]	Universal Time Coordinated
VFR	Visual Flight Rules

[1] About the time: For the purpose of this report, time will be indicated in UTC, unless otherwise specified.

TERMINOLOGY USED IN THIS REPORT

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence.

Contributing safety factor: a safety factor that, had it not occurred or existed at the time of an occurrence, then either:
(a) the occurrence would probably not have occurred; or
(b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or
(c) another contributing safety factor would probably not have occurred or existed.

Other safety factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.

Safety issue: a safety factor that
(a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and
(b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Safety action: the steps taken or proposed to be taken by a person, organisation or agency on its own initiative in response to a safety issue.

Safety recommendation: A proposal by the accident investigation authority in response to a safety issue and based on information derived from the investigation, made with the intention of preventing accidents or incidents. When AAIU(Be) issues a safety recommendation to a person, organization, agency or Regulatory Authority, the person, organization, agency or Regulatory Authority concerned must provide a written response within 90 days. That response must indicate whether the recommendation is accepted, or must state any reasons for not accepting part or all of the recommendation, and must detail any proposed safety action to bring the recommendation into effect.

Safety message: An awareness which brings to attention the existence of a safety factor and the lessons learned. AAIU(Be) can distribute a safety message to a community (of pilots, instructors, examiners, ATC officers), an organization or an industry sector for it to consider a safety factor and take action where it believes it appropriate. There is no requirement for a formal response to a safety message, although AAIU(Be) will publish any response it receives.

Federal Public Service
Mobility and Transport
Air Accident Investigation Unit

AAIU-2015-16

SYNOPSIS

Date and time:	Thursday 17 December 2015 at 09:45 UTC
Aircraft:	SOCATA TBM 700
Serious incident location:	Aerodrome of Genk / Zwartberg
Aircraft owner:	Private
Type of flight:	General Aviation – Cross Country
Phase of flight:	Landing
Persons on board:	One
Injuries:	None

Abstract:

At the end of a short 12-minute flight from EBLG to EBZW the pilot checked the landing gear position indication lights, confirmed he saw three greens and no red light and entered the landing circuit.
In the final leg, after the flaps were extended to landing position, the pilot checked again the landing gear position lights.
The touchdown and the first phase of the landing were uneventful, however the nose landing gear collapsed as soon as it made contact with the runway.

Occurrence type: System/component failure or malfunction (non-powerplant) – SCF-NP

Cause:

The cause of the serious incident is the failure of the nose landing gear actuator to lock down combined with the landing gear control system wrongly indicating that this landing gear was properly extended and locked.

The root cause of the serious incident is an spurious triggering of the NLG actuator extend dual switch into “extend and locked”.
Investigation determined that the activation system of the dual switches has the potential to cause simultaneously a false indication (showing 3 greens and no red light) on the LGCP and stop the operation of the electro-hydraulic generator, interrupting the landing gear leg extension before reaching the locked position.

Contributing factors:

- The mechanical improvement of the actuators involving the installation of differential plungers (MOD70-0334-32), introduced in December 2012, was not applied to the aircraft.
- The possibility to improve the safety of the landing gear system by installing the differential plungers (MOD70-0334-32) was not communicated and was not recommended to the end-users.

1 Factual information.

1.1 History of flight.

The purpose of the flight was to position the aircraft from its home base Liège Airport EBLG to the airfield of Gent/Zwartberg EBZW for a repair on the flux valve. The pilot stated that when he went to the hangar in the morning, he found the aircraft totally beaded with dew. He prepared the aircraft for the flight and took off at around 09:30 UTC.

The flight from EBLG to EBZW was very short (12 minutes). About 2 minutes before joining the downwind leg of the active Runway 21, the flaps were lowered (1 notch or take-off position) and the landing gear extended. The pilot stated he checked the landing gear lights, confirmed he saw three greens and no red light. When in final, the flaps were further extended to landing position and the pilot checked again the landing gear position indication lights.

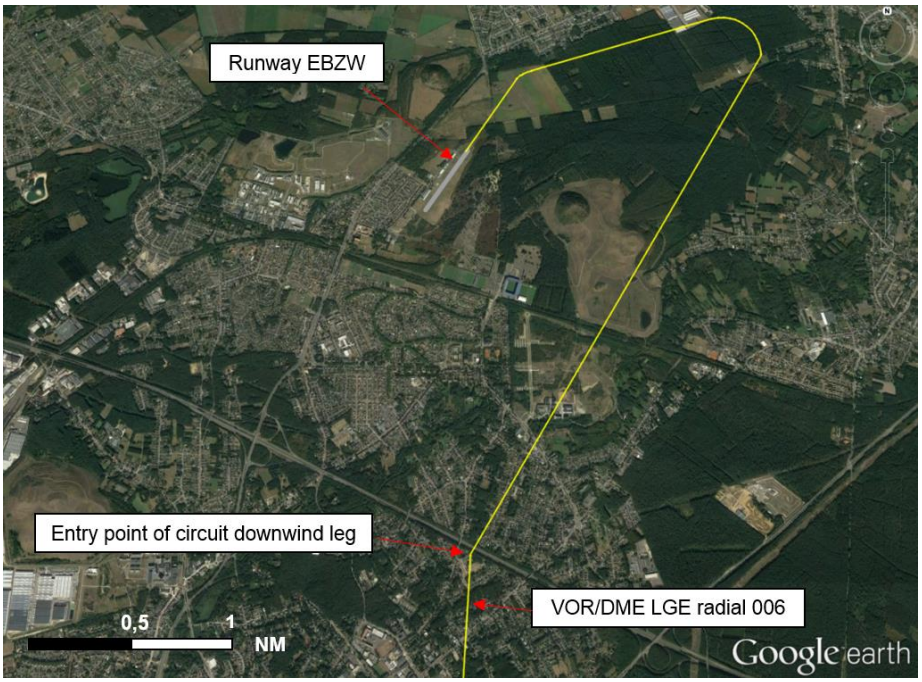


Figure 1 : Reconstructed flight path

During the landing, the pilot felt an abnormal vibration accompanied by a noise when the nose gear touched the ground. He realized the nose landing gear was collapsing. The aircraft came to a stop after a 400m landing run. The pilot climbed out, uninjured.

Maintenance personnel came to evacuate the aircraft from the landing strip, tilted the airplane and pushed the nose landing gear forward until the 'locked' sound was heard. The airplane was then pushed in the hangar.

A plane spotter took several pictures of the event as it unfolded. The photographer and other witnesses confirmed the landing gear were down long before the touchdown.

Figure 2: Pictures of the serious incident taken by a spotter

1.2 Injuries to persons.

Injuries	Crew	Passenger	Others	Total
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	1	0	0	1
Total	1	0	0	1

1.3 Damage to aircraft.

The propeller blades were damaged, the engine air intake cowling was deformed and nose landing gear doors were scratched.

1.4 Other damage.

Minor damage to the runway surface (scratches).

1.5 Personnel information.

Pilot:
Male, 57 years old. Belgian nationality. Holder of a valid Private Pilot certificate PPL(land), first issued on 7 February 2000, last issued by BCAA on 29 September 2013.
Rating: TBM with IR class, first issued 26 June 2007, last renewed on 2 March 2015, valid until 31 March 2016.
The pilot has a total flight experience of 900FH, including 500FH on TBM 700.

1.6 Aircraft information.

The SOCATA TBM 700 is a high performance single-engine turboprop light business and utility aircraft manufactured by Daher-Socata.

The TBM 700 is a six to seven seat, low-wing monoplane of mainly aluminium and steel construction, but with the tail surfaces built of Nomex honeycomb.

It has a retractable tricycle landing gear and is powered by a Pratt & Whitney Canada PT6A-64 engine delivering 700 shp (522 kW).

The first prototype TBM 700 made its maiden flight on 14 July 1988. About 900 TBM 700 have been delivered since 1990 (All variants, including aircraft holding the TBM850 and TBM900 trade names).

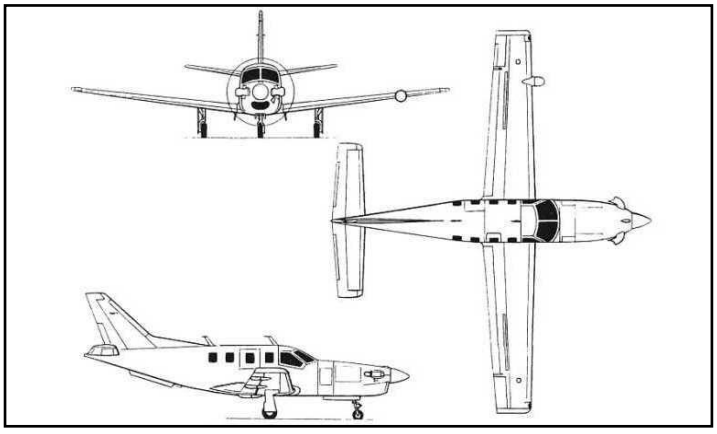


Figure 3: 3 view drawing of the TBM 700

General characteristics (TBM 700 A)

- Crew: one or two pilots
- Passengers: Standard version: 5
- Length: 10,64 m
- Wingspan: 12,675 m
- Height: 4,36 m
- Empty weight: 1965 kg
- Max. take-off weight: 2987 kg (6579 lb)
- Powerplant: 1 × Pratt & Whitney Canada PT6A-64 turboprop, 515 kW (700 hp)

Airframe:

Manufacturer:	Daher-Socata
Type:	TBM 700 A
Serial number:	3
Built year:	December 1990
Registration:	The aircraft is registered in Belgium.
Certificate of registration:	Issued by BCAA on 13 December 2006
Certificate of Airworthiness:	Issued by BCAA on 12 Jan 2007 in the normal cat.
ARC:	Performed by BE.MG.0106, valid until 7 Jan 2016.
Annual inspection:	Performed by BE.MF.006 on 11 December 2015
Airplane total time:	3672,5 FH
Airplane total cycles:	3954 FC

Engine:

Manufacturer:	Pratt and Whitney Canada
Type:	PT6A-64
Total flight hours:	3470 FH
Serial number:	PCE-111022

Propeller

Manufacturer:	Hartzell Propellers
Type:	HC-E4N-3 / E9083SK
Total flight hours:	3465 FH
Serial number:	HH39

Flight manual

A flight manual in French language entitled “Manuel de Vol TBM 700 Version A et B” was available in the aircraft. It was regularly updated up to revision 14 dated 31 October 2014.

The following information pertaining to the landing gear operations are incorporated into the flight manual (translated into English for this report):

LANDING GEAR INDICATOR (Figure 7.5.1)

Landing gear position indication is accomplished by 4 warning lights :

– 3 green indicator lights (one per landing gear) indicate that each landing gear is down–locked,

– 1 red warning light indicates that landing gears are operating, or not locked down or up.

NOTE :
For airplanes equipped with modification No. MOD70–021–32, the red warning light flashes as soon as landing gears are operating and remains continuously on in case of locking problem.

When landing gear is correctly retracted, all warning lights are OFF. In case of doubt about "landing gear down–locked" position, an independant electrical circuit with the "CHECK DN" switch on the same panel as the warning lights allows testing of the control circuit, therefore providing a countercheck capability of the indication system.

Indication panel is provided with two tests which allow checking green indicator lights and red warning light bulbs through two distinct electric power supplies.

Figure 4: Extract of Flight Manual Chapter 7.5.: Landing Gear Description

Section 3 "Emergency Procedures" details amongst others the procedure to be applied in case of landing gear retraction and retraction discrepancies. The text does distinguish the symptoms between pre and post MOD70-021-32 aircraft.

LANDING GEAR RETRACTION DISCREPANCY

NOTE:
Symptoms have to be considered at the end of the sequence.

- **Symptoms:**
  Red warning light OFF and 1 to 3 green light(s) ON.
  or
  Steady red warning light ON and 0 to 3 green light(s) ON.

- **Actions**
  Refer to "EMERGENCY GEAR EXTENSION".

Figure 5: Extract of Flight Manual Emergency Procedures pre MOD 70-021-32

LANDING GEAR EXTENSION DISCREPANCY

NOTE:
Symptoms have to be considered at the end of the sequence.

- **Symptoms:**
  Red warning light OFF and 1 to 3 green light(s) OFF.
  or
  Steady red warning light ON and 0 to 3 green light(s) OFF.

- **Actions**
  Refer to "EMERGENCY GEAR EXTENSION".

Figure 6: Extract of Flight Manual Emergency Procedures pre MOD 70-021-32

Additionally, Service Letter SL 70-050-32 was released in December 2008 to remind the users about the necessity to comply with the instructions provided in the Pilot's Operating Handbook/ Flight Manual.

Following recent incidents due to non-compliance with procedures described in the Pilot's Operating Handbook, we believe it useful to remind everyone of the following. It is mandatory to apply the procedures described in the Pilot's Operating Handbook when the pilot detects a problem which occurs during landing gear extension or retraction.

Especially, **any indication discrepancy** must lead to application of actions described in Paragraph 3.11, depending on your aircraft configuration (Pre- or Post-MOD70-021-32).

Examples (non exhaustive) of indication discrepancies :

- one red warning light fixed at the end of landing gear retraction maneuver,
- one red warning light fixed at the end of landing gear extension maneuver,
- one green indicator light does not go off (whatever the duration may be) during or at the end of landing gear retraction maneuver,

IMPORTANT NOTE :

In case of doubt about the indication, emergency landing gear extension must be applied as a rule. This will lock the landing gears in down position, while observing a marked hardening (or stiffening) of the manual control at the end of the maneuver (hydraulic sign of end of travel).

The actions described in Paragraph 3.7 must be applied as soon as an evident indication of one or several landing gear non-extension or non-locking is established.

Figure 7: Extract of SL 70-050-32

Landing gear description and operation

The aircraft is equipped with a hydraulically operated retractable landing gear system consisting of one nose landing gear and two main landing gears. The main landing gears swivel on two ball joints installed on wing spars and retract towards the fuselage. The nose landing gear also swivels on two ball joints and retracts aft.

