Health and Usage Monitoring System (HUMS) Strategy to enhance the Maintainability & Flight Safety in a Flight Control Electromechanical Actuator (EMA)

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Abstract

Concerning flight control actuation systems, the current state of the art is the fly-by-wire control of servo actuators hydraulically operated. In the last decades several research programs have been dedicated to analyze the replacement of these equipments with the implementation of Electro-Hydrostatic Actuators (EHA) or Electro-Mechanical Actuators (EMA), pursuing the challenge to get More Electrical Aircraft (MEA).
This paper focuses on the HUMS strategy proposed to provide diagnosis and prognosis of the EMA as one way to enhance Flight Safety and Maintainability for its use in Primary Flight Controls.
Considerations related to Flight Safety are analyzed, specially linked to the main problem associated to the EMA, the critical effects derived from the mechanical jamming of some parts of the EMA, and the advantages of the HUMS implementation to anticipate and mitigate these consequences.

Keywords: *Electromechanical Actuator (EMA), Jamming, Health Monitoring & Usage Systems (HUMS), Prognosis, Flight Safety, Failure Modes and Effects Analysis, (FMEA), Flight Controls, More Electric Aircraft (MEA).*

1. Introduction

Despite arising drawbacks, the benefits of the MEA in the long term implementation shall lead to:

- Weight saving of the aircraft, together with the flight control actuation system power complexity, and at the same time decrease the total take-off weight
- Improve Aircraft dispatchability simplifying and reducing the cost of technical service
- Elimination of fluid of the systems
- Reduce the direct costs
- Improve the unification of onboard equipment.
- Reduce fuel consumption
- Improve safety of the flight
- Power distribution and reconfiguration capability that hydraulic systems cannot offer

Currently, the flight control actuation systems of commercial transport aircraft rely on digital control of hydraulically powered servoactuators from pilot controls signals. These systems reach a higher level of performance, reduced weight, less cost and fulfils safety objectives beyond the certification requirements, in order to fulfil the satisfaction of the customer.

Today aircrafts rely on several hydraulic systems in order to provide the hydraulic power required to operate the different consumers: landing gear, cargo doors, primary and secondary flight surfaces, etc. Figure 1 shows a simplified example of traditional hydraulic architecture.

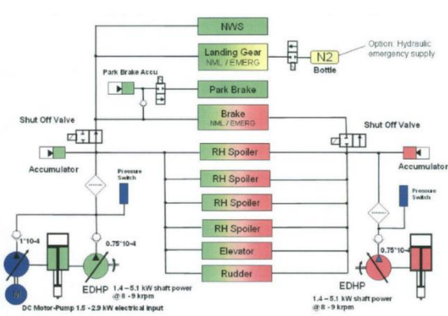

Figure 1. Example of Hydraulic Power System.

To substitute hydraulic circuits, including pumps, reservoirs, accumulators and so on, the objective is to implement electrical actuation of control surfaces, using Electro Mechanical Actuators (EMA). Figure 2 shows a possible configuration with all electric Flight Control System based in the use of Eletrohydrostatic Actuators (EHA) and Electromechanical Actuators (usage of EMAs also in Rudder and Elevator surfaces in particular, is the object of the EMA presented in this article).

