NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

March 18, 2016

Systems Group Chairman's Factual Report

WPR-15-IA-046

A. INCIDENT

Operator:	Hawkeye Aviation Holdings Ltd
Location:	Palm Springs International Airport (PSP), Palm Springs, California
Date:	November 23, 2014
Time:	1052 pacific standard time
Vehicle:	Embraer EMB-505, C-GJOL

B. GROUP

Group Chairman: Scott Warren
National Transportation Safety Board
Washington, D.C.

C. SUMMARY

On November 23, 2014, about 1052 Pacific standard time, an Embraer EMB-505 airplane, C-GJOL, experienced an uncommanded severe yaw to the right immediately after takeoff from the Palm Springs International Airport (PSP), Palm Springs, California. Neither the airline transport pilot nor the 4 passengers on board were injured. The airplane, which was owned by a private individual, was operated by Hawkeye Aviation Holdings Ltd, Kelowna, British Columbia. Visual meteorological conditions prevailed for the planned cross-country flight, which was being operated in accordance with 14 Code of Federal Regulations Part 91. An instrument flight rules flight plan was in effect at the time of the event, with Springbank, British Columbia, the reported destination.

The systems group chairman reviewed the rudder gust lock testing, teardown and examination reports.

D. DETAILS OF THE INVESTIGATION

1.0 Rudder gust lock system description

The EMB-505 flight controls have a control lock system installed which is designed to prevent damage to the control column and flight control systems caused by wind gusts. There are two parts of the control lock system, namely the elevator and aileron control lock and the rudder control lock.

General Description
The aileron, rudder and elevator control systems are locked by means of the installation of the gust lock safety pin in the pilot control yoke assembly.

The rudder gust lock actuator is installed in the aircraft rear fuselage, at frame 46.

The function of the rudder gust lock is to prevent rudder surface movement due to ground gusts by locking the rudder control system at the rear fuselage torque tube.

In order to preclude in-flight uncommanded locking, system has the following interlocks:

- TLA (Thrust Lever Angle)
- WOW (Weight-on-Wheels)

No scheduled maintenance is required over the rudder gust lock actuator life.

Components

The gust lock system comprises the following elements:

- Aileron/rudder/elevator gust lock cockpit assembly;
- Gust lock safety pin;
- Rudder gust lock mechanism;
- Gust lock quadrant.

The rudder gust lock mechanism has the following elements:

- Gust lock actuator;
- Command spring;
- Bellcrank;
- Control box with connector.

The bellcrank, pivoted by the action of the actuator, locks one of the grooves on the gust lock quadrant, which is connected to the rudder rear torque tube, therefore preventing the movement of the rudder surface in case of gust (see figure 1).

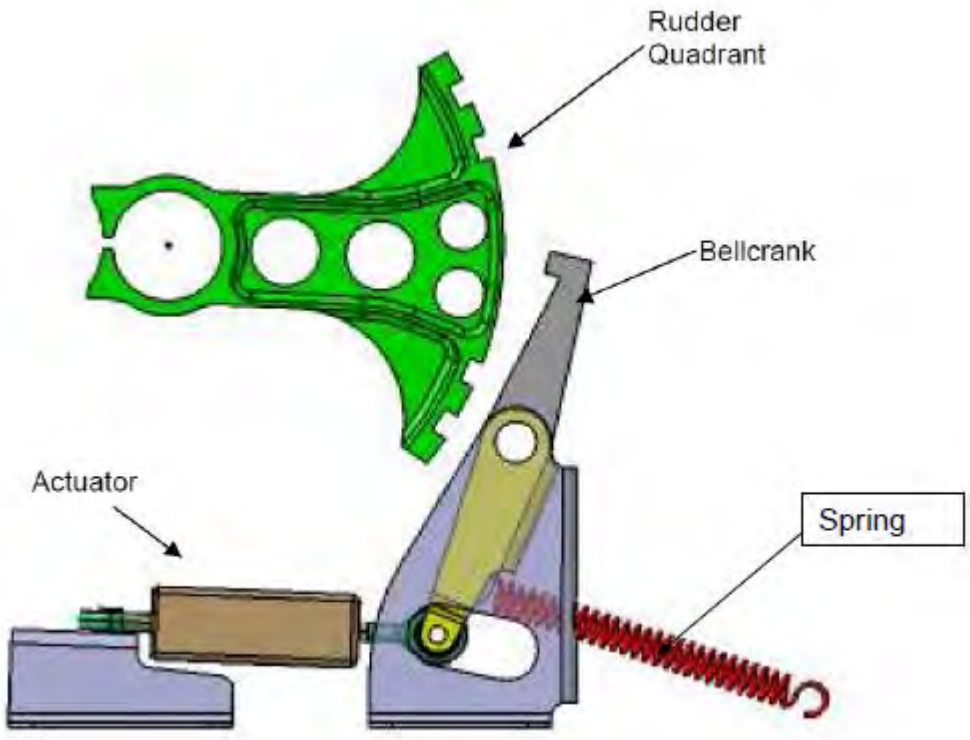


Figure 1
Rudder gust lock actuator components

Operation

The aileron control system and the elevator control system are mechanically locked by means of the installation of the gust lock pin in the pilot's control yoke assembly. The rudder control system gust lock mechanism is actuated through an electromechanical actuator.

When the gust lock safety pin is inserted into the pilot control wheel to lock the aileron and elevator control system, two switches are activated, providing automatic engagement of the rudder gust lock system.

When the aileron and elevator control systems are unlocked by the removal of the gust pin, the rudder gust lock system is designed to be automatically disengaged. As designed, the rudder gust lock system in a locked position is evident to the pilots because of the following conditions:

- Gust lock pin is inserted in its hole.
- Both pedals are locked in a deflected position.
- Aircraft cannot taxi with rudder surface locked.

1.1 Rudder gust lock actuator examination – Umbra Cusinetti

The rudder gust lock actuator was examined by the manufacturer, Umbra Cusinetti, in the presence of ASNV representatives on June 16, 2015. An additional examination of the electronic circuit board within the actuator was conducted on October 14, 2015. The results of both of these examinations are presented in appendix A[1].

1.2 Rudder gust lock actuator position determination – Embraer

The rudder gust lock actuator dimensional information gathered during the Umbra Cusinetti examination was evaluated by Embraer. Embraer determined that with the screwshaft in the "as found" position, the bellcrank would be in contact with the rudder quadrant. It could also engage in the slots on the rudder quadrant (see figures 2, 3, and 4).

[1] The Umbra Cusinetti report contains analysis and comments that should not be confused with an official NTSB analysis. Any analytical statements contained in the Umbra Cusinetti report represent only the opinion of that organization.

Figure 2
Mechanism condition as found based on actuator stroke (6.8mm shorter than full stroke)

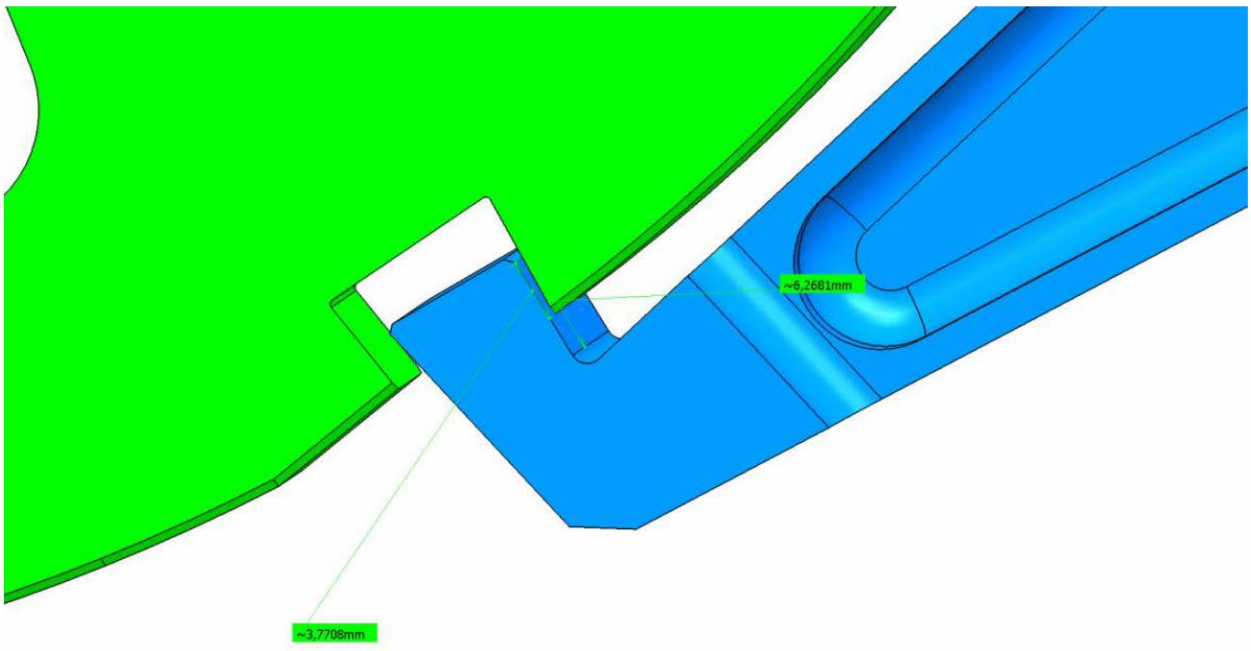


Figure 3
Inner side – Locking finger engagement (3.77 mm out of 6.26 mm total)