Each landing gear is operated by a hydraulic actuator for the extension and retraction. Each actuator has a locking device integrated at both ends. A common electro-hydraulic generator delivers hydraulic pressure between 580 psi (typically for extension) and up to 2175 psi for retraction (40 - 150 bar). It is electrically controlled by a switch actuated through a lever on the landing gear control panel (LGCP).

The landing gear control panel LGCP, located at the bottom of the left pilot instrument panel, also incorporates 4 warning lights:

- 3 green indicator lights (one per landing gear) that indicate that each landing gear is in fully extended position and down-locked
- 1 red warning light, that indicates that the landing gear is operating and/or that the landing gear is not locked

Mechanically operated electrical dual switches on each end of the actuator activate to control the electro-hydraulic generator and to indicate that the locking position is reached. The electrohydraulic generator only delivers hydraulic pressure during the retraction or extension phases and stops operating as soon as all gears are locked, i.e. when all 3 actuators respective dual limit switches are triggered. The same dual switches also establish (or interrupt) the electrical inputs that triggers Green lights ON (or OFF) and red indication lights through LGCP wired logic.

During operation, the 3 landing gears do not move at the same speed. In particular, in flight, the nose landing gear, due to the airspeed (dynamic pressure), generally locks first when retracting and on the contrary, locks the last when extending.
As a back-up, the landing gear system is provided with a hand-operated pump which is supplied by an auxiliary hydraulic oil reservoir.

Landing gear electrical circuit description and operation (pre MOD70-021-32)

The electrical system on the aircraft is typical for early production aircraft equipped with a PN: T700A3260005004 LGCP.

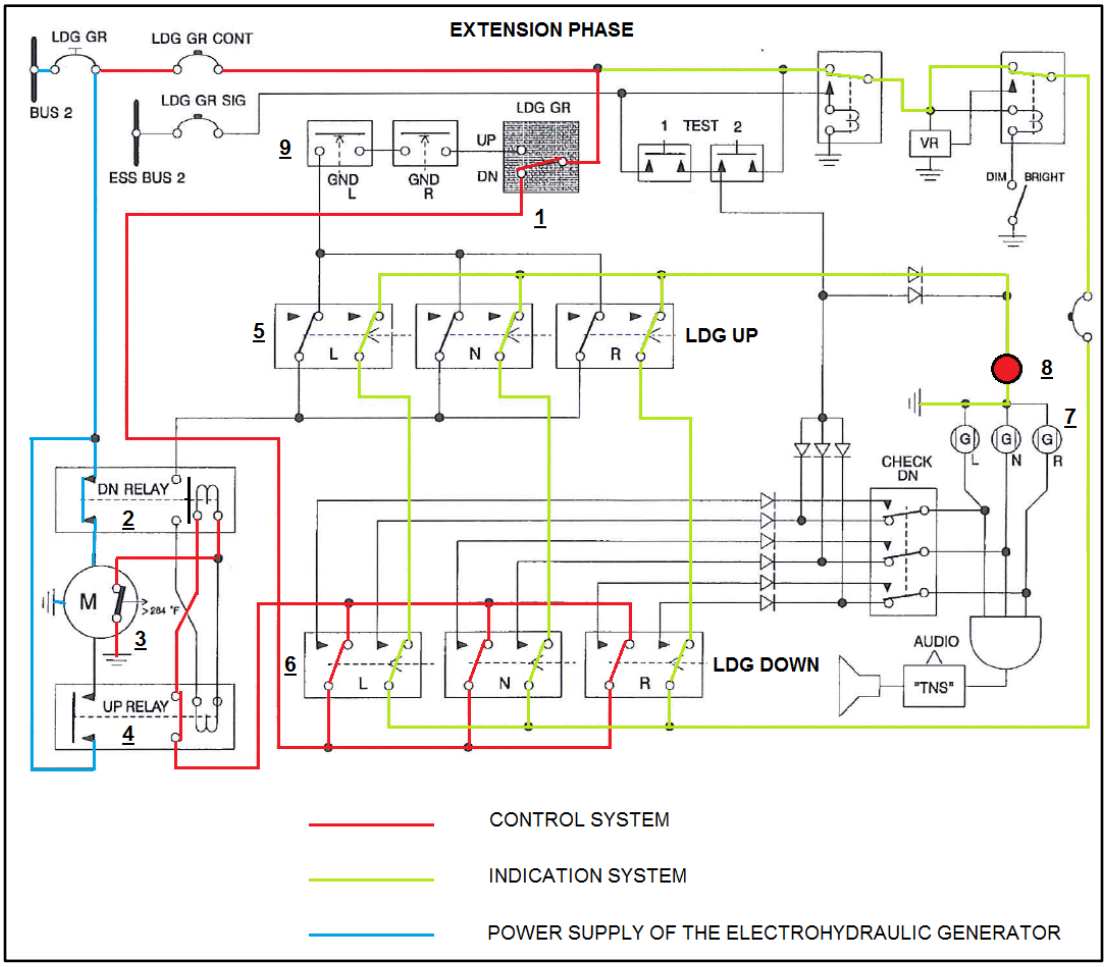


Figure 8: Electrical drawing "Extension Phase"

Landing gear extension phase

The electrical circuit shows the different switches positions when the landing gear is moving from retracted (UP) to extended (DOWN) positions.

- The landing gear control lever is in DOWN position.
- The control lever DN switch (1) is electrically closed causing the activation of the electro-hydraulic generator DN relay (2).
- The electro-hydraulic generator (3) is running and is sending hydraulic pressure for extension to each actuator.
- All 3 actuators are in transition causing both the UP lock and DOWN lock mechanisms to be in unlocked position. No dual limit switch (5)(6) is activated meaning they are all in normally open positions.
- The 3 green lights (7) are OFF because all landing gears are not yet locked in DOWN position.
- The red warning light (8) is ON because at least one landing gears is not yet locked in DOWN position.

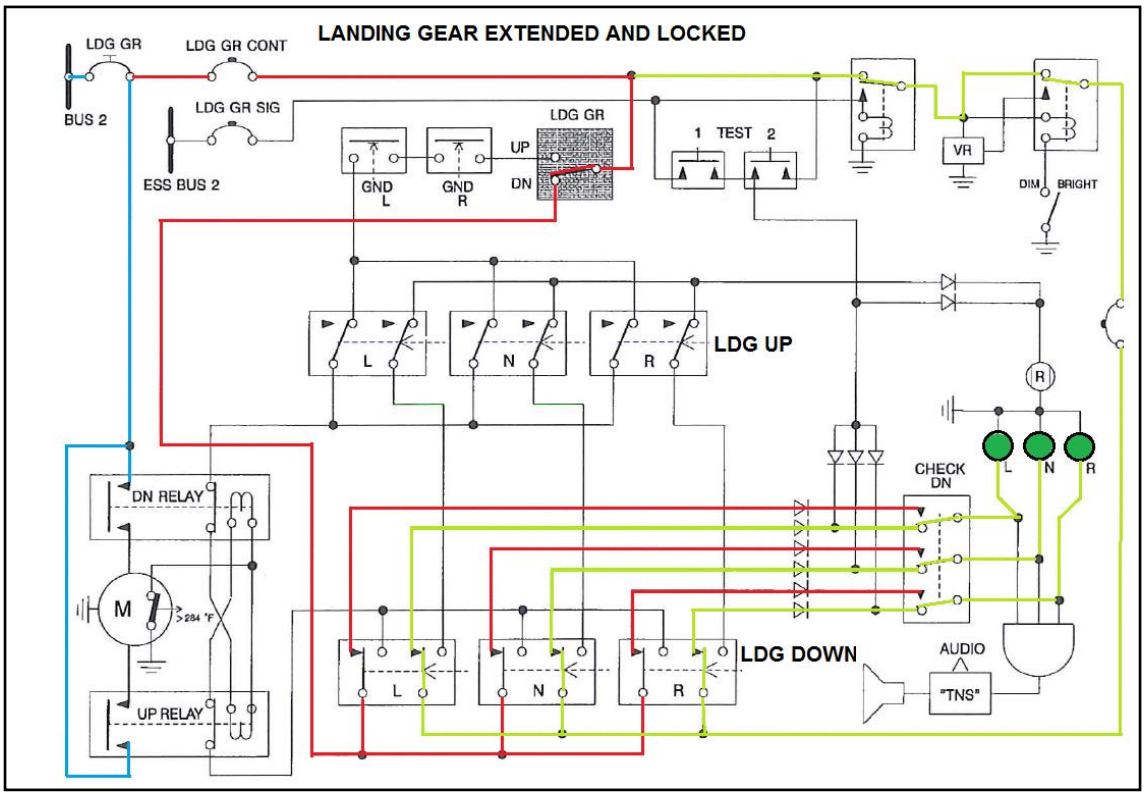


Figure 9: Electrical drawing "Extended and locked"

Landing gear extended and locked

The electrical circuit shows the different switch positions when the landing gear is in DOWN position. The full landing gear movement from UP to DOWN is achieved, the 3 actuators are DOWN locked and the indicating system is working normally.

- The landing gear control lever is in DOWN position and the DN switch is electrically closed.
- The UP lock mechanisms of all actuators are in unlocked position and their dual limit switches are not activated (normally open position).
- The 3 actuators are fully extended and DOWN locked causing the extension dual limit switches (LDG DOWN) to be activated by their respective plunger mechanisms.
- The 3 green lights are ON through the contact of each limit switch
- The red warning light is OFF
- The DOWN relay of the electro-hydraulic generator is not activated and the internal hydraulic pump is not running.

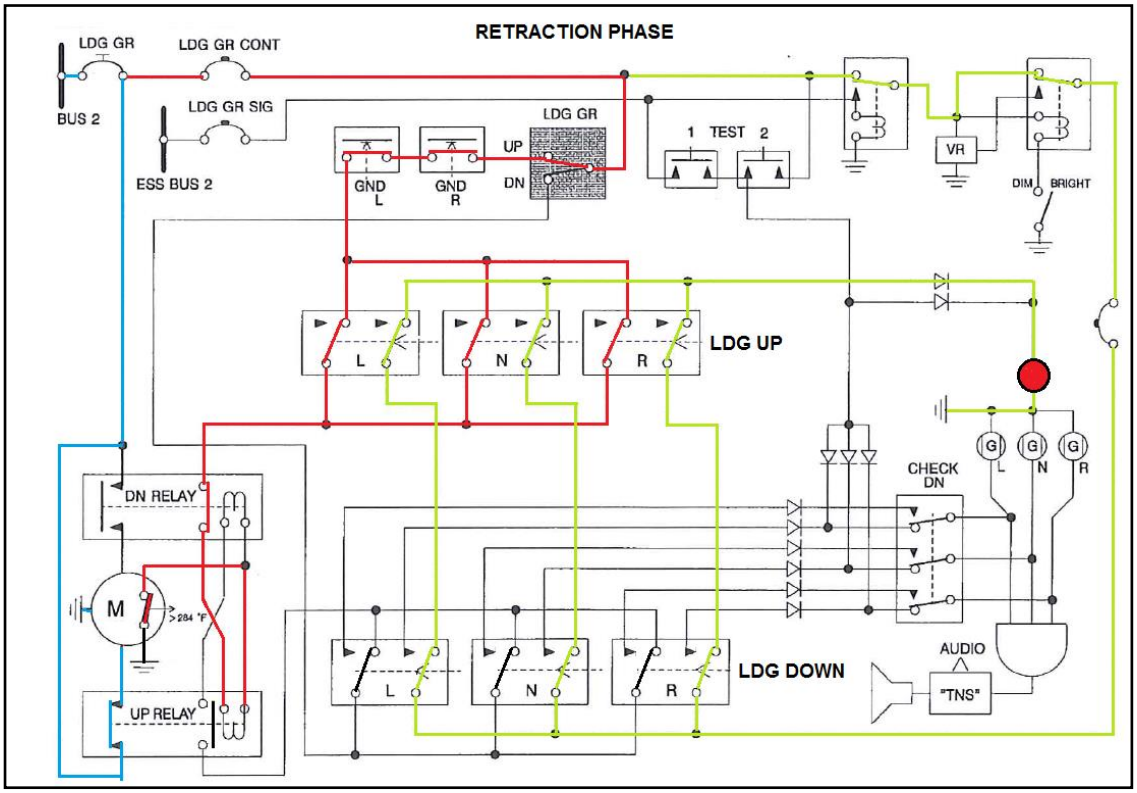


Figure 10: : Electrical drawing "Retraction Phase"

Landing gear retraction phase

The electrical circuit shows the different switch positions when the landing gear is moving from extended (DOWN) to retracted (UP) positions.

- The landing gear control lever is in UP position.
- When the aircraft is in the air, the shock struts are extended and the safety (squat) switches (9) on the main landing gears are closed.
- The control lever UP switch is electrically closed causing the activation of the electro-hydraulic generator UP relay.
- The electro-hydraulic generator is running and is sending hydraulic pressure for retraction to each actuator.
- All 3 actuators are in transition causing both the DOWN lock and UP lock mechanisms to be in unlocked position. No dual limit switch is activated meaning they are all in normally open positions.
- The 3 green lights are OFF because all landing gears are no longer locked in DOWN position.
- The red warning light is ON because at least one landing gear is not yet locked in UP position.