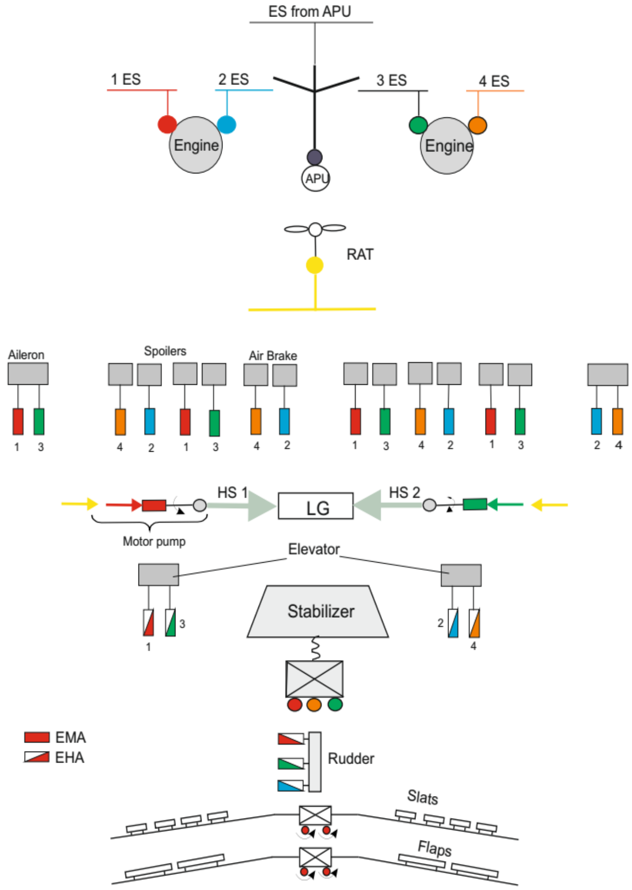

Figure 2. All Electric Flight Control System Example

This conceptual change, although feasible in theory, represents a number of challenges, such as the radical change in technology and the maturity of the Actuators' design. In fact, some specific operation and safety issues as mechanical jamming susceptibility, thermal behavior, power electronics optimization, life duration of some components have to be overcome.

Concerning mechanical jamming, typical solutions used in the past deal with clutches between Gear Boxes and screws, which did not solve the root cause of the vast majority of jamming problems because these kind of solutions avoid jamming events but only just before screws, not screw jamming itself.

To resolve these problems, a great advantage of the selection of this architecture with EMAs is the possibility to include a HUMS.

The application of HUMS to anticipate and mitigate the possible effects associated to the main failure modes of the EMAs, as the jamming, could enhance the Flight safety of the system, beside to improve the maintainability of the system.

Since their introduction into the aviation world, health and usage monitoring systems (HUMS) have gained traction and expanded from the offshore oil and gas industry to the military, unmanned aerial systems, and commercial and business operations. HUMS has been designed to automatically monitor the health of mechanical components in an aircraft, as well as usage of the airframe and its dynamic components.

2. HUMS STRATEGY FOR EMA

2.1. Benefits of HUMS for Maintainability and Flight Safety

HUMS have been shown to enhance safety, decrease maintenance burden, increase availability and readiness, and reduce operating and support costs.

Maintainability benefits of HUMS include:

- More efficient maintenance, as unscheduled events can be pushed to align with scheduled actions
- Troubleshooting and diagnosis on Aircraft of potential faults through proper use of the system, without necessity of scheduled removal of the equipments
- Decrease or elimination of some maintenance inspection intervals
- Diagnosis of problems before they cause other parallel effects
- Additional improvements of the HUMS implementation have been remarked as repair cost reduction, increase of the useful life and significant reduction in downtime for unscheduled maintenance events

HUMS improves Flight safety of the A/C. There are several examples in aviation today where a fault was detected early enough to avoid an emergency landing or possibly even a catastrophic failure during flight (Keller et at (2012) talks about the prevention of a potentially catastrophic dual clutch failure and Antolick et Al (2010), about the identification of a nose gearbox gear fault). Safety Benefits of HUMS include:

- Identification of faults prior to catastrophic or hazardous failure
- Possibility to take actions during flight leading to minimize risks associated to failure in flight
- Decrease of the risk of emergency landings

Related to architecture including EMAs for Flight Control system, the Jamming appears as a very demanding safety requirement which could discard the EMA usage for this application (as well as for Landing gear use). The jamming probability of an EMA used in primary flight control application is difficult to predict and it would be substantiated from existing in-service experience. Data are not available even some information from other systems like secondary flight controls applications are known but not directly transferable to primary flight controls. This risk of jamming is an important question mark for the certification of EMA in primary flight control applications.

However, CESA has developed an EMA based on single screw architecture with an anti-jamming system, avoiding any effect due to a possible mechanical single failure (even screw jamming) assuring the free movement of the Flight Surface governed by the redundant actuator. This antijamming system has also the advantage that can be re-engaged automatically after the use by the Electronic Controller.