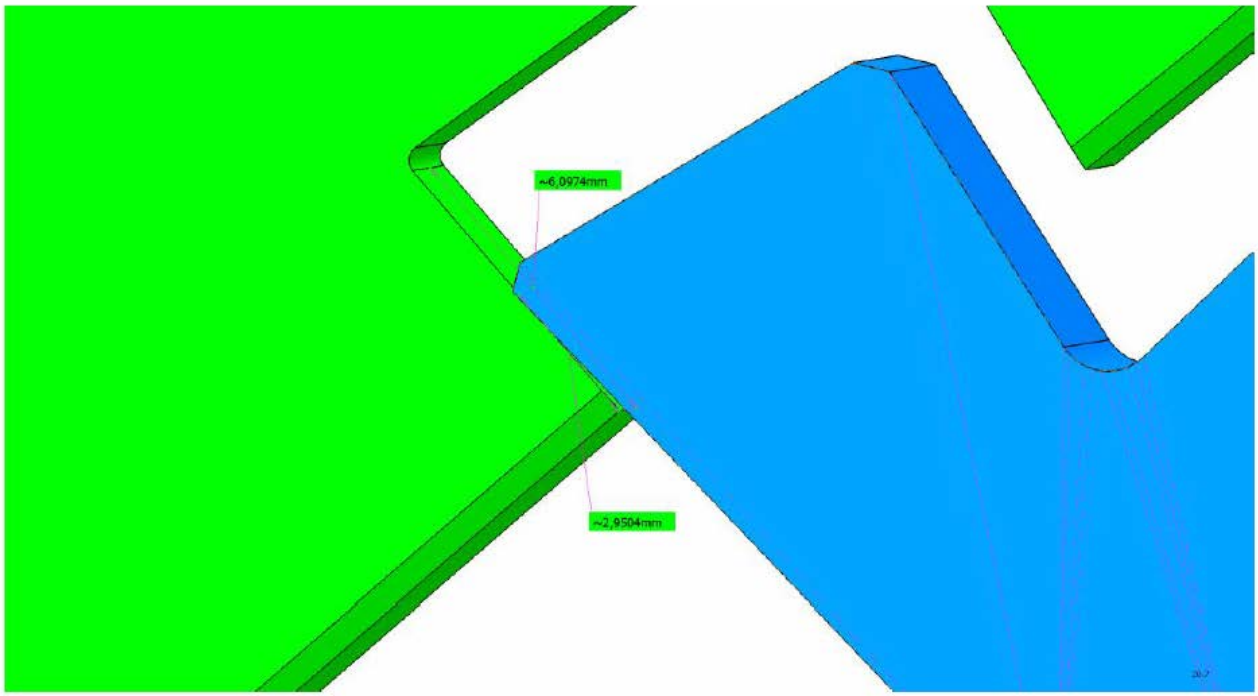


Figure 4
Opposite side - Locking finger engagement (2.95 mm out of 6.09 mm total)

1.3 Rudder gust lock actuator irreversibility, spring forces, and component replacement

According to Embraer, the irreversibility of the gust lock actuator is provided by a plunger that is commanded by a solenoid. In normal operation, the spring is not able to overpower the actuator, since the plunger provides an irreversibility function. The listing below summarizes the forces required to overpower the actuator motor assuming the solenoid fails in the energized position which prevents the plunger actuation (resulting in a loss of irreversibility), and the forces provided by spring:

- The force required to overpower the energized motor to extend the actuator is approximately 130N;

- The force required to overpower the de-energized motor to extend the actuator is approximately 40N;

- The spring force is at a maximum when the actuator is in the retracted position and the spring is in its maximum extended position (on the order of 40N), and it decreases linearly to its minimum when the actuator is in the extended position (~3N). Considering an actuator stroke of 22.4mm, as observed in this event, the spring force would be in the order of 7N.

Embraer also stated that, “90% of Phenom 300 fleet has incorporated a new gust lock actuator, which is same PN from ERJ-145 family, with successful operation history and simplified architecture – irreversible jack screw actuation, which does not require solenoid/plunger. Embraer is also about to release an Avionics software update which includes a CAS message that alerts the crew when gust lock actuator is not completely retracted.”

Scott A. Warren
Lead Aerospace Engineer

Appendix A

Umbra Cusinetti Failure Analysis Report
Dated: 11 November 2015
(Personal identifying items redacted)

Customer P/N (Assy): -	**Umbra P/N (Assy): 09762P000-03**
Nomenclature: Gust Lock Actuator	**Serial Number: 00075** (see photo 1)

WORK TO BE CARRY OUT:
Inspection required following an Accident/Incident Notification from NTSB (Figure 1).

Inspection Attendees

ANSV	EMBRAER	UMBRA
Alessandro Cometa	Victor Bellei P. Soares	Marco Nardeschi
Vittorio Borsi	Luis Savio dos Santos	Paolo Nasoni
		Federico Perni

Inspection Procedure

The inspection took place on June 16th 2015 at Umbra Cuscinetti in Foligno (Italy) and has adhered to the agreed agenda. See Attachment 1.

Actuator History

Actuator S/N 00075 was delivered by Umbra to Embraer on February 28th 2011.
The Actuator S/N 00075 failed during tests in ACFT S/N 00052 at Embraer assembly line in May 19th of 2011.
The non conformity reported by Embraer quality department was *"Rudder gust lock actuator inoperative"*.
See figure 2 and 3.
The Actuator was returned to Umbra on 15/07/2011 by Embraer.
The Actuator was repaired: both the microswitches were replaced, and delivered to Embraer on November 28th 2011.
Then, the Actuator returned to Embraer stock and was assembled in the ACFT S/N 00089 (C-GJOL).

Even if not specified in Embraer documentation it seems that a microswitch was not working properly at the assembly line; in Umbra documentation there is not any comment concerning the failure confirmation but both microswitches were replaced.

It seems that the Actuator, before being removed from the A/C at the presence of the Embraer area representative at Palm Spring International airport (PSP), was confirmed to have failed in locked position (i.e. extended) and was very hot. Before the removal, it seems the technicians there tried to operate the Actuator.

DIMENSIONAL CHECKS / VISUAL INSPECTION

Check of pin to pin distance

Scope

To verify if the Actuator is at its end stroke position or locked in an intermediate one.

Check

The Actuator has been installed in the test rig (see photo 2 and 3), which is tuned at the correct pin-to-pin distance, and it was not possible to insert the Pin 2 because the Actuator length is shorter than required. Measurements of the rod end in respect of the Actuator body confirm the pin-to-pin distance is shorter in respect of the full-extended position (i.e. 6.8 mm shorter, 29.2 vs. 22.4 mm, new and 00075 unit respectively). The minimum stroke is 25.4 mm. See photos 4, 5, 6 and 7.

Result

The Actuator is locked in a position closed to the extended one.

DISASSEMBLY

Disassembly

Scope

To identify the cause of Actuator seizure.

Check

The Actuator was coupled to the test rig supply and management system and when operated did not move even if the max current at rated voltage was supplied.

The Actuator cover (see photo 8) was removed and then the solenoid/locking system. The electronic board was moved on side but kept connected. The cam, which actuates the microswitch, is closed to the microswitch actuating lever but does not operate it. See photo 9.

The solenoid was not disassembled. The solenoid/locking system is found locked at extended position or close by (i.e. the locking system engages the ballnut/screwshaft preventing the rod end to move). See photo 10 and a sketch of the solenoid section, figure 4. The reel function is to guide the Pin that, pushed by the solenoid spring, engages the ballnut and locks the screwshaft/rod in position. The Pin resulted to be sized inside the solenoid body, likely due to distortion of the plastic reel heated. The Pin position was closed to the full extension. Measurement of the exact position was prevented by pin misalignment due to distortion of the solenoid plastic reel. The functionality of the microswitches was checked with positive result. Even if with the solenoid/locking system removed the Actuator did not move electrically, even if the max. current at rate voltage was supplied, and manually as well (the load applied was not measured but a new unit would have moved under such load).