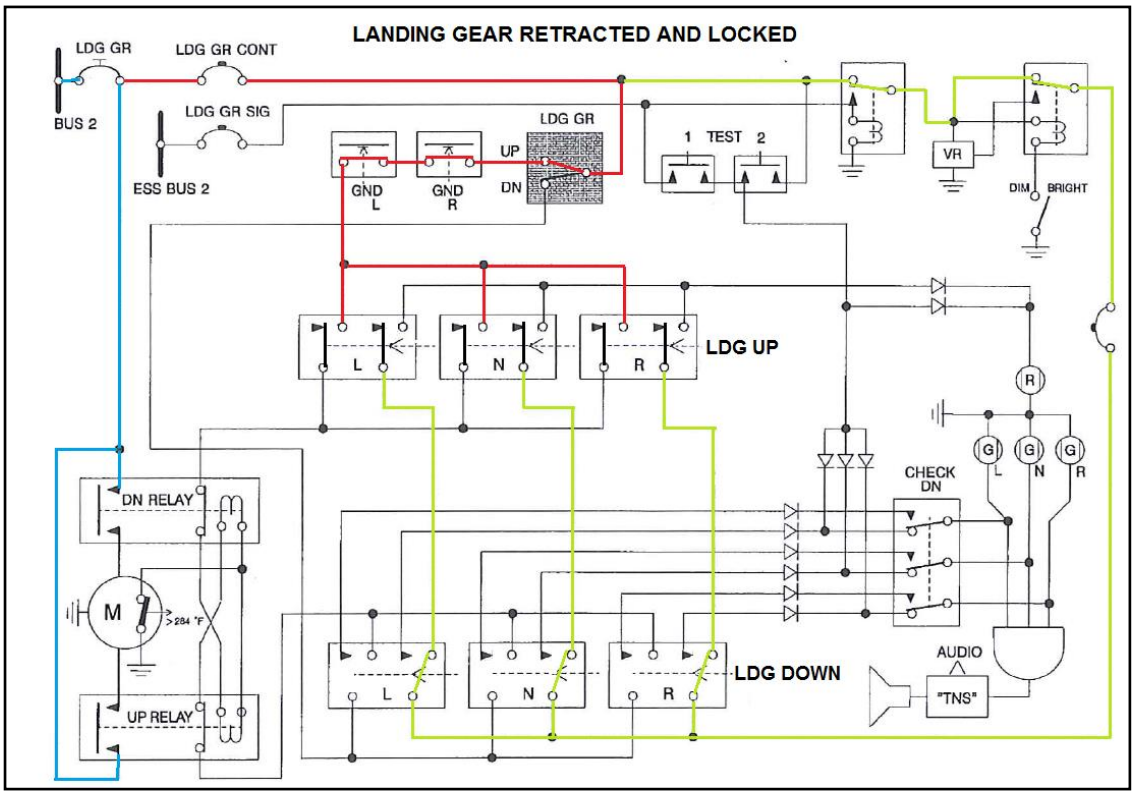


Figure 11: : Electrical drawing "Retracted and locked"

Landing gear retracted and locked

The electrical circuit shows the different switch positions when the landing gear is in UP position. The full landing gear movement from DOWN to UP is achieved. The 3 actuators are UP locked and the indicating system is working normally.

- The landing gear control lever is in UP position and the UP switch is electrically closed.
- The UP relay of the electro-hydraulic generator is not activated and the internal hydraulic pump is not running.
- The 3 actuators are fully retracted and UP locked causing the retraction dual limit switches (LDG UP) to be activated by their respective plunger mechanisms.
- The 3 green lights are OFF
- The red warning light is OFF

Landing gear control Panel (LGCP)

The LGCP evolved throughout the years, for technological purpose, to provide a solution to problems encountered in service. The main evolutions of the LGCP are as follows:

- PN: T700A3260005000 (the original PN) incorporated, in addition to 3 green lights and a red warning light, an amber light to indicate the landing gear doors position. The airplane was delivered from production with this LGCP.
- PN: T700A3260005004, replaced the original PN further to SB 70-073-32 R1 and DGAC CN 96-037(B) R1, during the removal of the inner main landing gear doors. The amber light was removed. The new LGCP incorporated three green lights indicating that all gears are locked down and a red light that, when on, indicates that at least one gear is moving, or that at least one gear is not locked up or down. This LGCP was installed in May 1997 on the aircraft.

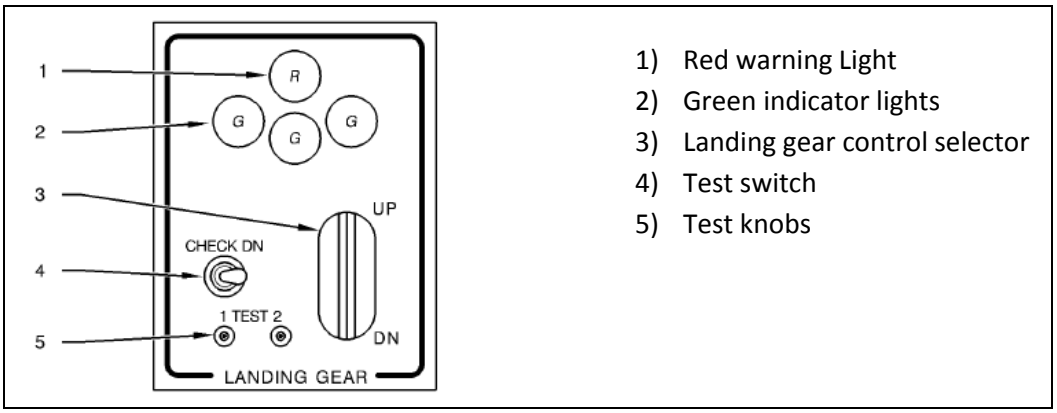


Figure 12: Installed Landing Gear Control Panel (PN T700A3260005004)

- P/N's LGCP 94-11 and LGCP 07-07 were later developed and introduced in the production line, approximately from A/C serial number 107. These new LGCPs incorporate electronic equipment which allows not only to control landing gear retraction/extension but also to advise the pilot and maintenance personnel about a possible system malfunction. The airplane MSN 3, as most of the early production aircraft, was not equipped with these new LGCPs.
- Installation of LGCP 94-11 and LGCP 07-07 as per MOD70-021-32 into the early production aircraft requires a major modification of the landing gear electrical system. No documentation, service bulletin or equivalent, pertaining this modification was made available to the aircraft operators but the CMM was modified accordingly and Daher implemented this modification at owner's request on about 30 aeroplanes, mostly French State aircraft, during an upgrade program The main visible differences compared with the original LGCP T700A3260005004 are:
  - During retraction and extension operations, the red warning light flashes while the electro-hydraulic unit is operating.
  - In case of anomaly, the red warning light remains ON (without flashing) to indicate an operation defect.
  - One LED is installed on the back to facilitate troubleshooting.

- Daher-Socata designed several further evolutions of the LGCP 94-11 and LGCP 07-07. The latest ones, identified as LGCP 94-11 Amdt H or LGCP 07-07 Amdt D, were introduced in the production line in 2008 to reduce the detection of less severe anomalies and the triggering of false warnings. It was developed, amongst others, because some operators had the tendency to ignore the warnings when these happened too often.
- On 22 September 2014, Daher-Socata proposed, through the "Service Information" 2014-007, the installation of these enhanced LGCP to all earlier produced TBM 700 and TBM 850 already equipped with LGCP 94-11 and LGCP 07-07.
  This Service Information states that:
  - The enhanced LGCP LGCP94-11 Amdt H and LGCP07-07 Amdt D is able to filter accurately the erratic warnings that should significantly reduce the occurrence of the steady red light during the gear transition.
  - When the landing gear is selected up or down, for the first 1.5 seconds the LGCP logic verifies that the three actuator up-lock or down-lock switches are open. If they are not, then the red light comes ON and latches.
  - If the switches initially operate correctly (are open when the gear is in transit), the red light is flashing during gear transition and turns off when all three of the actuator switches are closed.
  - If the red light stays ON, then one of the three actuator switches is not closed correctly.
  - Three LEDs are installed on the back to facilitate identification of the faulty landing gear.

  However, as already indicated above, early production aircraft, such as the aeroplane MSN 3, not incorporating MOD70-021-32 require a costly significant modification of the electrical system which was not mentioned in the SI 2014-007. Therefore, most of the concerned aircraft were not modified.

- In 2014, a new version of the LGCP, identified as 14-01, had also been introduced in the aeroplane assembly line. This LGCP cannot be installed as a retrofit.

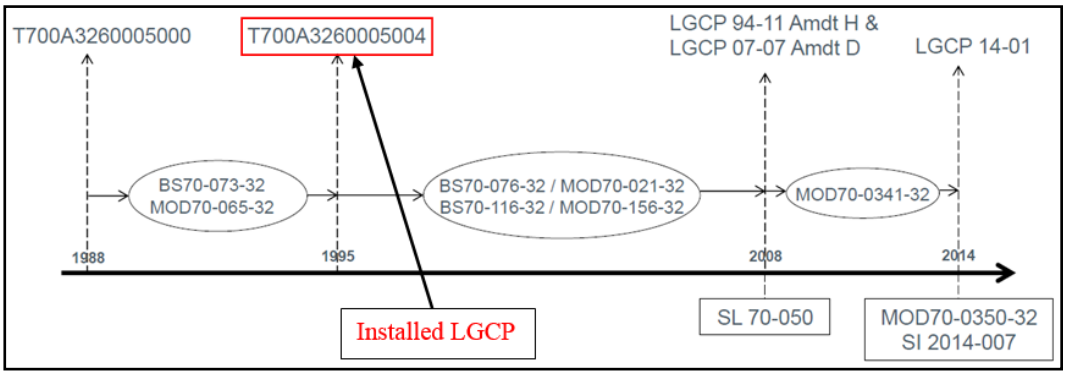


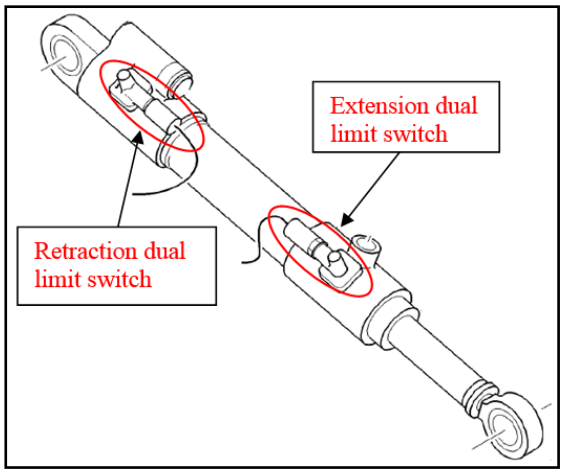
Figure 13: Chronological evolution of the Landing gear control Panel (LGCP)

Regardless of the successive developments of LGCP, an indication of 3 green lights, if combined with a latching red warning light, indicates that there is no guarantee that the landing gears are correctly locked. In this case, a manual landing gear extension according to the Flight Manual § 3.11 must be performed.

Landing gear actuator

The actuator is a double-action cylinder with a mechanical locking system for the retraction and extension positions. Locking of the rod in extended position ensures gear down-locking. Locking of the rod in retracted position ensures gear up-locking. A hydraulic system selector valve, built into the actuator, allows emergency extension of the landing gear.

Each actuator incorporates an internal mechanical uplock and a downlock device as well as two dual limit switches, i.e. one dual limit switch at the extension end of the actuator and another one at the retraction end.



Each dual limit switch performs a dual role: one internal microswitch activates the electro-hydraulic generator and the other internal microswitch operates the landing gear position lights and warning system. The respective dual switches are activated by a mechanical system operated by the locking mechanism (retract or extend). By contrast, when the actuator unlocks, this mechanical activation is just released and the dual switch is only reset by an internal spring helped by a small spring installed inside the switch holder.

Figure 14: Position of the extend and retract dual switches

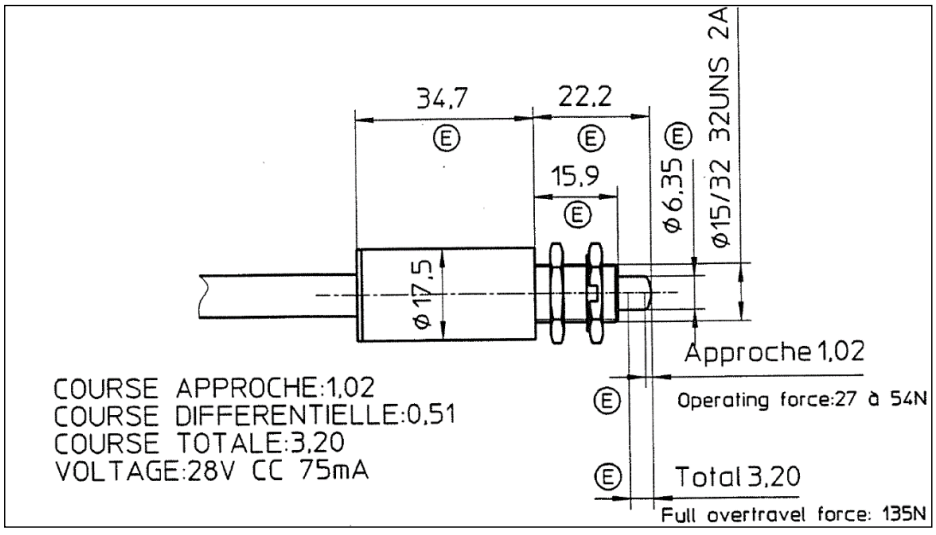
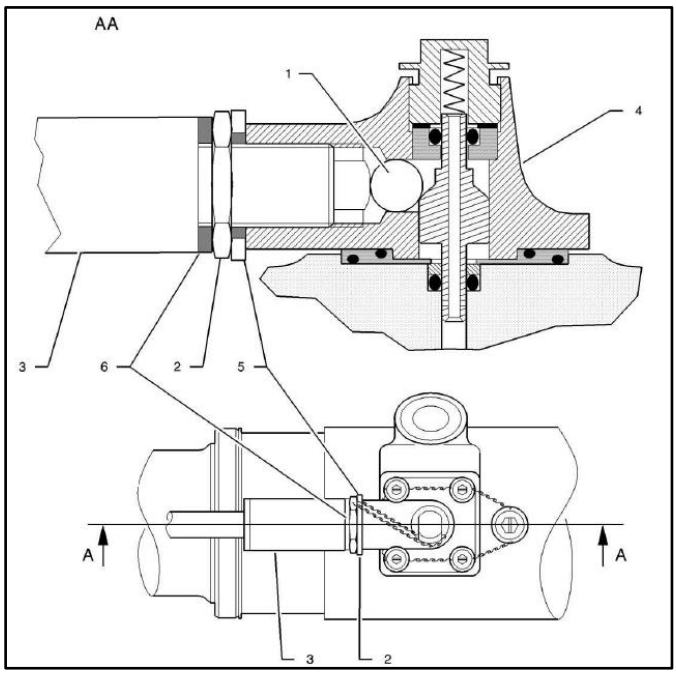


Figure 15: Drawing showing the dimensions of a dual switch

The movement of the dual switch is very short, and its setting is very sensitive. By design, the first internal micro switch is activated after 1.02 mm before that the second micro switch is activated 0.51 mm further, after 1.53 mm.
The procedure to adjust a dual switch on its holder requires that, after the activation of the second micro switch, it must be further turned between ¼ and ½ turn which

corresponds to 0.2 to 0.4 mm of longitudinal displacement of the dual switch[2]. The full movement of the dual switch moving part is between 1.73 mm and 1.93 mm.