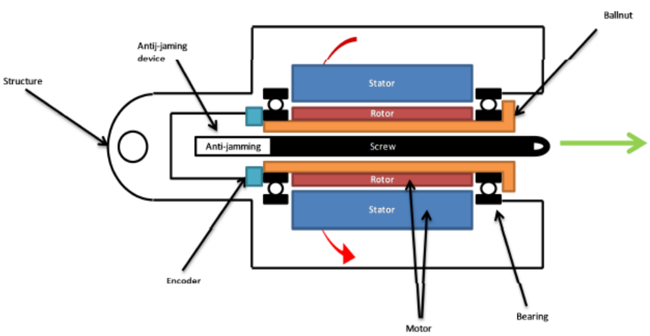

Figure 3. EMA Main Parts

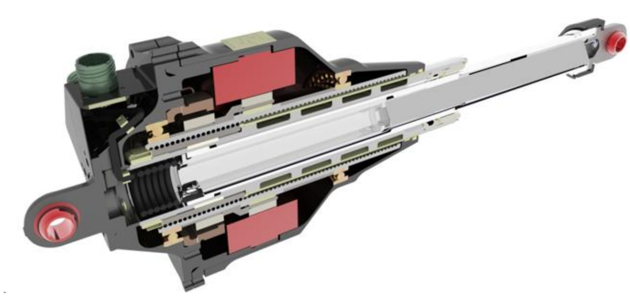

Figure 4. EMA Sectional View

Figure 3 and Figure 4 show an sketch of the main parts of the EMA (no details of antijamming systems shown in these figures; more details of the EMA functioning - Active mode, Damping Mode and Antijamming mode - can be found in Jiménez et Al (2016) paper). Figure 5 shows a real EMA developed by CESA for Rudder Flight Control surface with Antijamming Technology, which is the base of the one developed for the Elevator Flight Control Systems presented in this article.

Figure 5. CESA EMA with Antijamming Technology©

This antijamming concept, joined to a HUMS implementation will allow to enhance the Flight Safety of the system. Thus, once the potential failure is detected in advance, (through the Electronic Controller (ECU) of the EMA and the System (SECU)), the action can be carried out to maintain the safety condition. A degradation of performances is the only adverse effect (different operation mode), but always fulfilling the safety requirements.

Under a mechanical jamming condition within an EMA, Figure 6 summarizes the Control System loop action for Elevator Flight Control System run by two EMAs.

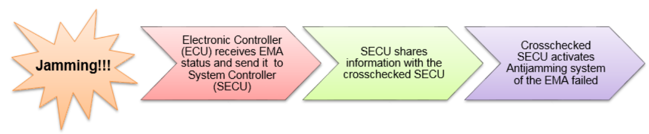

Figure 6. Control Loop in case of Mechanical Jamming detection of one EMA

2.2. Selection of monitoring variables and sensors for EMA

Health monitoring involves the selection of variables to be monitored to detect faults and predict failure (Prognosis/Usage). For helping this task the best tool is the Failure Modes and Effects Analysis.

2.2.1. Failure Modes and Effects Analysis (FMEA)

The cornerstone of a good Condition Based Maintenance system design is the understanding the physics of failure mechanisms. The use of a Failure Mode Effect Analysis (FMEA) is aimed at providing the designer with the tools and procedures that will lead towards a systematic and thorough framework for design.

A FMEA has the following properties:

– Identifying failure modes, their location, severity, frequency of occurrence and testability
– Relates failure events to their root causes
– Explain the impact of faults/failures on the system, subsystem or component performance
– Make suggestions for the sensors/monitoring equipment required to detect and track a particular fault

2.2.2. Failure Modes of EMA

Different failure modes are presented in electromechanical actuators. These failure modes have been established as the most common types of failures in systems performance and include a wide extension of the common types of failure in electromechanical actuators.

However, the main concern of actuator failure is mechanical jamming. There are a variety of underlying faults which can increase in severity and lead to actuator jamming. These have been identified through a Failure Mode and Effects Analysis (FMEA) of an actuator system as bearing damage, gear seizure or physical actuator ballscrew damage.

Table 1 shows a preliminary Blocks FMEA based in CESA experience, with information which helps to determining causes of failures and parameters to monitor those EMA faults. Column "Variables to detect Faults" presents the monitoring variables that could identify faults that could lead to potential failures in the EMA (Column "Effect on EMA").