The cap was then removed and the ballscrew was moving freely. See photos 11, 12 and 13 and a section of the actuator section, figure 5. The Cap is the seat of a bearing, preloads the bearing, is the seat of the dynamic seal and closes the actuator body. The Cap did not show any sign of interference with closed items.

The resistance of the three windings have been found between 4.3 and 7.3 ohm, it means that the windings are not short because such figures are acceptable for a new motor. The motor brushes were not checked.

The rotor OD shows signs of possible interference with the stator. See photo 14. The part measurements in three axial positions revealed that the gap between rotor and stator is per drawing (i.e. about 1 mm); if any contact between the two parts occurred that happened when the motor was hot. Such signs, which are not measurable, could have been even caused during handling of the rotor.

The bearings were found operative with no axial play.

Result

The Solenoid/locking system was found sized at approximately the full extended position.

ACCIDENT/INCIDENT NOTIFICATION

FROM:
National Transportation Safety Board
[redacted]
Federal Way, Washington 98003
Attn: Thomas M. Little, Acting WPR Phone Duty Officer, [redacted]

TO:
Air Accidents Investigation Branch
NAME: Investigator on Call
ADDRESS:
Agenzia Nazionale per la Sicurezza del Volo (ANSV)
[redacted]
Telephone: [redacted]
Fax: [redacted] Email: [redacted]

a) Identifying abbreviation ACCID/INCID:	INCID
b) Type, model, nationality and registration marks of the aircraft:	Embraer-505 Phenom
c) Name of owner, operator and hirer if any of the aircraft:	Owner: Hawkeye Aviation
d) Name of pilot-in-command:	Gregory G. McQuaid
e) Date and time (UTC) of the accident:	11.23.14 1052 PST
f) Last point of departure and point of intended landing of the aircraft:	Palm Spring Intl (PSP), Palm Springs, CA to Springbank, Alberta Canada (CYBW
g) Position of the aircraft with reference to an easily defined geographical point and latitude and longitude:	N 33 deg 49.78 min W 116 deg 30.40 min elev: 477 ft msl
h) Number of crew and passengers aboard, killed and serious injured; others killed and serious injured:	1 pilot and 4 passenger; no injuries.
i) Nature of the accident and the extent of damage to the aircraft so far as it is known:	Pilot reported an uncommanded, severe right yaw immediately after takeoff. Requested return to airport. On final approach had to use differential thrush to keep airplane aligned with runway. Subsequent to landing the airplane went off the side of ruwway. Minor damage only to left wing.
j) an indication to what extent the investigation will be conducted or is proposed to be delegated by the State of Occurrence:	Limited investigation
k) Physical characteristics of the accident area:	Flat terrain on airport.
l) Identification of the originating authority and means to contact the investigator-in-charge and the accident investigation authority of the State of Occurrence at any time:	NTSB IIC- Thomas M. Little [redacted]
m) Presence and description of dangerous goods on board aircraft.	None
n) Remarks:	Further examination of gust lock actuator required.

In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the Government of United States welcomes the participation of States with an interest in the investigation and representation from the

Figure 1

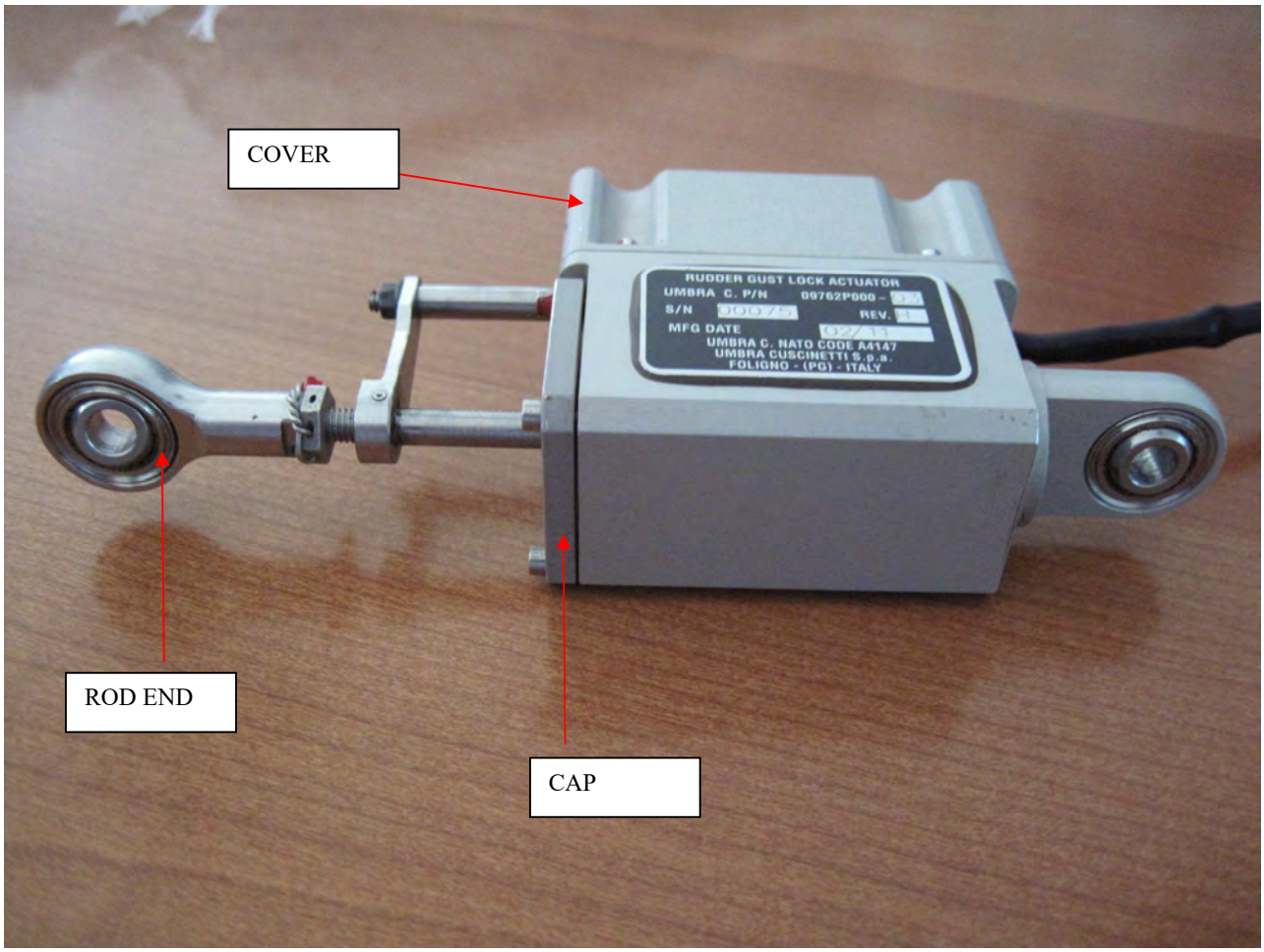

COVER
ROD END
CAP
RUDDER GUST LOCK ACTUATOR
UMBRA C. P/N 09762P000
S/N
REV.
MFG DATE
UMBRA C. NATO CODE A4147
UMBRA CUSCINETTI S.p.A.
FOLIGNO - (PG) - ITALY

Photo 1

Análise de Não Conformidade
Non Conformity Analysis (Page 1/2)

EMBRAER

Ordem / Order: 36114699
Nº de série do avião / Aircraft Serial Number: 0505 20052
CT Atual / Current Work Center: 11000
CT de Origem / Origin Work Center: 801290
Assunto / Subject: RUDDER GUST LOCK ACTUATOR
Descrição da não conformidade / Non Conformity descripition:

1 - (Informação do Produto não-conforme – Nome, PN, NS, Qtde) / (Information of the Product non conformity – Name, PN, SN, Qty)

RUDDER GUST LOCK ACTUATOR, P/N 09762 P000-03 / SN: 00075

2 - (Localização da não-conformidade)/ (Location of the non conformity)

N/A

3 – (Especificação de Projeto) / (Project specification)

N/A

4 – (Detalhamento da não-conformidade) / (Detail of the Non conformity) RUDDER GUST LOCK ACTUATOR, INOPERATIVE