1. Ball
2. Lock-nut
3. Dual switch
4. Switch holder
5. Seal
6. Seal

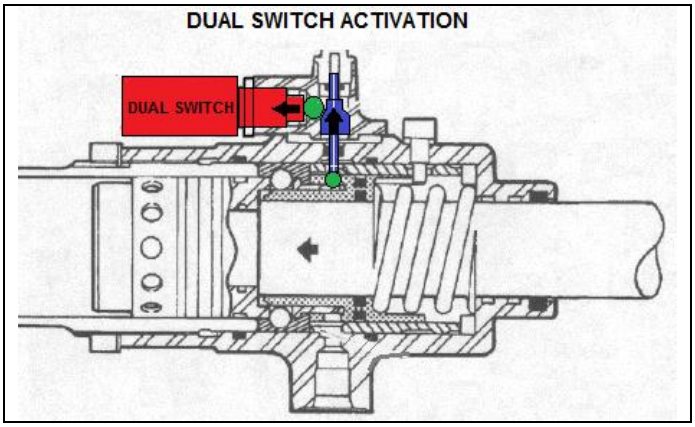


Figure 16: dual switch activation mechanism

When the actuator piston has run its course and locks, a plunger is pushed upwards by a ball operated by the movement of the locking mechanism inside the actuator.

The conical section of the plunger converts the vertical movement into a horizontal movement and pushes on another ball transferring the movement and finally activating the dual switch.

[2] Thread of the dual switch is 15/32-32, meaning that the pitch is about 0,8mm (2.54/32).

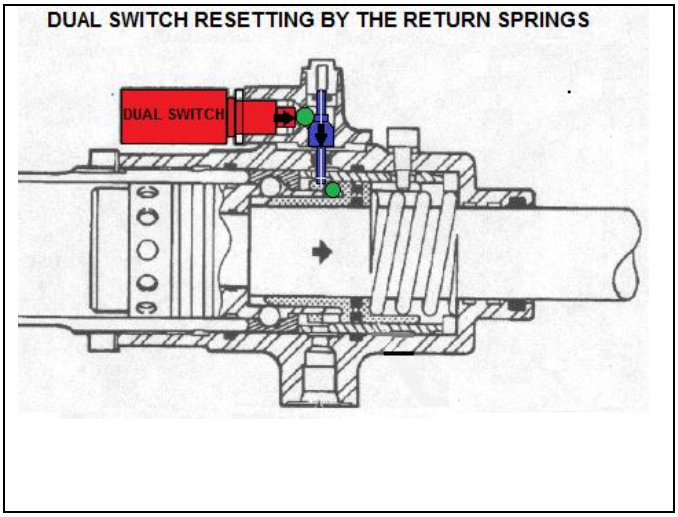


Figure 17: dual switch resetting mechanism

When the piston of the actuator unlocks and moves, the internal locking mechanism displaces its ball with the effect of releasing the vertical force applied to the plunger.

From that time, the combined force from the dual switch internal spring and from the spring of the plunger move the plunger downwards causing the dual switch to return to its rest position.

Actuator malfunctions

In-service, the operators of TBM 700 experienced some problems. One recurring problem was known as “lazy green”, where one green indication light could remain lit after the landing gear unlocked and was retracting. Daher-Socata determined that the origin of the problem was, amongst others, due to a delay in the movement of the plunger operating the dual switches. Therefore, Daher-Socata developed an improved plunger called “Differential plunger” for the activation of the dual switches.

As stated by Daher-Socata, actuators are systematically upgraded during overhaul[3]. Additionally, all the actuators sent back as a result of technical findings made during application of EASA AD2013-0227 “Security of landing gear actuator rod/piston” (SB70-197-32) are also systematically upgraded and modified to incorporate a secured rod/piston and a differential plunger.

Although the differential plunger modification is internally approved by the aeroplane manufacturer as MOD70-0334-32, the only technical information available for public is to be found in the actuator Component Maintenance Manual (CMM) T00.DMACMAEEE0R7. Daher-Socata elected to systematically incorporate this improvement during overhaul only, because of the skills required (overhauls are due at 7 or 10 years depending on configurations). No specific Service Bulletin or similar document was released by Daher-Socata to allow aircraft owners to request this modification.

After overhaul and incorporation of the differential plunger and the secured rod/piston kits, the actuators PN: T700A 32 30 050 000 00 Amdt N are re-identified as PN: VSTS 083550 Amdt A[4].

3 As per the manufacturer recommendations, the installed actuators T700A 32 30 050 000 00 Amdt N must be overhauled after 5000 landings or 7 years, whichever occurs first.

4 At user’s convenience, a conversion of the actuator to VSTS 083560 Amdt A is possible during the overhaul in order to increase its calendar time between overhaul to 10 years

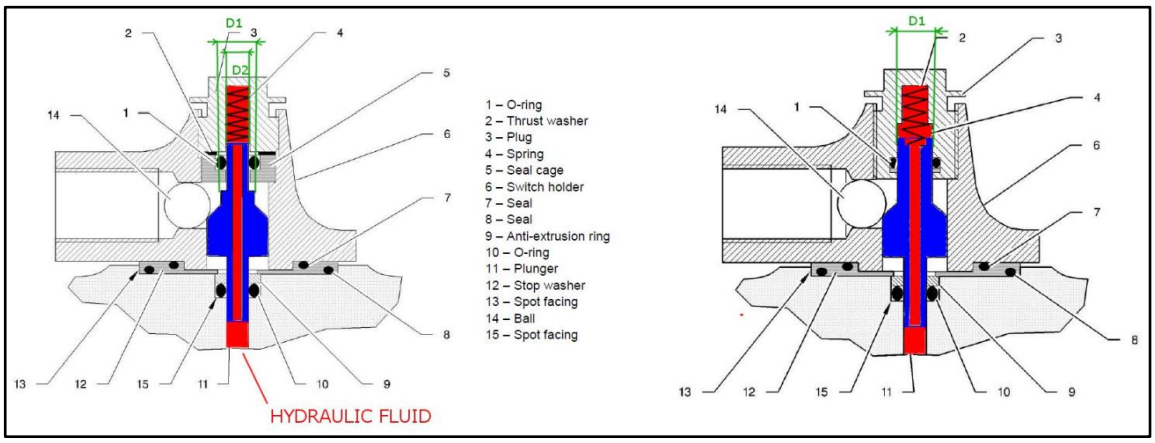


Figure 18: Installed plunger (Not modified)

Figure 19: Modified (MOD70-0334-32) plunger

The differential plunger modification consists of an increased diameter (D1) and thus increased area of the plunger upper end. It is intended to provide an improved return stroke of the plunger because of the hydraulic pressure generating a larger force in addition to the existing springs.

When asked about the effectiveness of the modification, Daher-Socata stated that the aeroplanes equipped with differential plunger actuators showed a significant improvement with respect to the lazy green phenomeon (however no actual figure available).

History of the NLG actuator Part N° T700A3230050000, serial number 286

The aircraft's 3 landing gear actuators were not due for overhaul, and the inspection performed on 13 December 2013, mandated by EASA AD2013-0227, revealed no anomaly.

As a consequence, the aircraft landing gear actuators were not sent to the manufacturer and the improved plunger – secured rod/piston improvement was not installed.

Installation date	A/C MSN	A/C TT at installation	A/C TT at removal	Removal date	Actuator TT at installation	Actuator TT or TSO at removal
Initial: 1994	105	New			New	
	105		880h	April 1997		880 hours
September 1997	095	1182h			O/H to Amdt M	
	095		1539h	July 1998		357h OH
July 1999	095	1883h			O/H	
	095		3649h	March 2004		1766h OH
August 2004	003	2684h			O/H	

	003		3416h	March 2012		732h OH
March 2012	003	3416h 3844 ldg			O/H to Amdt N	

Actuator data when the serious incident occurred:
Calendar time since overhaul: 45 months
Landings since O/H: 273
Flight hours since O/H: 256 h

1.7 Meteorological conditions.

METAR at Liège airport (EBLG) at 09:50 UTC:
Wind direction: 190 degrees. Wind speed: 11 kt. Visibility: CAVOK. Temperature: 13°C.
Dew point: 11°C. QNH: 1024 mb.

1.8 Aids to navigation:

Not applicable

1.9 Communication.

The pilot established a normal radio contact with Genk Radio in the vicinity of the airfield and reported position accordingly.

1.10 Aerodrome information.

The EBZW Zwartberg airfield (coordinates: N51 00.9 E005 31.6) is located 5 km North of the city of Genk and 43km North of EBLG Liege airport.

It features a 799 m long asphalt runway. Its orientation is 034°/214°. The use of the airfield is subject to prior permission from the airfield operator.

The traffic pattern of the airfield features limitations due to noise abatement rules and the proximity of a military zone to the North (EB-R5A, Pampa Range), hence the short final leg and the non-regular shape of the base leg at runway 21.

Basic radio information is provided by “Genk Radio” on frequency 120.400 MHz.

1.11 Flight recorders

The aircraft was not equipped with a flight data recorder or a cockpit voice recorder; neither was required by regulations.

1.12 Wreckage and impact information.

The runway showed superficial scratches in the asphalt pavement due to the propeller touching the surface. The traces are starting 60 m from the runway threshold, and continue for 400 m.

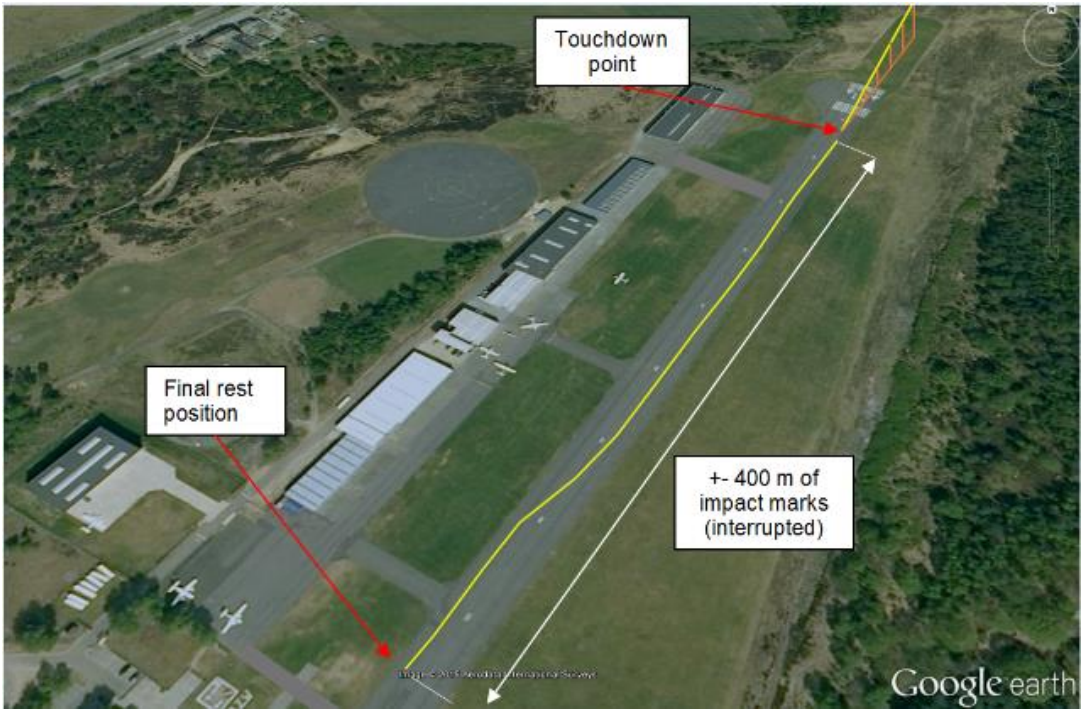


Figure 20: Aerial view of EBAW airfield showing the landing roll distance

1.13 Medical and pathological information

Not applicable

1.14 Fire

Not applicable

1.15 Survival aspects

Not applicable

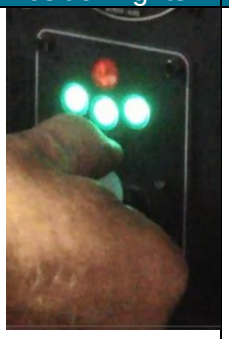
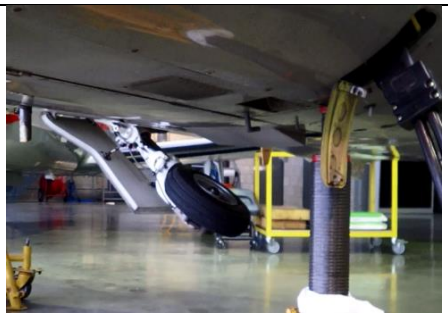
1.16 Tests and research

Test of the aeroplane landing gear

The aeroplane was inspected the day after the incident in the maintenance facility. Amongst others, a test of the landing gear was performed. The aeroplane was mounted on jacks, an external power unit was connected and the cycling of the landing gear was checked.