Table 1. EMA Preliminary Blocks FMEA

EMA PRELIMINARY BLOCKS FMEA							
Block	Failure Mode (FM)	% FM	Possible Causes	Effect on System	Effect on EMA	Variables to detect Faults	% FR
Electric Motor	Winding shorted or open	35%	Overcurrent, overheating, insulation degradation	Inability to provide torque. Loss of EMA. Passive Mode Fail safe activation	Motor does not respond to command	Measure current, temperature , intermitent current due to insulation deterioration or wire cut	30%
	Rotor blocked	25%	Lack of lubrication, Excessive friction, overstress	Inability to provide torque. Loss of EMA. Passive Mode Antijamming activation	Actuator blocked in its position	Torque measure, current consumptio n that would be much higher in all operating conditions	
	Other (drifts, switch failure...)	40%					
	Maximu m current		rotor blocked, jamming on ball screw	Rotor motor blocked.	Actuator blocked in its position, stall motor	Measure current, temperature	
Ball screw	Jamming	30%	Lack of lubrication, Excessive friction, overstress	EMA seized. Passive Mode Antijamming activation	Actuator blocked in its position	Torque measure, current consumptio n much higher in all operating conditions	12%
	Other broken, corroded	70%					
Bearings	Seized	50%	Lack of lubrication, Excessive friction, overstress	Rotor motor blocked. Inability to provide torque. Loss of EMA. Passive Mode Antijamming activation.	Actuator blocked in its position	Torque measure, current consumptio n much higher in all operating conditions	6%
	Other (excessi ve play, etc.)	50%					
Antijamming system	Failure (winding of electric motor open or shorted, mechani cal jamming etc.)	95%	Overcurrent, overheating, insulation degradation	Under another failure jamming failure, inability to engage Passive Mode Antijamming	Pre-fligth test. Motor does not respond to command	Measure current, temperature	24%
	Mechani cal part broken	5%	Excessive Friction / Overstress / Vibration / Lack of lubrication / Fatigue	EMA accidentally in passive mode antijamming. The other surface EMA can take over the surface	Pre-fligth test. Inability to re-engage the antijamming system	Visual (preflight)	
Resolver	Stator or rotor loose	50%	Vibration	Position error signal of Electric Motor Control. Passive Mode Fail safe activation	Erroneous signal of one bobbin		6%
	Open or shorted windings	50%	Overcurrent, overheating	Loss of signal of motor control. Passive Mode Fail Safe activation	Erroneous signal of one bobbin		
Temperature sensor	Tempera ture sensor failure (loss of indicatio n)	50%	Vibration / Overcurrent	No temperature information of the EMA			4%
	Tempera ture sensor failure (erroneo us indicatio n, drift value)	50%	Vibration / Overcurrent	TBD depending of the control system			
	Maximu m and minimum temp		anomalies actuator behavior, lack of lubrication, Excessive friction, overstress	TBD depending of the control system			
Force sensor	Force sensor failure (loss of indicatio n)	50%	Vibration / Overcurrent / Humidity /High Temperatur e	No force information of EMA.			4%
	Force sensor failure (erroneo us indicatio n, drift value)	50%	Vibration / Overcurrent / Humidity /High Temperatur e	TBD depending of the control system			
LVDT	Windings open or shorted	50%	Thermal stress /Vibration	Loss of EMA ballscrew position. Loss of LVDT position indication. Position can be	Erroneous signal and isolation of LVDT bobbin failed		4%

EMA PRELIMINARY BLOCKS FMEA							
Block	**Failure Mode (FM)**	**% FM**	**Possible Causes**	**Effect on System**	**Effect on EMA**	**Variables to detect Faults**	**% FR**
				known by means of Resolver indication			
	drift value, erroneous output	50%	Thermal stress / Vibration	Erroneous position information. Resolver signal and LVDT signal do not match. Passive Mode Fail safe activation	Erroneous signal and isolation of LVDT bobbin failed		
Mechanical parts	Mechanical Parts failure (A/C attachments broken, cylinder broken, etc.)	100%		Loss of EMA			10%

In previous FMEA table, effect on the EMA also include information of the eventual effect at Surface Level (Elevator application governed by two EMAs). It shall be noted, that the inadvertent activation of the antijamming system in flight would not have safety repercussions higher than MAJOR, as the architecture selected is made by two active/active EMAs configuration. At the light of this assessment, it shall also be noted that a potential jamming in one actuator could be detected by torque and current consumption of this particular EMA and the Control System will be able to isolate which EMA of the Control Surface could present a jamming issue and therefore, command the antijamming mode of this actuator.