OBS: SEND TO SUPPLIER AS PP2007B9859

Log Card e/ou Log Book: ☐ Sim / Yes ☐ Não / No

Análise preliminar executada por / Preliminary analysis performed by:
Qualidade (Quality): JOÃO [redacted]
Logística (Logistic) / Suprimentos (Supplies): N/A
Produção (Manufacturing): Carlos Rodrigo [redacted]
Engenharia EMBRAER (EMBRAER Engineering): N/A
Engenharia de Produção EMBRAER (EMBRAER Manufacturing Engineering): DANILO [redacted]
Engenharia do Fornecedor ou Qualidade de Fornecedor (Supplier Engineering or Supplier Quality): Eduardo [redacted]

Emissor / Author: JOÃO
Ramal / Extension: [redacted]
Área / Area: GQX-QXM02
Data / Date: 19/MAIO/2011

Engenharia do Fornecedor ou Qualidade de Fornecedor / Supplier Engineering or Supplier Quality:
Disposição / Disposition:

Send back to supplier. [redacted]

Supplier contacted: ---------- (AM / PM) Returned: ---------- (AM / PM)

☐ Sucata / Scrap ☑ Devolução / Devolution ☐ Reparo Interno / Internal Repair ☐ Retrabalho Interno / Internal Rework

Responsável / Responsible: [redacted]
Chapa / Register Embraer:
Ramal / Extension:
Data / Date: 19/MAI/2011
Área/Area: [redacted]
Assinatura/ Sig[redacted]

Figure 2

Análise de Não Conformidade
Non Conformity Analysis (Page 2/2)

EMBRAER

Ordem / Order: 36114699

Engenharia EMBRAER / EMBRAER Engineering:
Disposição / Disposition:

send item to supplier for rework [redacted]

☐ Sucata / Scrap ☑ Devolução / Devolution ☐ Aceito no estado / Use as is ☐ Reparo Interno / Internal Repair ☐ Retrabalho Interno / Internal Rework

Análise Complementar / Complemental Analysis

Modificação no Projeto de Tipo / Type Design Change :	☐ Sim / Yes ☑ Não / No
Catálogo de Peças (IPC) / Illustred Parts Catalog :	☐ Sim / Yes ☑ Não / No
Manuais de Manutenção / Maintenance Manuals:	☐ Sim / Yes ☑ Não / No
Peça Intercambiável Contratual / Contractual Interchangeable Part:	☐ Sim / Yes ☑ Não / No
Ensaios Afetados / Test Campaign Affected:	☐ Sim / Yes ☑ Não / No

Restrição de Uso / Usage Restriction: NO

Responsável / Responsible: DAVID Antonio WCK
Chapa / Register Embraer: [redacted]
Ramal / Extension: [redacted]

Data / Date: 19/MAI/15
Área/Area: GG2/MPS
Assinatura/ Signature: [redacted]

Qualidade / Quality:
Validação / Agreement: N/A

Informative Report: ☐ Sim / Yes ☐ Não / No

Responsável / Responsible:
Chapa / Register Embraer: N/A
Ramal / Extension:

Data / Date:
Área/Area:
Assinatura/ Signature: N/A

Figure 3

Photo 2 Gust Lock Test Rig
(a new Actuator is installed)

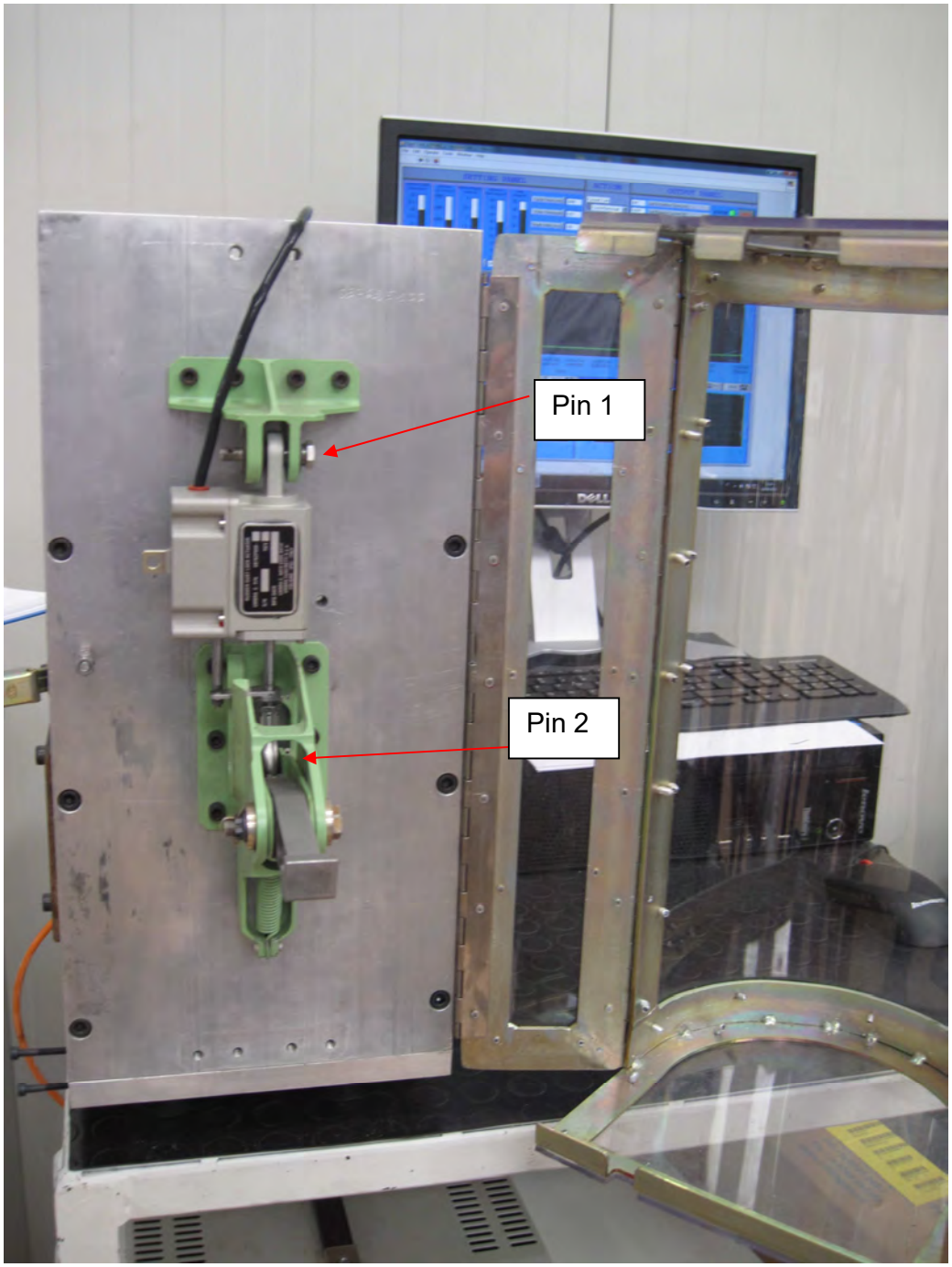


Photo 3 Gust Lock installed into the test rig
(a new actuator is installed)