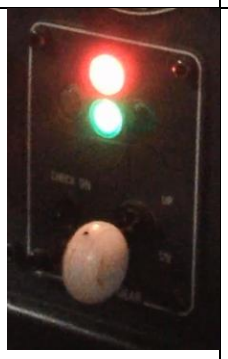
While the cycling of the gear showed no mechanical trouble regarding the locking of all gears, the position light sequence showed some anomalies. During a retraction test the nose landing gear green light stayed lit seven seconds after the red light extinguished and all gears were locked at the end of the retracting sequence. Details of the test are as follows:

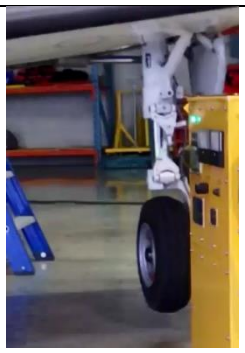
Landing gear retraction

Time and comments	Position lights	Landing gear position
00:00 Start of the sequence from extended and locked position 3 green lights ON		
00:01 NLG de-locks NLG Green light OFF Red warning light ON		
00:02 All 3 gears are moving up Left green extinguishes **NLG light comes ON again** **RH MLG green light remains ON**		
00:06 NLG retracted and door closed MLG continues to retract RH MLG green OFF **NLG green light remains ON**		

00:10 All gear UP Red light OFF Electro-hydraulic generator shuts down **NLG green light remains ON**		
00:17 17 seconds after gear UP selection, NLG green light extinguishes **16 seconds long "lazy green"** (7 seconds long after red light OFF)		

Landing gear extension

00:00 Start of the sequence Red warning light ON		
00:09 NLG locks NLG green light goes ON		

00:13 MLG locks Red light extinguishes 3 green lights ON Electro-hydraulic generator shuts down		 ,

Test of the nose LDG actuator

The actuator was brought to the manufacturer Hydro René Leduc and tested on 22 January 2016 in the presence of investigators of both the AAIU(Be) and the BEA and an advisor from Daher-Socata.
Before installing the actuator on a test bench and starting the test, the hydraulic fluid contained in the actuator was drained in order to send samples (contamination) to a chemical lab for analysis (contamination).

In addition to the hydraulic system, the test bench is provided with two electrical boxes to visualize the position of the dual limit switches. The first box gives the position of the electrical contacts of the “retract” dual limit switch and the second gives the position of the electrical contacts of the “extend” dual limit switch.

Each electrical box is equipped with 4 red lights. Two lights located at the bottom of the boxes are triggered ON when the dual switch is activated, i.e. when the actuator is in locked position. The 2 lights located at the top are triggered ON as soon as the actuator unlocks. The lights on the left side of each box are used to test the switch for the indication system (Green lights etc) while the lights on the right side are used to verify the switch used to control the electro-hydraulic generator.

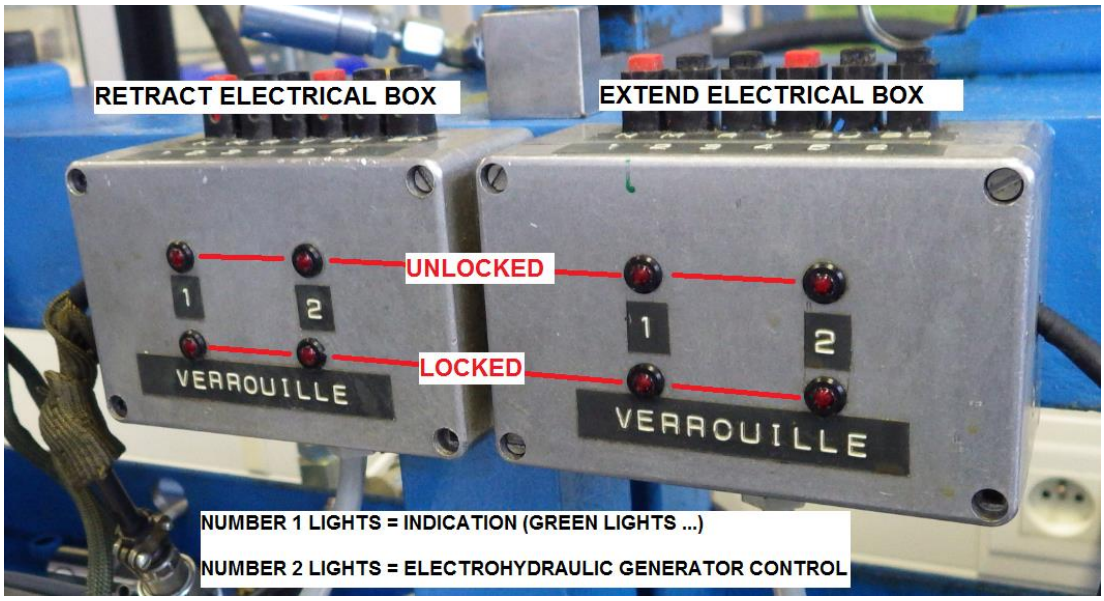
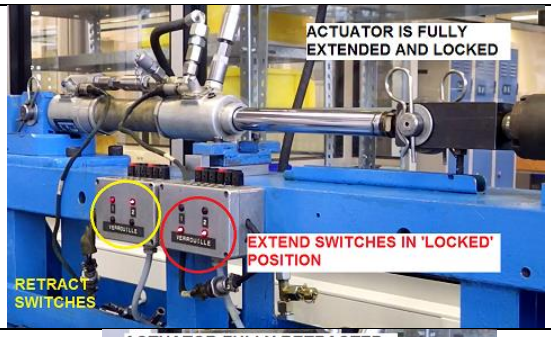
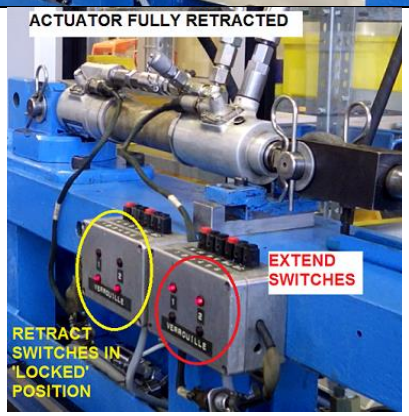
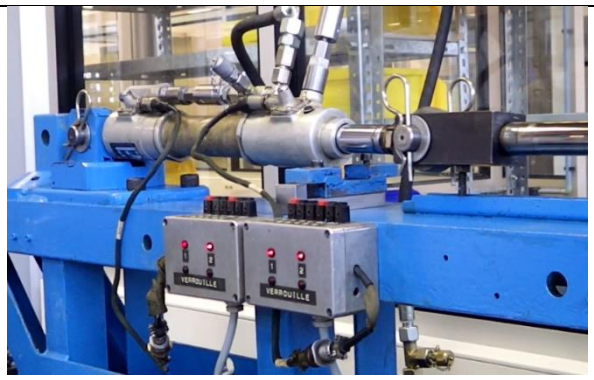
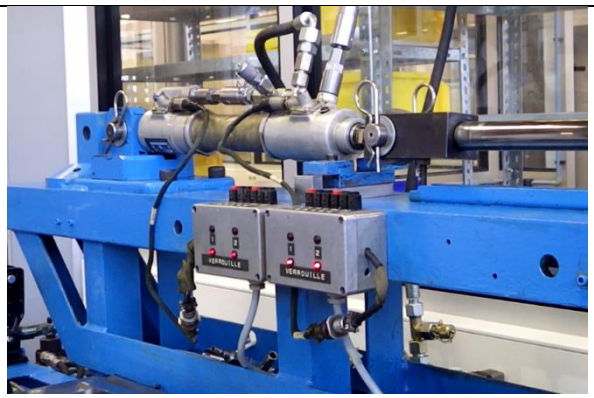
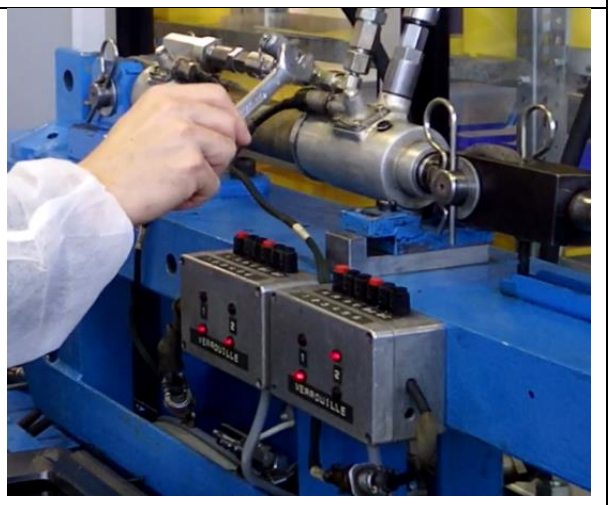
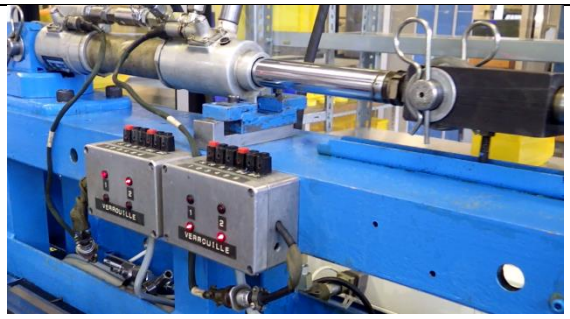
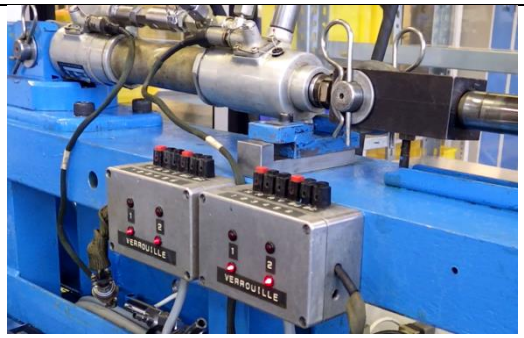
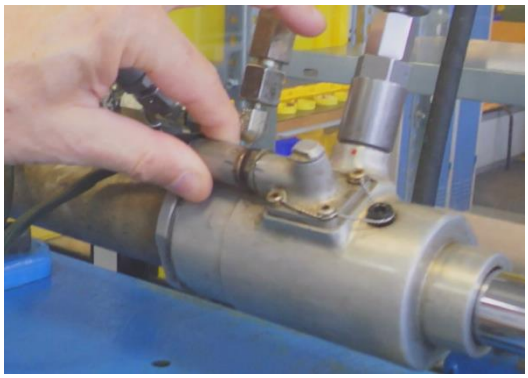


Figure 21: Test bench limit switches indication lights

The unit was installed on the bench in an intermediate position. All 4 contacts of the dual switches were in unlocked position, which is normal. The following events were witnessed in sequence:

EXTENSION 1st extension of the actuator to the 'fully extended' position. At the end of the extension phase, locking and activation of the extend dual switch contacts (normal).	
RETRACTION 1st Retraction of the actuator to the "fully retracted" position. Normal switching of the extend dual switch contacts at the beginning of the retraction. Normal activation of the retract dual switch contacts at the end of the retraction.	
EXTENSION 2nd Extension of the actuator to the 'fully extended' position. Normal switching of the retract dual switch contacts at the beginning of the extension. Normal activation of the extend dual switch contacts at the end of the extension.	
RETRACTION 2nd Retraction phase of the actuator to the "fully retracted" position. Normal de-activation of the extend dual switch contacts.	

At the end of the retraction phase, normal activation of the retract dual switch contacts. **But almost at the same time both 2 extend dual switch contacts also activated to the locked position**. Thus abnormal activation of the "extend" dual switch contacts when the actuator locked in retract.	
The "extend" dual switch contact N°2 (used to control the electro-hydraulic generator) switches to the "unlock" position after a few minutes. The "extend" dual switch contact N°1 (used for the indication) switches to the "unlocked position" after "tapping" (with a wrench) a few seconds on the actuator around the switch body.	
<u>EXTENSION</u> 3rd extension of the actuator to the 'fully extended' position. Normal switching of the retract dual switch contacts at the beginning of the extension. Normal activation of the extend dual switch contacts at the end of the extension.	
<u>RETRACTION</u> 3rd Retraction of the actuator to the "fully retracted" position. **The "extend" dual switch contacts don't switch OFF at the beginning of the retraction.**	

Normal activation of the retract dual switch contacts at the end of the retraction. **Both "extend" dual switch contacts, supposed to move to the unlocked position as soon as the mechanical unlocking occurs, remain in the locked position.**	
<u>VERIFICATION OF THE ADJUSTMENT OF THE EXTEND DUAL SWITCH</u> The actuator piston was moved to a intermediate position, between the extended and retracted positions. This caused all four extend and retract lights to switch to the unlock position, which is normal. The setting of the switches was checked and the adjustment was found within limits, i.e. the setting was such that the dual switch was screwed between ¼ and ½ turn further to the point of switching, which is correct.	

Actuator and dual switch plunger examination

External examination of the actuator showed that a lock plate washer used to secure the assembly of a guide rod with the casing of the actuator was not bent, but the parts were not loose. The plug of one plunger holder was also found to be damaged by a previous use of an inadaquate wrench for unscrewing it. Finally, traces of hydraulic oil seepage were visible around the extend dual switch holder.

The retract dual switch and switch holder were first removed from the actuator. No visible anomaly was found, the different parts showing no trace of hydraulic fluid contamination and no other anomaly in the area of the plunger.

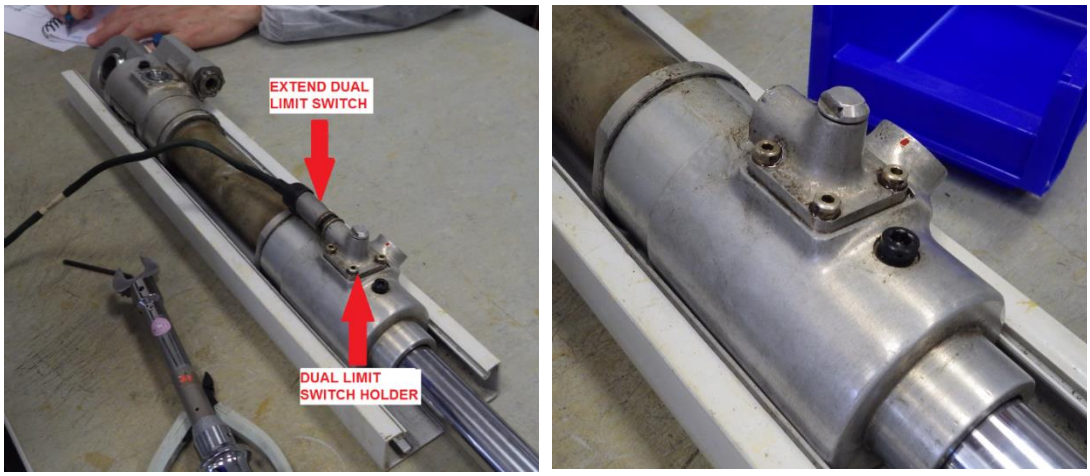


Figure 22: Pictures of the NLG actuator extend dual limit switch

As shown on figures 23 and 24, the dual switches and switch holders were removed and disassembled. The extend dual switch showed the presence of what seemed to be a low viscosity light brown grease around the plunger and its surrounding parts.

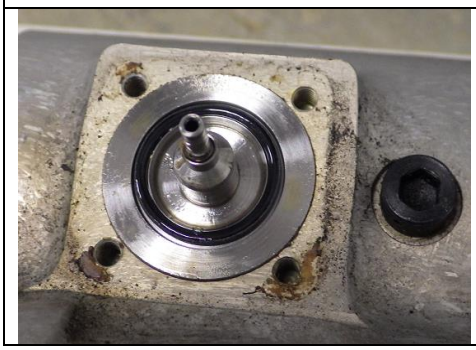
Retract dual switch	Extend dual switch
	
	

Figure 23: retract limit switch and plunger

Figure 24: extend limit switch and plunger

Testing and inspecting the Honeywell 602EN16-6B switch

Testing:

The switches were tested at Hydro Rene Leduc using the actuator test bench indicating system (electrical box).
The perceived operating force was found to be similar for both extend and retract dual switches and were percieved to be within the manufacturer's tolerances (27 to 54 N – Full overtravel force: 135 N).
The switches were manually actuated about 20 times, pushing on it in every way, slowly and rapidly. During this test, the dual switch worked perfectly.

Inspecting

A CT-scan of the dual switch was performed at the BEA facility in Le Bourget, France.
Nothing abnormal was detected.

Thereafter, the switch was disassembled.
No electrical or mechanical anomaly and no contamination was found.

Figure 25: dual switch dismantling

Examination of the construction of the dual switch, made of 2 independent micro switches operated by a simple mechanical plate cannot explain the cause of the blockage or dampening as seen during testing.

Hydraulic oil testing.

A sample of the oil contained in the actuator was taken and sent for analysis to a specialized laboratory.

In summary, the results of the test show that the hydraulic fluid contained a lot of small particles and a great quantity of water, both still within limits, but close to the maximum acceptable values. The report from the laboratory also observes the presence of lithium and advises:

- That the presence of water should be monitored.
- That the hydraulic fluid should be filtered.
- That the cause of the presence of lithium should be determined unless the lithium originates from the hydraulic fluid itself.

1.17 Organizational and management information

Not applicable

1.18 Additional information.

Other events

The websites of several safety investigation authorities (AAIB-UK, BEA-France, BEAD-Air-France, BFU-Germany and NTSB-USA) were searched for investigation reports involving TBM 700. 9 events were found.

BEAD-Air performed a safety investigation and study (BEA-Air-A-2008-004-I) further to a NLG collapse and analysed several similar events that occurred on state aircraft TBM 700.

AAIB EW/C2008/03/04 – 27 March 2008 – Alderney – N700GY MSN 302

The aircraft with one person on board, took off from Biggin Hill bound for Alderney. When the pilot selected the landing gear up, the green nose gear light did not extinguish and the red landing gear warning light remained on.

When the actuator was functionally tested on a rig, an anomaly was found. It successfully retracted, giving the correct UP lock indications, but almost simultaneously, the switch indications for DOWN lock were detected. This meant that the actuator would have sent an indication to the landing gear control unit that the nose gear leg was locked both UP and DOWN. This anomaly could have produced the continuous red light reported by the pilot.

BEA – 4 September 2007 – Paris Le Bourget – F-GTJM – MSN 145

After take-off from Runway 09 of Le Bourget, upon retraction of the landing gear, the red warning light remained flashing and the green nose gear light remained on. At the end of the sequence, the green nose gear light and the red light remained on. The pilot decided to return to Le Bourget for landing on Runway 03. The pilot observed that the three greens and a constant red light were illuminated after selecting the gear down. The pilot consulted the ATC controller, who confirmed that all three gear legs appeared to be down. The POH procedure to operate the landing gear hand pump was not followed and the nose gear collapsed during the rollout.

BEAD-air – 18 March 2008 – Bordeaux – French Air Force – MSN 105
(Report: BEAD-Air-A-2008-004-I)

After take-off from Bordeaux airport, the crew detects an anomaly upon retraction of the landing gear, the green nose gear light remained on for 5 seconds after the red light extinguished. The pilot decided to return to the airport. The landing gear was selected down. The nose gear collapsed during the rollout.
NLG actuator N° 125
TSO: 4.6 years
CSO: 1347 (landings since overhaul)

BEAD-air incident - French Air Force - 25 March 2008 - MSN 93

After take-off, the crew detects an anomaly upon retraction of the landing gear, the green left hand Main Landing gear light remained on for 5 seconds after the red light extinguished. The pilot aborts the mission, and applies the emergency procedure « unsafe gear » and operates the manual hydraulic pump. The airplane lands safely.
NLG actuator N° 505
TSO: 2.5 years
CSO: 538 (landings since overhaul)

The defect is not repeated on the test bench. Some corrosion is found on the plunger.

BEAD-air incident - French Air Force – 26 March 2008 - MSN 35

After take-off, the crew detects an anomaly upon retraction of the landing gear, the green Nose Landing gear light remained on for a few seconds after the red light extinguished. The pilot applies the emergency procedure « unsafe gear », and operates the manual hydraulic pump. The airplane lands safely.

The defect is not repeated on the test bench. No corrosion is visible.

BEAD-air incident - French Air Force – 22 April 2008 - MSN 125

After take-off, the crew detects an anomaly upon retraction of the landing gear, the nose gear green light lits two seconds after the red light extinguished. The landing gear is cycled with the same anomaly appearing. The pilot applies the emergency procedure « unsafe gear », and operates the manual hydraulic pump. The airplane lands safely.
The findings during inspection of the actuator:
Retract switch;
- No anomaly found on the micro-switches
- The ball and plunger are stuck in position, and show signs of corrosion.
- Clogs of rust and grease are found on the plunger.

Extend switch;
- Ball and plunger are moving easily.
- The balls shows some corrosion pitting

NLG actuator N° 11
TSO: 5.4 years, CSO: 2041 (landings since overhaul)

D-FGYY - 18 October 2014 Augsburg - MSN 162

NLG collapse during landing roll.

Unofficial feedback from BFU: The hydraulic pump stopped too early but the pilot had three green.

N709MC - 25 May 2006 – Petersburg, FL – MSN 168

NLG collapse during landing roll.

N9UE - 28 November 2011 – Dayton, OH – MSN 224

NLG collapse during landing roll.

All French Air Force TBM 700 involved in the above-mentionned events were equipped with the same landing gear control panel (PN: T700A3260005004) than the aircraft MSN 3.

Reportedly, the French Air Force fleet was futher equipped with LGCP 94-11 (or LGCP 07-07).

1.19 Useful or effective investigation techniques

Not applicable

2 Analysis.

2.1 The landing gear extension

The pilot reported that, during the flight:

- No evident anomaly was detected during landing gear retraction after take-off from EBLG, however the pilot did not recall having specifically checked the landing gear warning lights at the end of the retraction sequence.
- He could not rule out a possible delay in the extinguishing of the NLG green light, but he was sure that at a certain moment during flight, all landing gear green lights were extinguished.
- He selected the landing gear down about 2 minutes before joining the downwind leg and witnessed without any doubt three greens and no red light.

It can be suspected that, during the extension, the NLG “Extend” dual switch went unexpectedly to “extend” position before the actuator was fully extended and locked, causing at the same time the electro-hydraulic generator to stop operating and a spurious green light.

<u>The landing gear system was tested on the aircraft:</u>

During the retraction phase all 3 gears mechanically unlocked at about the same time, which is normal.
Although the mechanical unlocking occurred almost simultaneously, the green lights didn’t extinguish at the same time:

- The left green extinguished after 2 seconds.
- The right green extinguished after 6 seconds.
- The nose green extinguished after 16 seconds, long after all the gears were fully retracted and locked.

There was thus a delay in the switching off of both the right and the nose landing gear green lights (Lazy Green).

<u>The nose landing gear actuator was bench tested:</u>

The test showed the following anomalies:

- At the end of a retraction phase, the retract dual switch activated normally, but almost at the same time, the extend dual switch also activated (“locked” position).
- At the end of another retraction phase, the extend dual switch, supposed to move to the unlock position as soon as the mechanical unlocking occurs, remained in the “locked” position.
- The anomalies are random.

The test of the landing gear when the aeroplane was in the hangar could not recreate the flight conditions.
In flight, due to the airspeed:

- During the extension phase, the nose landing gear has the tendency to reach its final extend position last i.e. after the main landing gears, as it gets more drag due to the dynamic pressure of the airspeed.
- During the retraction phase, the nose landing gear has the tendency to reach its final retract position first, due to this same dynamic pressure.

The electro-hydraulic generator stays running as long as it is activated by any one of the three landing gear dual switches. Therefore, it is the landing gear retracting or extending the last that actually shuts down the electro-hydraulic generator.

The tests performed showed a series of anomalies to the activation of the “extend” dual switch of the NLG actuator. Such anomalies at the nose landing gear “extend” dual switch will not prevent the nose landing gear from properly retracting. Nevertheless, it can result in NLG indication light anomalies such as a “lazy green” or even a permanent green light after the retraction.

During the extension phase however, the same anomalies would have led the electro-hydraulic generator to stop as soon as the 2 main landing gears would have reached their extended position. As seen above, in flight the NLG would be the last to extend and would stop extending before complete extension and locking. This is shown on Figure 26; the extend dual switch of the NLG is already activated (1) giving a green NLG indication light (2) although the actuator is not yet fully extended (3). As soon as the MLG actuators are extended and locked (and their extend dual switches activated), the power to the down relay is interrupted (4) stopping the operation of the electro-hydraulic generator.

The NLG would therefore collapse when the weight of the aircraft would be applied to it during the ground roll. Thus, the same consequence as in this event.

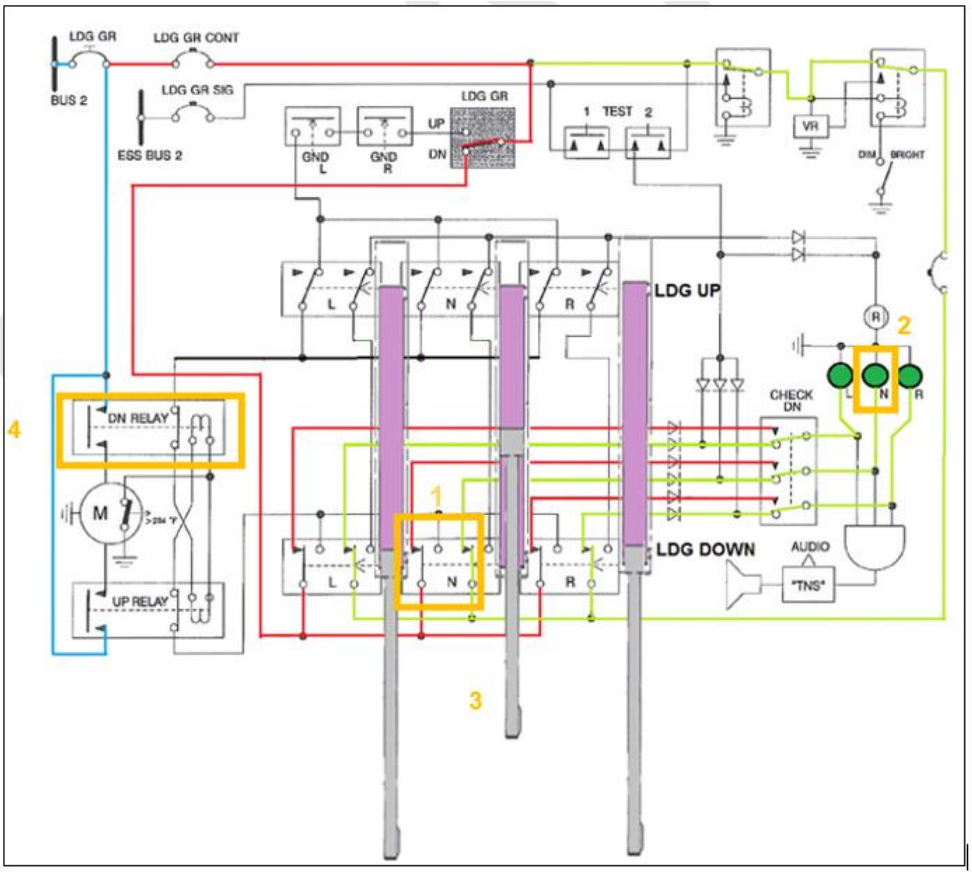


Figure 26 : Three greens are lit while the NLG is not locked

2.2 Spurious triggering of the nose landing gear "extend" dual switch

A possible cause of this unwanted activation of the dual switch would be that a pressure spike in the hydraulic circuit was produced internally at the end of the retraction course, causing an upwards movement of the "extend" plunger. This type of phenomenon is not a unique case as it is also described in the investigation report BEAD-air-A-2008-004-I dated February 2009.