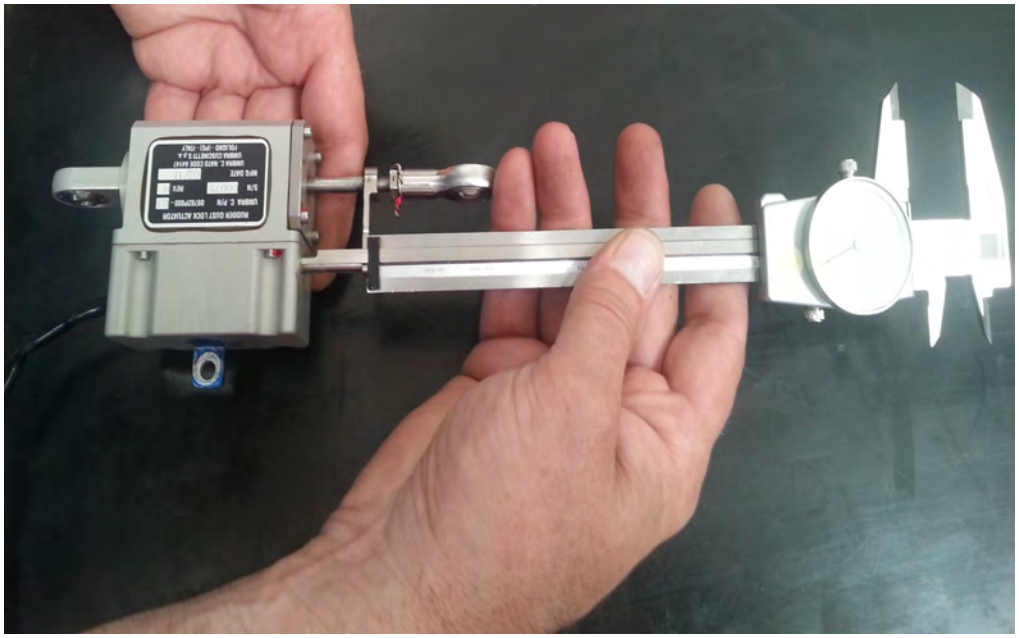


Photo 4 – S/N 00075

Photo 5 – S/N 00075

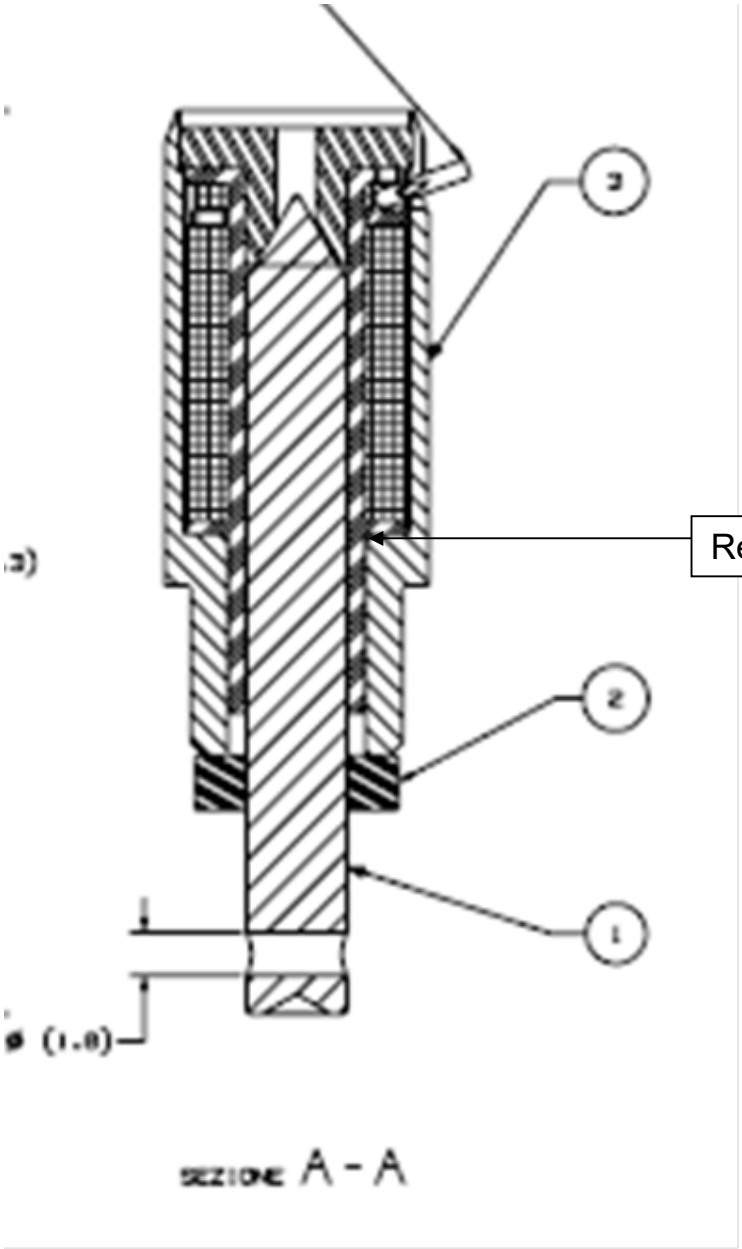


Figure 4

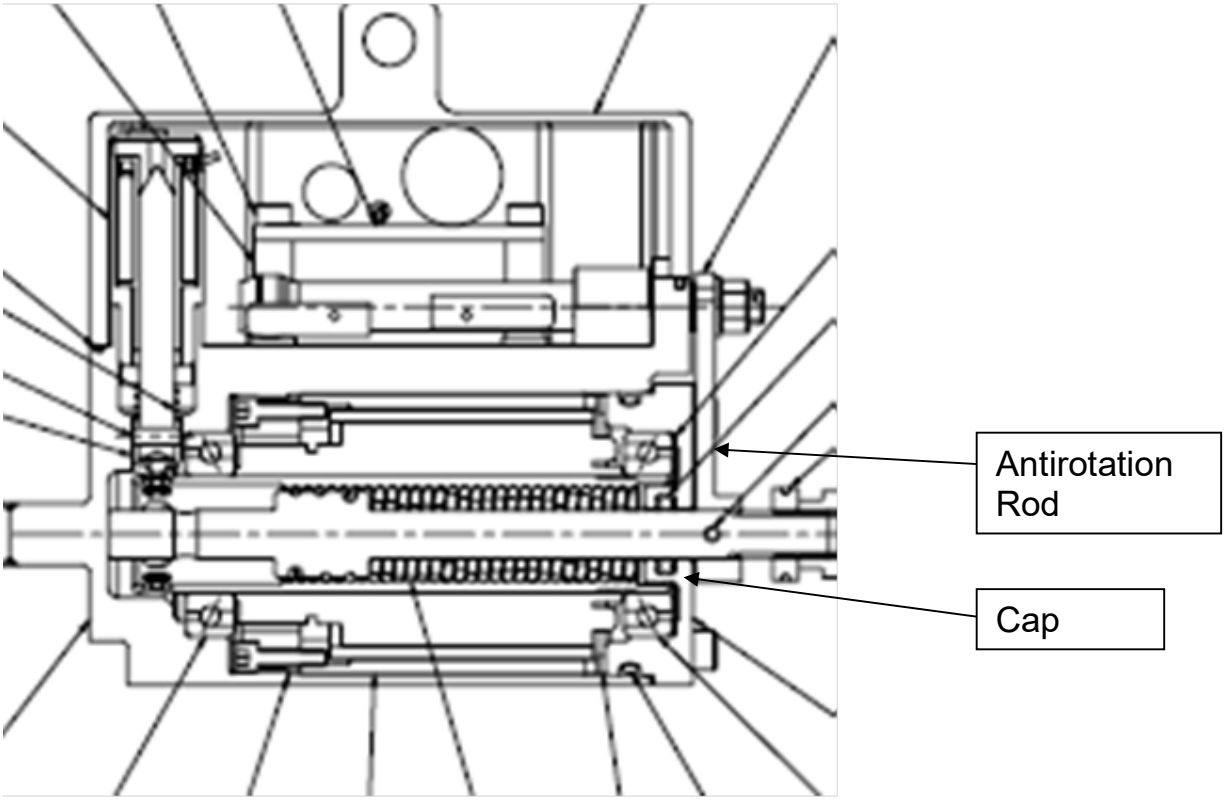


Figure 5

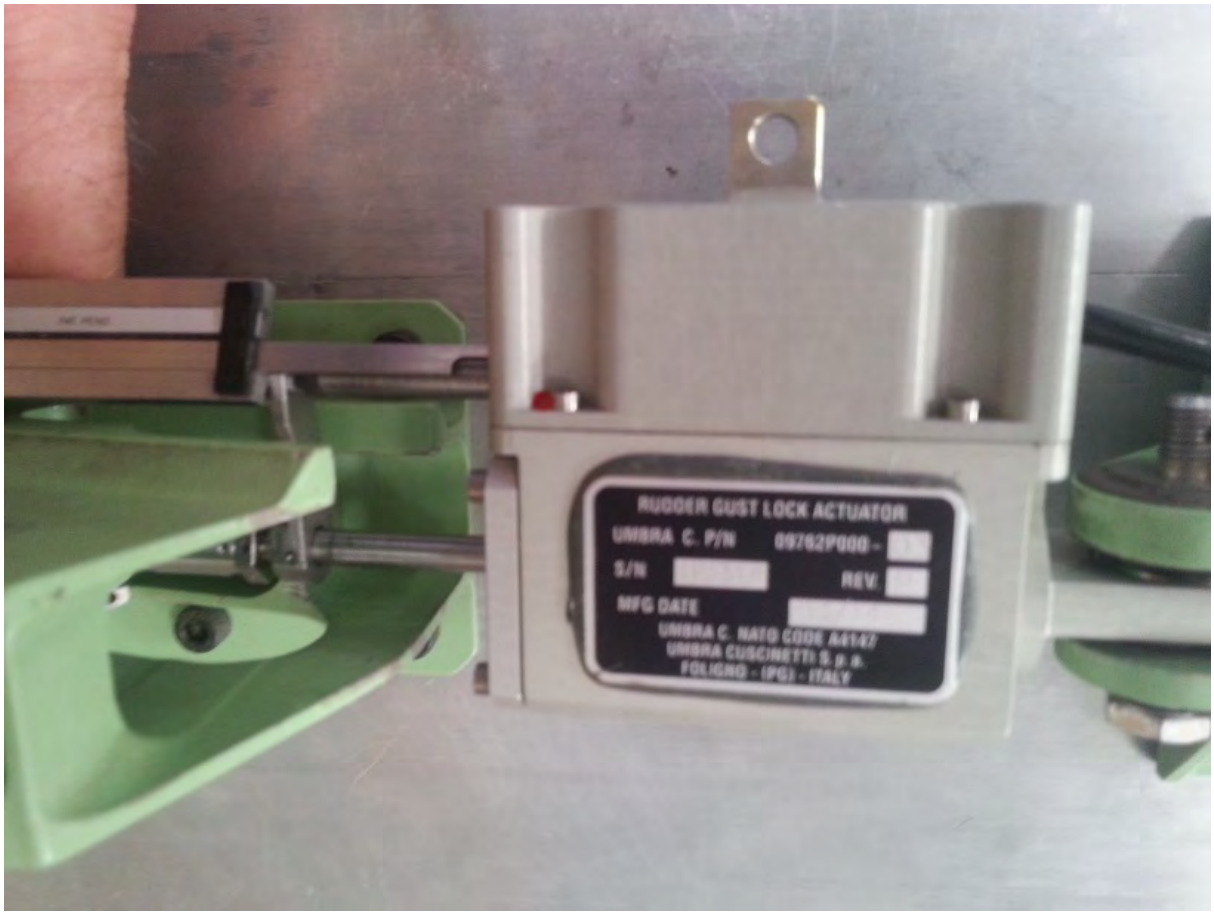


Photo 6 – New Unit

Photo 7 – New Unit

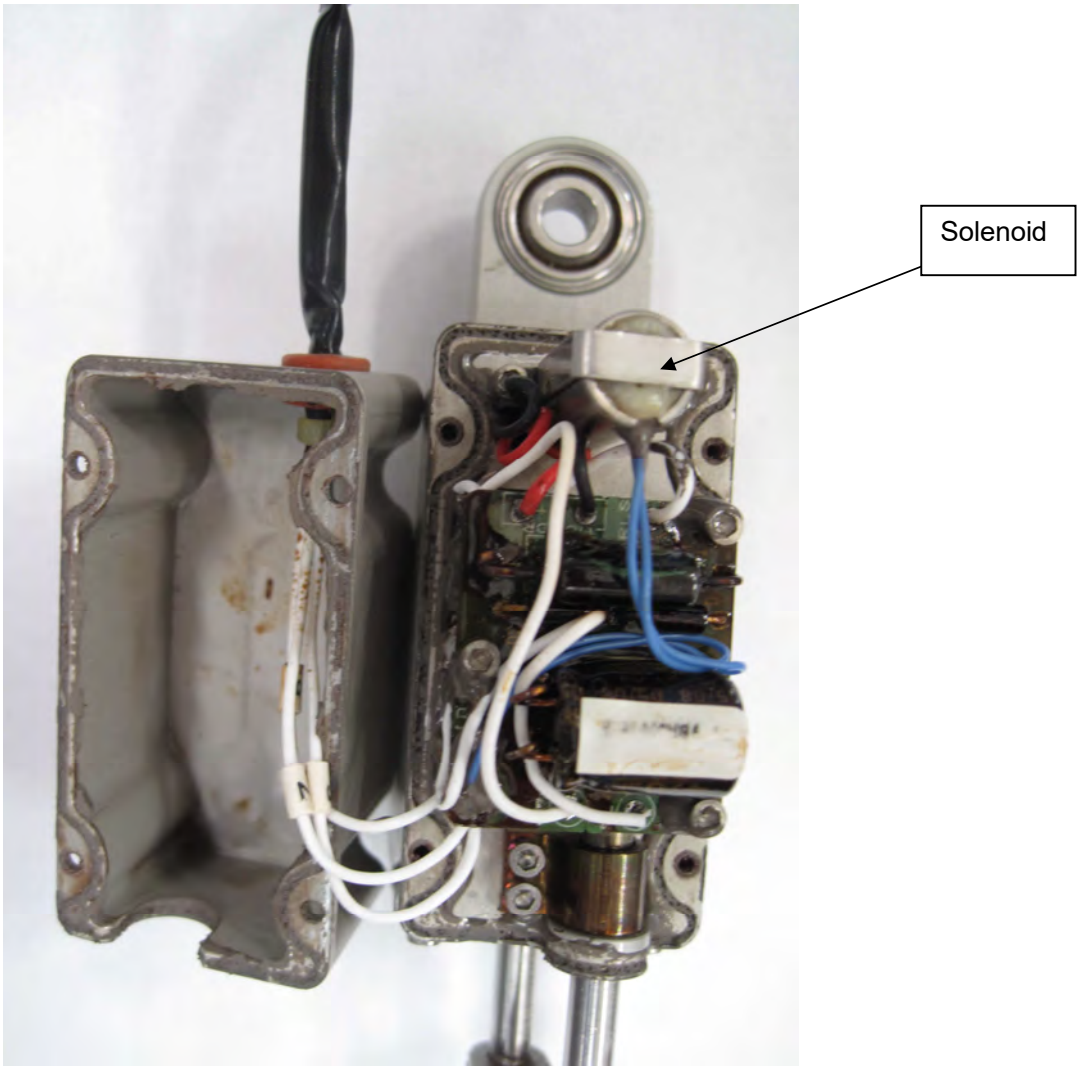