In flight, a rather similar phenomenon could have happened. One possibility would be that pressure spikes originating from the locking of any main landing gear actuator could have been transmitted to the entire hydraulic circuit, resulting in a possible unexpected actuation of a dual switch plunger.

During the last retraction performed after the take-off at EBLG airport, it is likely that the plunger did not move fully down. This might have been caused by the presence of abundant low viscosity grease on the underside of the plunger, causing a cushion effect and reducing the movement of the plunger.
In this case, a very small upwards movement of the plunger, possibly caused by a pressure spike, has the potential to cause an early activation of the dual switch.

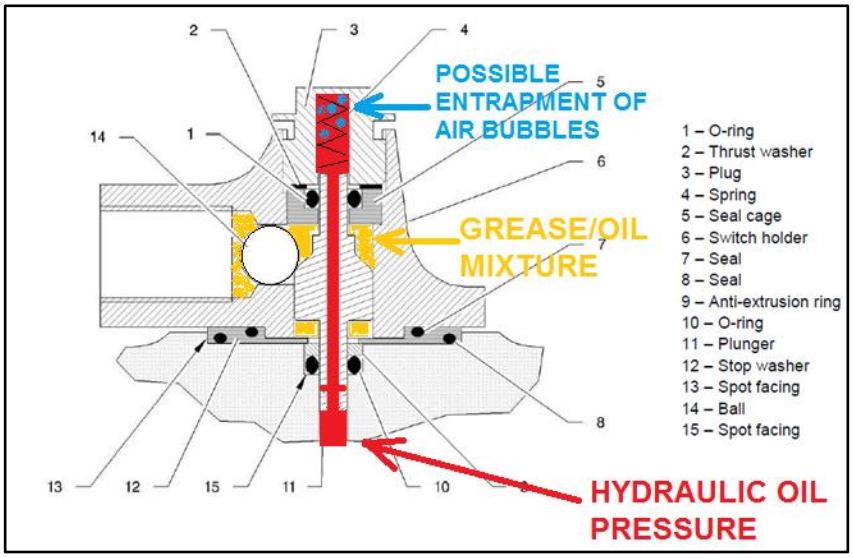


Figure 27: Drawing of the dual switch holder

It is also possible that air bubbles were present on the top end of the plunger, facilitating the unwanted upwards movement of the plunger. In this case, the plunger can be submitted to pressure unbalance originating from pure hydraulic fluid on one end and fluid containing air bubbles on the other end.

However, this hypothesis was contradicted by Daher-Socata who stated that tests were performed showing that, due to the high hydraulic pressure, air bubbles are easily trapped and evacuated by the hydraulic fluid.

Finally, the hydraulic fluid was analysed in order to investigate a possible relationship with the erratic working of the plunger. The result of the analysis was not conclusive.

2.3 Interaction between the dual switch and the actuator

The test performed at Hydro René Leduc and a careful disassembly of the dual switch could conclude that it was in good condition and not the cause of the erratic working.

When installed on the test bench, the actuator always locked mechanically as it should, while the bench test lights showed an erratic working of the extend dual switch. Examination of the blueprint and study of the operation of the actuator allows it to be concluded that the anomaly very likely originated from the activation system of the dual switch and not from the dual switch itself.

Some of the indication symptoms detected during the test suggests a dampened movement or a temporary blockage of the plunger. Other symptoms suggest that unwanted upward movements of the plunger occurred, likely under the effect of a hydraulic pressure spike.

Low viscosity grease was found on the plunger and its surrounding parts that could be the result of a small internal hydraulic fluid leak at one or both plunger O-ring(s) combined with the grease placed on the plunger and its ball during installation.

It could explain the erratic operation witnessed during the aircraft landing gear tests performed the day after the serious incident and the NLG actuator tests performed on Hydro Leduc:

- Presence of a thick liquid under the plunger would damp the return stroke of the plunger, only actuated in this direction by springs. The dampening effect would be proportional to the quantity of thick liquid and its viscosity, which can vary amongst others due to the temperature. The difference in diameter between the plunger and the holder cylinder bore is only 0.26 mm meaning a probable squeezing effect of the liquid when passing through the 0.13 mm large circular ring.
- It is also possible that the quantity of thick liquid under the plunger was most of the time not sufficient to disturb the deactivation of the dual switch while it was sufficient to prevent its full return stroke. In that case, the plunger position would have remained very close to the activation position meaning that any small upwards movement possibly caused by a pressure spike in the hydraulic circuit could have cause an unwanted activation of the dual switch. However, Daher-Socata considers that this explanation is not relevant since the plunger diameter has functional play in the bore where it travels.

2.4 Enhancement of the actuator dual switch activation system

As seen in the chapter “Other events”, malfunctions of the dual switch activation system occurred several times in the past, leading not only to erroneous landing gear indication problems but also to actual malfunctions of the hydraulic system and finally landing with an unlocked landing gear leg except when the emergency procedure was applied.

The problem has been known for decades, almost since the beginning of the production of the TBM 700 and Daher-Socata developed a series of improvements related to the working of the plunger system, combined with improvements to the

LGCP. However, none of these improvements could definitively eradicate possible malfunctions of the plunger system.

A latest improvement of the plunger was introduced in December 2012 (MOD70-0334-32) to replace the original design with an improved "differential" plunger intended to provide an additional load, helping the return course. As stated by Daher-Socata, this differential plunger offers a considerable improvement causing a reduction of the indicating kinematics malfunctions. However, Daher-Socata stated that residual malfunctions may still exist, although they are much limited in number.

Because no service bulletin or similar document was published to recommend or request the installation of an improved "differential" plunger, the actuators are only upgraded when they are sent for overhaul or repair.

On the other side, EASA published EASA AD 2013-0227 dealing with the safety of landing gear actuator rod/piston, focusing on the risk of unscrewing of rod and piston on landing gear actuators and uncrimping of actuator ball joint. The AD mandated the inspection of the TBM 700 landing gear actuators and, depending on the findings, the installation of actuator P/N VSTS 083550 or VSTS 083560 (which have MOD70-0334-32 incorporated). EASA AD 2013-0227 mentioned, as information only, that the application of MOD70-0334-32 will not only "secure rod/piston assembly" but also "reduce retraction/extension indication failure through improvement of switch kinematics" (by the installation of the differential plunger).

As a matter of fact, part 2 of MOD70-0334-32 incorporates "the improvement of switch kinematics using hydraulic pressure to help the plunger movement". However, that is only applied during the actuator's overhaul or in case of findings during the application of EASA AD 2013-0227 and related bulletins.

Aircraft msn 03 was inspected in accordance with EASA AD 2013-0227 before the serious incident and no findings were made on the risk of unscrewing of rod and piston and uncrimping of actuator ball joint. For this reason, the actuators were not sent back to the manufacturer and MOD70-0334-32 was not applied.

As the overhaul is only recommended in the Maintenance Manual chapter 05-11-00 "Time Limits", the operator is strictly not obliged to adhere to the recommended overhaul operating limit (the actuator is not considered as an airworthiness limitation item). This means that, depending on the local aviation regulation and the way to approve the maintenance programs, some operators will decide to exceed the recommended overhaul time limits, especially since no service bulletin, informing the operator on the possible improvements applied during overhaul, was released.

This will likely cause unmodified actuators to remain in service for a long time.

2.5 Design of the last evolution of the landing gear control and indication system

The last evolution of LGCPs, identified as LGCP 94-11 Amdt H or LGCP 07-07 Amdt D is only able to detect wrong dual switch positions during the first 1.5 seconds of activation of the landing gear. Therefore, it cannot detect all dual switch activation anomalies, in particular if one dual switch is triggered by a pressure spike produced further in the movement of the actuator. Therefore, it is possible that the installation

of the last evolution of LGCP 94-11 Amdt H or LGCP 07-07 Amdt D would not have allowed the detection of the anomaly that caused the serious incident. Nevertheless the incorporation of the differential plunger could probably have prevented this situation.

In any case, the aircraft could not be easily equipped with the last generation LGCP because it requires an extensive change to the electrical system, not currently supported by published approved data available in the field (Service Bulletin …).

2.6 Flight manual and Service Letter 70-050-32 recommended procedure regarding the landing gear operations

The flight manual for TBM 700 A and TBM 700 B, in section 4, distinguishes the pre- or post MOD70-021-32 aeroplanes regarding the modus operandi of the red warning light. It states also, regardless the aeroplane is pre- or post MOD70-021-32:

"At sequence end, check : All warning lights OFF ".

On the other side, Service Letter SL 70-050-32 describes, amongst others examples of possible indication anomalies, the "Lazy green" phenomenon:

"One green indicator light does not go off (whatever the duration may be) during or at the end of landing gear retraction maneuver"

The service letter is more stringent and more comprehensive than the flight manual as it suggests that the pilot has to check the warning lights not only at the end but also during the retraction. It states also that any "Lazy green", whatever the duration may be, must lead to application of actions described in Paragraph 3.11 of Flight manual, chapter "Emergency procedures", which refers to the emergency extension of the landing gear. However, it is not clear how the pilot can determine the precise moment of the end of the retraction manoeuvre, which is an important moment, as from that time any green light is undoubtedly an indication of anomaly.

AAIU(Be) doesn't see how a "Lazy green" occurring during the retraction can be accurately detected as the pilot has no way to verify when the unlocking occurs (the 3 landing gears don't unlock systematically at the same time).
Additionally, the flight manual itself notes that *"it is possible that the 3 landing gear position green indicator lights flash uncertainly*[5] *then go off at the end of the sequence"* (Cfr Chapter Amplified procedure "Take-off"). This makes it more difficult, if not impossible, to detect a "Lazy green" during the retraction manoeuver.

A "lazy green" phenomenon, visible 7 seconds after the red light extinguished, has been observed one time during several retraction tests performed the day after the incident. Assuming that a similar phenomenon had occurred in flight during the last gear retraction, it means that the pilot should have had his eyes on the LGCP precisely during this period to realize that something was wrong with the landing gear system.

[5] "*Clignote de manière aléatoire*" in the French version of the Flight Manual. This indicates that the green indicators may intermittently go ON and OFF during the sequence.

Although it is likely, but not demonstrated, that a “lazy green” occurred during or at the end of the last gear retraction, and if it occurred, how long it lasted, Daher-Socata point of view is that:

> *“The pilot was not familiarized with the need to closely monitor the retraction sequence according to the POH in order to identify any possible issues with the indicating system”.*

In addition, Daher-Socata stated also:

> *“For this aircraft : 3 green light ON and the red light OFF at the end of the extension phase is not enough to indicate that landing gear is properly extended and locked : no anomaly must have been detected when retracting the landing gear (e.g. no delay for the lights OFF)*

When asked about how he was familiarized with the need to closely monitor the retraction sequence, the pilot stated that he did not have this information.

He was aware that no warning light, including a green light, could remain lit after the retraction, but he didn’t know that this verification had to be done exactly at the end of the retraction, and also during the retraction sequence.

The pilot stated that during the theoretical training delivered by Daher-Socata in June 2007, the possible landing gear anomalies have been described in detail. But he doesn’t remember that during this training it has been emphasized that a close monitoring of the retraction sequence was needed in order to detect any possible temporary “lazy green”.

He is adamant that no mention was made about landing gear problems such as temporary phenomenon of “Lazy green” that was encountered on the TBM700 fleet and that these problems would have required a particular attention. When reading the chapter “landing gear” of the theoretical course given at Daher-Socata to the pilot, including his handwritten notes, no mention is found showing that a close monitoring of the retraction is needed and the way it should be performed.

This raises the question whether it is safe for a single-pilot configuration (without co-pilot) to look at the LGCP during the entire retraction sequence. AAIU(Be) believes that it’s not safe in a single-pilot configuration to closely monitor the retraction sequence after take-off while flying at low altitude. The workload of the pilot immediately after the take-off or during the initial climb is hardly compatible with a close and uninterrupted observation of the landing gear indicators. Moreover, closely monitoring an indicator, even for a few seconds, is in contradiction with the basic rule of attitude flying; for about 90 % of the time looking outside (under VFR) or monitoring the attitude indicator (under IFR). Focusing on the LGCP indicators during this flight phase would prevent the pilot to adequately monitor the aircraft attitude, crucial for flight safety.

3 Conclusion

3.1 Findings.

- The pilot was qualified and licenced to pilot TBM 700 aircraft.
- The aeroplane was issued a valid airworthiness certificate and a valid Airworthiness Review Certificate.
- The maintenance was regularly performed by a Part M subpart F certified maintenance organization and was under the supervision of the same company, also approved as a Continuous Airworthiness Management Organization.
- The pilot stated that he did not detect any anomaly during the retraction of the landing gear after take-off, however the pilot did not recall having specifically checked the landing gear warning lights at the end of the retraction sequence.
- The landing gear was lowered before entering the landing circuit, long enough before the landing. The pilot stated that he checked the landing gear position lights twice before landing and he was sure that there were three greens and no red light.
- The nose landing gear collapsed during the landing roll out, as soon as the weight of the aircraft applied on it.
- The tests performed on the aircraft showed, amongst others, that the nose landing gear green light once remained illuminated for a few seconds after full retraction of the corresponding gear. The tests of the nose landing gear actuator performed on the test bench showed additional anomalies in the activation of the extend dual switch.
- The NLG actuator extend dual switch itself was determined to be in good working condition.
- Inspection of the extend switch plunger determined it was contaminated by a thick liquid, which was supposed to be a mixture of hydraulic oil and grease. This, added to the fact that the dual switch was in good condition concluded that the anomalies were due to an erratic working of the extend plunger, more precisely a too slow return movement, sometimes accompanied by an unwanted upwards movement of the plunger likely caused by a pressure spike in the hydraulic circuit when another actuator stopped at the end of its course.
- The landing gear actuators have evolved over time into the TBM 700 production in order to improve their reliability. The last improvement called “Differential plunger” (MOD70-0334-32) is only incorporated when the actuator is sent back to the manufacturer for overhaul or repair. This improvement is not supported by any currently published approved data (Service Bulletin etc.) recommending this modification.
- Daher-Socata stated that the aeroplanes equipped with actuators modified to incorporate differential plungers show a significantly lower rate of failure.
- The landing gear control panel (LGCP) has evolved over time into the TBM 700 production in order to be able to detect some dual switch anomalies and to trigger a warning. The aircraft msn: 03 was not equipped with such a LGCP.
- Investigation determined that the installation of the last evolution of the LGCP could not 100% eliminate the likelihood of the specific event.

3.2 Causes.

The cause of the serious incident is the failure of the nose landing gear actuator to lock down combined with the landing gear control system wrongly indicating that this landing gear was properly extended and locked.

The root cause of the serious incident is an spurious triggering of the NLG actuator extend dual switch into “extend and locked”.
Investigation determined that the activation system of the dual switches has the potential to cause simultaneously a false indication (showing 3 greens and no red light) on the LGCP and stop the operation of the electro-hydraulic generator, interrupting the landing gear leg extension before reaching the locked position.

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Contributing factors:

- The mechanical improvement of the actuators involving the installation of differential plungers (MOD70-0334-32), introduced in December 2012, was not applied to the aircraft.
- The possibility to improve the safety of the landing gear system by installing the differential plungers (MOD70-0334-32) was not communicated and was not recommended to the end-users.

4 Safety actions and recommendations.

4.1 Safety issue: The existing safety improvement of the installation of actuators with differential plungers (MOD70-0334-32 part 2) is currently neither promoted nor mandated.

An anomaly to the dual switch plunger movement caused the Nose Landing Gear on msn 03 aircraft to collapse.

The investigation determined that similar safety deficiencies may happen on the TBM 700 fleet, possibly leading to a MLG or NLG failure during landing or roll-out and consequent damage to the aeroplane and injury to occupants.

EASA published EASA AD 2013-0227 to secure the actuator rod/piston assembly. The AD mandated the inspection of the TBM 700 landing gear actuators and, depending on the findings, the installation of improved actuators VSTS 083550 or VSTS 083560 (which have MOD70-0334-32 incorporated). However, installation on an aeroplane of a landing gear actuator P/N T700A3230050000 or P/N T700A323005000000 or P/N T700A323005300000 (which do not have MOD70-0334-32 incorporated) was still allowed by the EASA AD 2013-0227, provided that, following installation, the part passes the inspections as specified in paragraph (1).

MOD70-0334-32 incorporates 2 separated improvements:

- Part 1.: To secure the rod/piston assembly (subject connected to the AD).
- Part 2.: To reduce retraction/extension indication failures through improvement of switch kinematics (subject NOT connected to the AD).

Therefore, the application of the part 2 of the modification, which is very relevant for this event, will only be performed in case of findings to the rod/piston assembly during the application of EASA AD 2013-0227, or during the actuator's overhaul, causing unmodified actuators to remain in service. Moreover, the installation of serviceable unmodified actuators is allowed by EASA AD 2013-0227.

The investigation determined that it is highly probable that, had part 2 of MOD70-0334-32 been applied on msn 03, the NLG would not have collapsed. Therefore:

Recommendation BE-2017-0011 to EASA[6]:

It is recommended that EASA mandates the improvement of the switch kinematics using hydraulic pressure to help the plunger movement by the application of Part 4.2. of MOD70-0334-32 to all landing gear actuators not already modified during application of EASA AD 2013-0227. This would include the prohibition of the installation of unmodified actuators, which is currently allowed by EASA AD 2013-0227.

[6] The recommendation BE-2017-0011 was formally addressed to EASA on 15 May 2017.

4.2 Safety issue: Simultaneous false indication on the LGCP and stopping of the landing gear leg extension before reaching the locked position.

Although Daher-Socata improved the design of the plunger system several times, feed-back from operators show that problems can still occur, but less frequently.

There might be complementary alternatives to the solutions already developed by Daher-Socata to definitively avoid the occurrence of simultaneous false indication (showing 3 greens and no red light) on the LGCP and stopping of the landing gear leg extension before reaching the locked position.

Taking into account that each landing gear leg extends at a different speed and that the electro-hydraulic generator is actually controlled by the last extending landing gear leg, AAIU(Be) believes that one of such alternatives might be to have the electro-hydraulic generator remaining operating a few seconds after switching of the last dual switch, possibly using a time (delay) relay. In case of a dual switch malfunction, the electro-hydraulic generator would be operating long enough to extend and safety lock all 3 gears. This could guarantee the extension and locking of any landing gear leg even in case of one dual switch malfunction. The probability of reoccurrence of a similar serious incident could then be further reduced. Therefore:

Recommendation BE-2017-0012 to Daher-Socata:

It is recommended that Daher-Socata considers complementary alternatives to the solutions already designed, in order to further improve the safety of the landing gear operations of the TBM 700.

5 Appendices

5.1 EASA Airworthiness directives No.: 2013-0227

EASA	AIRWORTHINESS DIRECTIVE
	AD No.: 2013-0227 **Date: 23 September 2013** Note: This Airworthiness Directive (AD) is issued by EASA, acting in accordance with Regulation (EC) No 216/2008 on behalf of the European Community, its Member States and of the European third countries that participate in the activities of EASA under Article 66 of that Regulation.

This AD is issued in accordance with EU 748/2012, Part 21.A.3B. In accordance with EC 2042/2003 Annex I, Part M.A.301, the continuing airworthiness of an aircraft shall be ensured by accomplishing any applicable ADs. Consequently, no person may operate an aircraft to which an AD applies, except in accordance with the requirements of that AD, unless otherwise specified by the Agency [EC 2042/2003 Annex I, Part M.A.303] or agreed with the Authority of the State of Registry [EC 216/2008, Article 14(4) exemption].

Design Approval Holder's Name:	**Type/Model designation(s):**
SOCATA	TBM 700 aeroplanes

TCDS Number:	EASA.A.010
Foreign AD:	Not applicable
Supersedure:	None

ATA 32	**Landing Gears – Nose and Main Landing Gear Actuators – Inspection / Replacement**
Manufacturer(s):	SOCATA (formerly EADS SOCATA)
Applicability:	SOCATA TBM 700 aeroplanes, all manufacturer serial numbers.
Reason:	During maintenance check, possible unscrewing of rod and piston during operation was detected on a landing gear actuator. Investigation showed that this was likely caused by maintenance operation not conforming with the procedure described in the SOCATA maintenance manual. Moreover, following in-service landing gear collapse, uncrimping of a right hand main landing gear (MLG) actuator ball joint was detected. Investigation revealed a manufacturing non-conformity of some actuator rod end assemblies. These conditions, if not detected and corrected, could lead to MLG or nose landing gear (NLG) failure during landing or roll-out and consequent damage to the aeroplane and injury to occupants. To address this potential unsafe condition, SOCATA issued Service Bulletin (SB) 70-197-32 to require a one-time inspection of the landing gear actuator piston/rod and SB 70-206-32 to require a one-time inspection of the landing gear actuator ball joint centering and, depending on findings, accomplishment of corrective actions. SOCATA also developed modification 70-0334-32, embodied in production to secure rod/piston assembly through addition of a pin and to reduce retraction/extension indication failure through improvement of switch kinematics. These modified actuators have a new part number (P/N). For the reasons described above, this AD requires a one-time inspection of the landing gear actuators piston/rod and ball joint centering and, depending on findings, accomplishment of applicable corrective actions.

Effective Date:	07 October 2013
Required Action(s) and Compliance Time(s):	Required as indicated, unless accomplished previously: (1) Within 8 months after the effective date of this AD, for aeroplanes on which landing gear actuator P/N T700A3230050000 or P/N T700A323005000000 or P/N T700A323005300000 is installed, accomplish the following actions concurrently: (1.1) Perform a detailed visual inspection (DVI) of pistons/rods of the NLG and left hand (LH) and right hand (RH) MLG actuators and measure the distance (A) in accordance with the instructions of SOCATA SB 70-197-32. (1.2) Perform a DVI of ball joint centering of NLG and LH and RH MLG actuators and measure ball joint mismatch in accordance with the instructions of SOCATA SB 70-206-32. Note: For the purpose of this AD, distance (A) is defined in SOCATA SB 70-197-32. (2) If, during any inspection as required by paragraph (1.1) or (1.2) of this AD, any discrepancy is identified, before next flight, replace the affected actuator or rod end assembly, as applicable, with a serviceable part, as specified in Appendix 1 of this AD, in accordance with the instructions of SOCATA SB 70-197-32 or SB 70-206-32, as applicable. (3) From the effective date of this AD, installation on an aeroplane of a landing gear actuator P/N T700A3230050000 or P/N T700A323005000000 or P/N T700A323005300000 is allowed, provided that, following installation, the part passes the inspections as specified in paragraph (1) of this AD.
Ref. Publications:	SOCATA SB 70-197-32 original issue dated April 2013. SOCATA SB 70-206-32 original issue dated April 2013. The use of later approved revisions of these documents is acceptable for compliance with the requirements of this AD.
Remarks:	1. If requested and appropriately substantiated, EASA can approve Alternative Methods of Compliance for this AD. 2. This AD was posted on 01 August 2013 as PAD 13-113 for consultation until 29 August 2013. No comments were received during the consultation period. 3. Enquiries regarding this AD should be referred to the Safety Information Section, Executive Directorate, EASA. E-mail: ADs@easa.europa.eu. 4. For any question concerning the technical content of the requirements in this AD, please contact: SOCATA, Direction des services, 65921 Tarbes Cedex 9, France. Tel. +33 (0) 5 62 41 73 00, Fax : + 33 (0) 5 62 41 76 54. or for the U.S.A SOCATA NORTH AMERICA, North Perry Airport, 7501 South Airport Road, Pembroke Pines, Florida 33023, The United States of America. Tel.: +1 (954) 893 1400 Fax: +1 (954) 964 4141.

Appendix 1 – Corrective Actions

		Ball joint mismatch In accordance with SB 70-206-32	
		Equal or less than 0.3 mm (0.012 in)	Greater than 0.3 mm (0.012 in)
Distance (A) In accordance with SB 70-197-32	Less than 6 mm (0.236 in) if jam nut is 6 mm (0.236 in) thick, or less than 4 mm (0.157 in) if jam nut is 8 mm (0.315 in) thick	Replace the affected actuator with a serviceable part in accordance with the instructions of SOCATA SB 70-197-32.	Replace the affected actuator with a serviceable part in accordance with the instructions of SOCATA SB 70-197-32.
	Equal or greater than 6 mm (0.236 in) if jam nut is 6 mm (0.236 in) thick, or equal or greater than 4 mm (0.157 in) if jam nut is 8 mm (0.315 in) thick	No action required.	Replace the affected rod end assembly with a serviceable part in accordance with the instructions of SOCATA SB 70-206-32.

5.2 Actuator improvements regarding the working of the dual contactors[7].

Mod. Data Sheet N°	Retrofitting means	Actuator AMDT N° after modification	Subject	Objective of the improvement
OPT 70 K052-32	SB70-070-32 (12/1995)	H	Landing gear actuator plunger jamming causing false ldg gear position indication	To improve the return stroke of the plunger
MOD 70-0201-32 (Edition 1 : 04/2007 to Edition 4 : 02/2008	CMM 32-32-02 R 3 (12/2007) and subsq	M	Dual limit switch support water contaminant tightness	To reduce dual contactors malfunctions
FEE HL003	SB70-166-32	N (Actuator installed in the aircraft)	Improvement of the tightness of dual limit switch holder by adding two O rings in the centring washer	Due to water infiltration, corrosion traces have been detected on elements of actuator indicating mechanism
MOD 70-0334-32 Orig. 12/2012 Ed.2: 03/2013	CMM 32-32-02 R 5 (09/2012) and subsq.	?	Differential plunger installation (Upgrade kit “D” as per table 604 from CMM 32-32-02	To improve the return stroke of the plunger. Differential surface of the plunger, submitted to hydraulic pressure, generates an additional return force.

[7] When a modification data sheets covers few different improvements, only the improvement related to the working of the dual contactors is mentionned.

5.3 Landing Gear Control Panel (LGCP) history of modifications

Mod. Data Sheet or Option N°	Retrofitting means	LGCP - Boîtier A14 reference after compliance of the modification	Subject	Objective of the improvement
Initial installation (year 1988) LGCP - Boîtier A14 PN: T700A3260005000				
MOD 70-065-32	BS70-073-32 R1 + CN 96-037(B) R1	T700A3260005004 (Installed in the aeroplane since 14/05/97)	Removal of mlg inboard doors	To avoid mlg extension problems caused by non-unlocking of inboard doors
MOD 70-021-32 Electrical system mod OPT70-57-001	BS70-076-32 (April 1996) And SL70-050-32 (Dec 2008)	Unknown	Aerodynamical noise since the mlg inboard doors are removed (Appl. on A/C SN 1 => 121 that are modified iaw BS70-073-32)	Reduce the aerodynamic noise.
MOD 70-156-32	BS70-116-32 (January 2004)	LGCP 07-07 AmdtD	LGCP modification (A/C SN 107 =>288, except few serial numbers)	Reduce red light detection
MOD 70-341-32	Service information 2014-007 (September 2014)	A14 New LGCP 14-01 Currently installed in new TBM 900 A/C SN: 687 and 1000 => 9999	Red warning light of the LGCP going unexpectedly ON	To filter accurately the erratic warnings that should significantly reduce the occurrence of the steady red light during the gear transition
MOD 70-350-32 (Dec. 2012) OPT70K133-33	?	A14 - Variant LGCP94-11 and LGCP07-07	Applicable to A/C SN: 621 => 628 Post MOD 70-0333-33 DS1, DS2 - Navigation, position and anti-collision LED lights with shielded wiring	To set LGCP 07-07 as a variant unit for TBM equipped with LGCP94-11

/	SL 70-050 (December 2008)	/	Landing gear procedures	To sensitize the operators to properly apply the Flight manual procedure in case of any anomaly on the LGCP warning and/or indication lights


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AAIU-2015-16

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