Photo 8

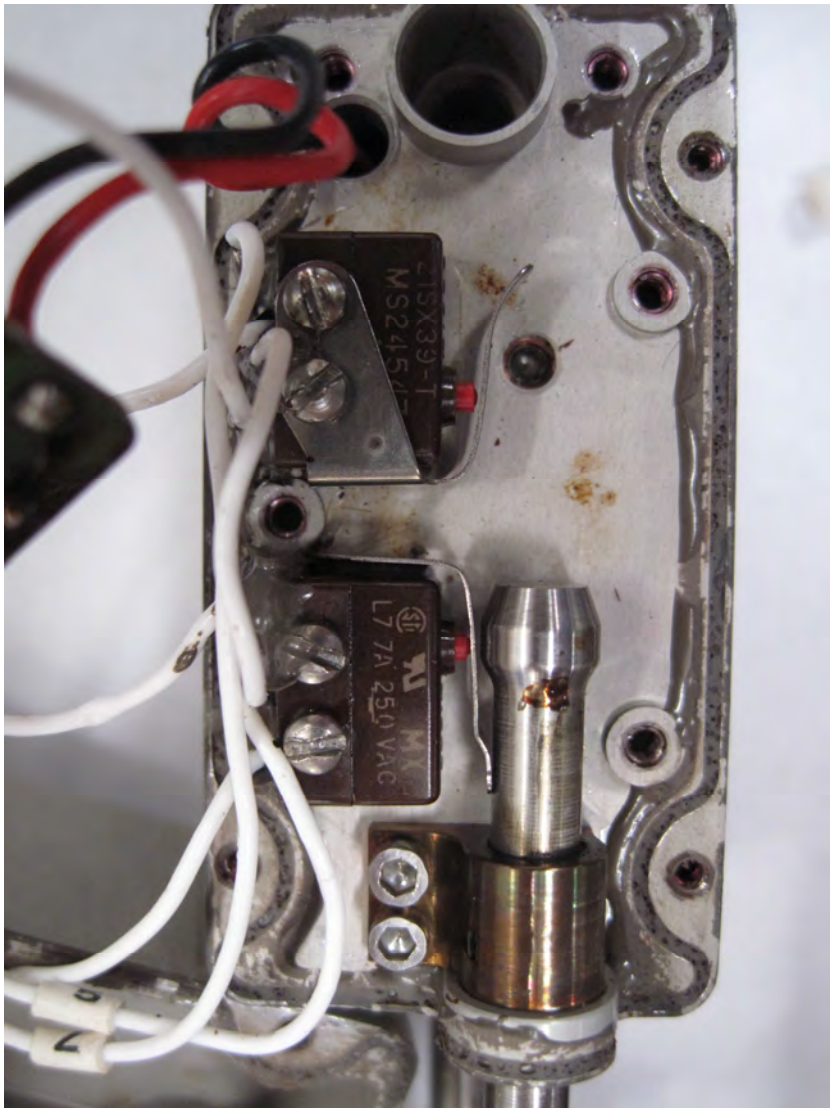


Photo 9

Photo 10

Photo 11

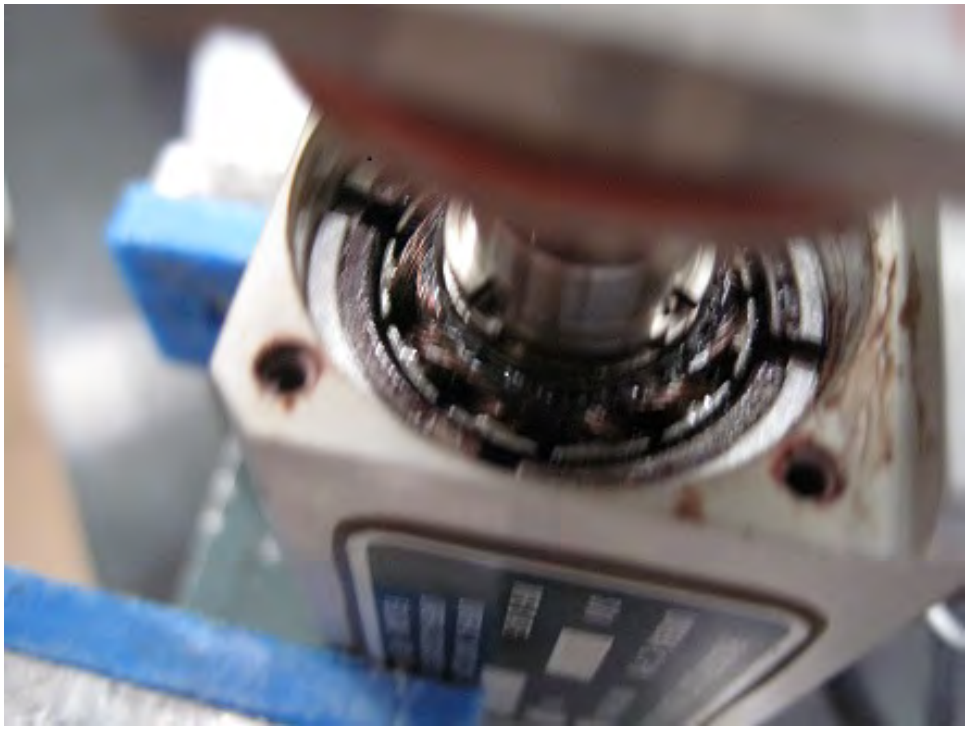


Photo 12

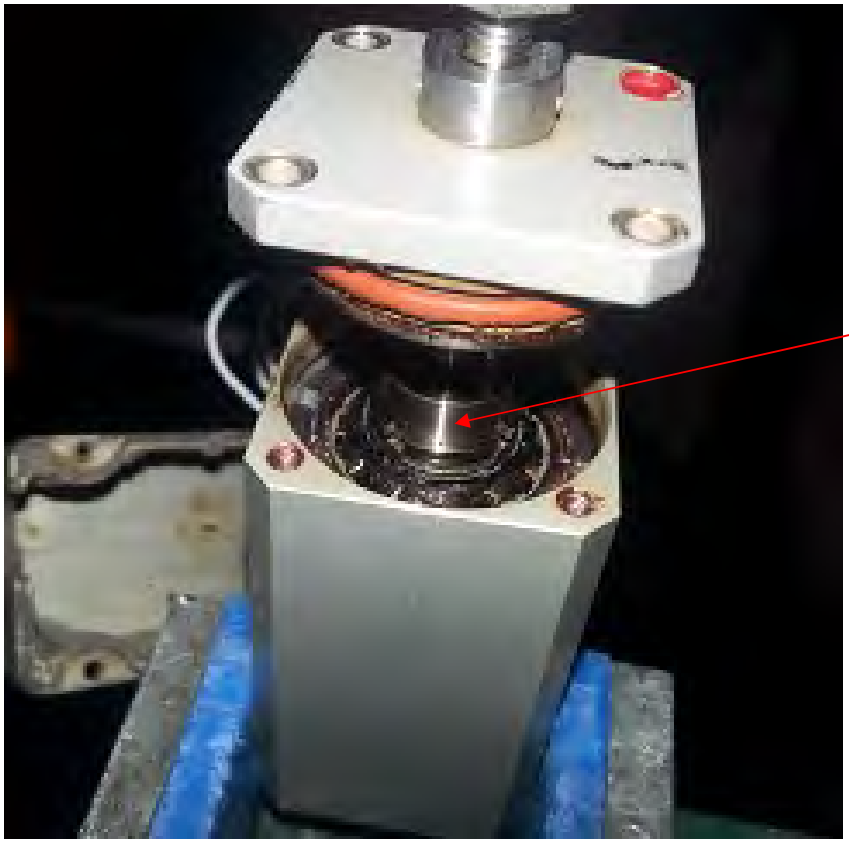


Photo 13

Photo 14

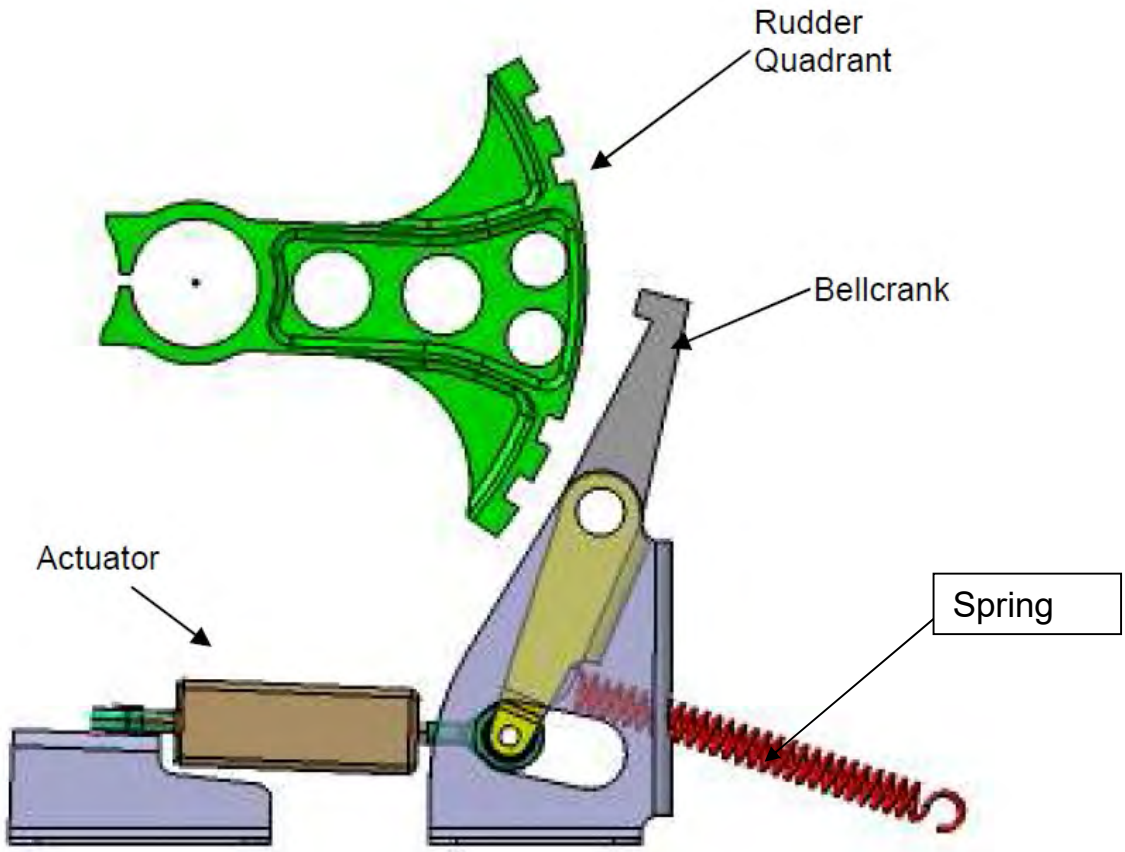


Figure 6

WORK TO BE CARRY OUT:

Inspection of the electronic board 09762P019-70 (see photo 15)

Inspection Attendees

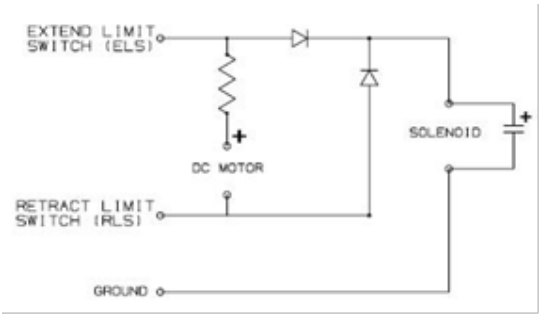
ANSV	EMBRAER	UMBRA
Vittorio Borsi	-	Marco Nardeschi
Mikael Amura		

Inspection

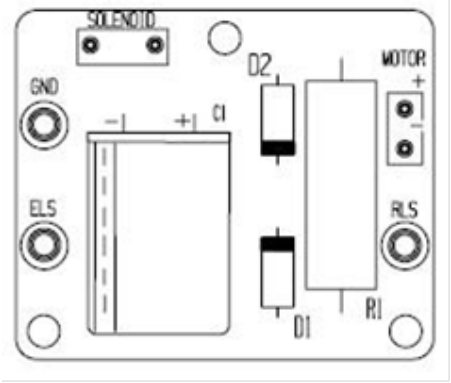
The inspection took place on October 14th 2015 at Umbra Cuscinetti in Foligno (Italy).

VISUAL INSPECTION

The schematic of the electronic board is shown below



The mounting scheme of the electronic board is shown below.



No evidence of mechanical failure on components and PCB. Surface coatings has been found damaged.

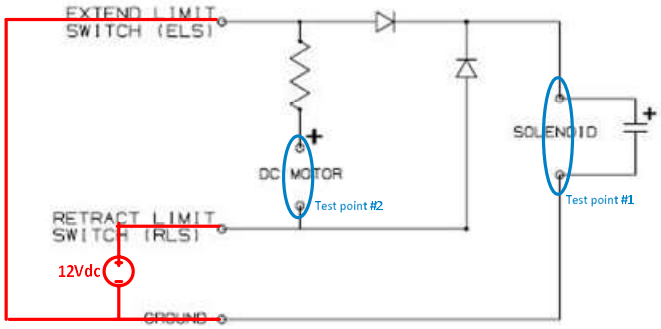
Power Off Test

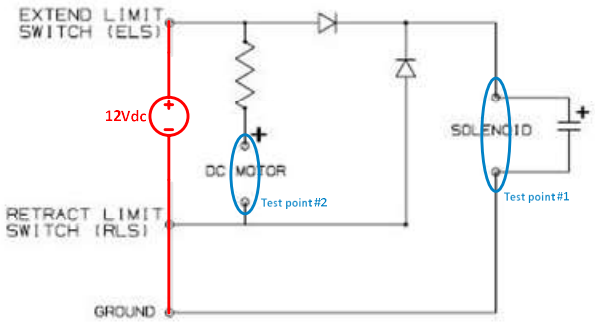
With the board powered off, the status of the components was:

Components	Type of test	Nominal value	Measured value	Test results
Resistor R1	Impedance	0.5 Ω	0.53Ω	Passed
Diode D1	Continuity test	-	-	Passed
Diode D2	Continuity test			Passed
Capacitor C1	Short/Open circuit test	Open circuit	Open Circuit	Passed
Solenoid 09762P037-01	Impedance	55Ω ± 20%	50KΩ	Failed

Power On Test

The test was performed according the test set-up below. See Photo 16.





To verify the health of PCB and component when the board was powered, the following tests was executed:

Test #	Type of test	Test Condition	Expected results	Test results
Test #1	To retract configuration test	ELS → +12Vdc RLS → 0Vdc GND → 0Vdc	Voltage of 12Vdc at: • Solenoid terminals • Motor terminals	Passed
Test #2	To extend configuration test	ELS → 0Vdc RLS → +12Vdc GND → 0Vdc	Voltage of 12Vdc at: • Solenoid terminals • Motor terminals	Passed

–

Electronic board inspection results
The electronic board 09762P019-70 works as expected. No evidence of damage or failure has been noted. The solenoid 09762P037-01 has been found with a high impedance at the coil terminal.

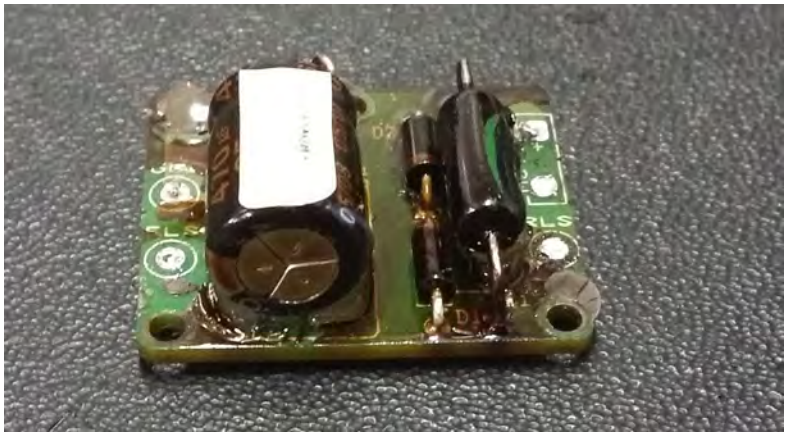


Photo 15

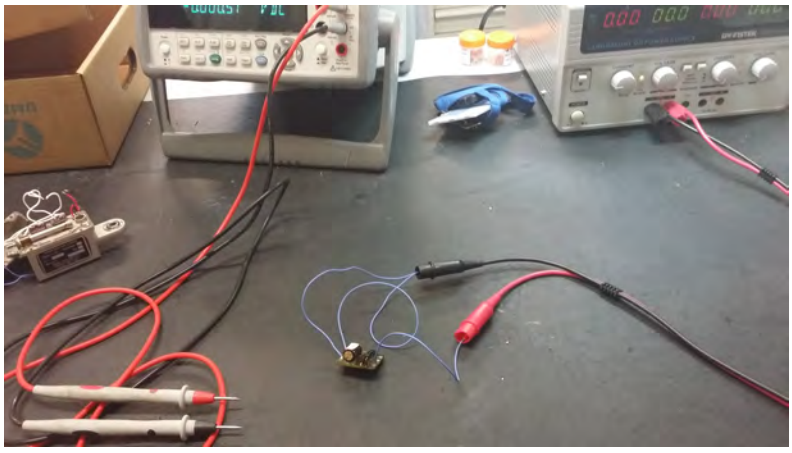


Photo 16

ANALYSIS

This investigation determined the following most likely failure scenario:

a) The Actuator was commanded to retract and reached the retracted position but failed to keep such position under the load applied by the spring (see figure 6);
b) The screwshaft/rod end extended under the load applied by the spring but, because the command to retract, the solenoid and the motor were supplied again until the retracted position was achieved over again;
c) The sequence depicted in point a) and b) was repeated until the solenoid temperature reached a level such to deform the plastic reel and the winding failed open; the electric motor brushes failed as well;
d) The screwshaft/rod end not locked by the solenoid/locking system and with the motor failed was pushed in the found position under the action of the spring;
e) The high temperature reached by the solenoid, electric motor and other parts closed to those (i.e. bearings, antirotation rod), could have caused a misalignment of the screwshaft/rod and thickened lubricant; this fact can explain why the actuator did not move after the solenoid/locking system was removed but did it freely after the removal of the cap.
f) From figure 38 of the report "*Embraer Phenom rudder gust lock actuator - CT factual report – final*" supplied by NTSB it seems that the solenoid/locking system is in a position such to engage the groove into the ballnut. It is likely that the locking system, under the force applied by its spring, reached such position while the actuator was cooling down.

COMMENTS

a) The failed Actuator was found about 6.8 mm shorter – i.e. pin-to-pin distance - than a new Actuator in the extended position. Umbra is not in the position to determine if the bellcrank would be in contact with the quadrant in such Actuator condition (see figure 6). The personnel who assisted at disassembly of the Actuator from the A/C at PS Airport could confirm the respective position between the quadrant and the bellcrank. Embraer could answer to such question from design point of view.
b) The Actuator design does not include any "unmistakable warning" of the engaged system. In rev. B (i.e. the latest) of Embraer's Technical Specification there is the requirement for an indication of the extended (i.e. engaged) position. A microswitch in the Gust Lock Actuator was provided to meet such requirement. Later (i.e. January 9th, 2009) Embraer requested Umbra to remove such microswitch. Dash number -03 was then generated and qualified. Dash number -03 is the only production actuator configuration provided by Umbra to Embraer. Umbra do not know if there are means in the whole gust lock system that provides unmistakable warning of the extended (i.e. engaged) position. Embraer could answer to such question.
c) The solenoid and electric motor, according the technical specification, are not sized for a continuous duty cycle; the requirement is a cycle (extend and retract) per flight.
d) There are no safety requirements for the Actuator: it is a single point failure item;
e) The contact in flight of the bellcranck with rudder quadrant in the circumferential area within the indentures, due to a failure of the Actuator, cannot cause the lock in position of the rudder;
f) During the meeting on June 16th 2015 in Foligno, Embraer, on the contrary of what is defined into the component technical specification, reported that the quadrant has two indentures instead of four and the indenture position can be reached during the flight if commanded by the pilot.

Analysis:	**Date:**	**Approval:**	**Date**
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