In future, early detection of a potential jamming problem in an EMA during flight could avoid the use of a specific antijamming system to overcome the jamming failure. Maintenance action could be planned to be performed after the fault detection prior next scheduled flight. It can be envisaged, that an EMA without antijamming technology for a Primary Flight Control is not feasible unless Health Monitoring capabilities are proved to be in a high maturity level.

2.2.3. Sensors to be implemented in EMA

Taking into account the blocks FMEA presented for the Electromechanical Actuator, a preliminary description of the variables to study and sensors to implement for EMA HUMS are:

- Double load sensor based on Wheatstone bridges of strain gages to measure the load applied by actuator
- Motor current sensor per each phase.
- Double temperature sensor integrated in motor windings.
- Triaxle accelerometer.
- Motor rotational position and speed measured by hall sensors or resolver.
- Actuator lineal position measured by an LVDT

The Test bench could also include additional monitoring capabilities not included within the EMA and Control System itself.

2.3. HUMS Strategy for Elevator Flight Control EMA

The main challenge of HUMS is to identify failures to mitigate or have knowledge of them before they occur. The main aim is to monitor and process results coming from learning algorithms to predict and anticipate faults which could result in critical failures (e.g. mechanical jamming of EMA).

HUMS concept includes two main modules, Health Monitoring and Usage.

- **Health Monitoring**
  It involves the part of diagnosis and isolation of faults (not failures). Degradation and performance out of tolerances will give an indication that a potential failure could happen. To monitor internal parts and deliver feedback to SECU and ECU, several sensors shall be installed in the Actuator. With the help of the FMEA of the EMA, the variables to measure and sensors to be implemented are selected.

- **Usage (Prognosis)**
  Usage is also referenced as Prognosis. Usage module should integrate one or more models that are able to predict failures in critical components, which need to be monitored. Prognosis will be based on simulation modelling and data driven techniques. The approach followed will be similar to the one presented by Alia et Al (2013) in their paper. Usually, the main barrier to achieve good algorithms that comprise the Health Monitoring system is to obtain the data from which to establish patterns of the system behavior and test theories. Early in this project in which this work is carried out, neither the actuator nor its test bench are completed or available, this is because they are still in a design phase, thus makes the real experimentation unfeasible. As a consequence, a model based on simulation modelling will be developed, taking into account initial requirements and design specifications. This model will be updated as new specifications have been obtained, until the development of the final simulation model. This final model will be able to fix the behavior of the actuator by means of simulation techniques (Simulink model), which makes it possible to analyze, identify and select those signals to be

utilized for the development of the state detection and prediction algorithms of the Health Monitoring system of the actuator, and also to be monitored later in the real EMA system as input to these algorithms.

As it has been commented before, one of the most investigated problems today in electromechanical actuators is jamming detection before it occurs (in hydraulic systems is an unlikely failure), so the detection of the potential seizure may avoid EMA jamming. Then, the next step after detecting a fault that could lead to jamming is to provide a diagnosis and health indicator of actuator, and even the Remaining Useful Life (RUL) prediction of the actuator by adopting some regression methods, taking into account the working life of the system and using the result of the state detection for every operating cycle or its components (prognosis). Thanks to historical data obtained by tests of other units regarding efficiency, number of cycles and behavior due to degradation of components, the system compares health monitoring with Lookup Table and can make a prognosis in real time.

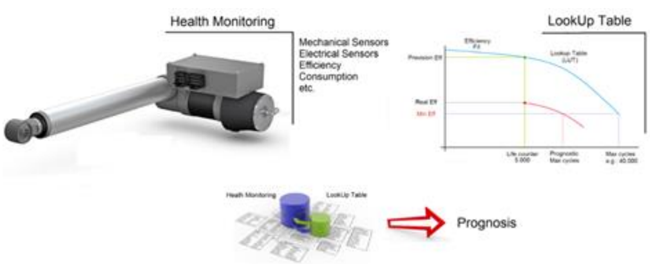

Figure 7 – HUMS Strategy for EMA

A cycle counter will be implemented to have a histogram storing variables temperature, speed, torque, etc. Lookup table will be derived from endurance test and will adapt the theoretical efficiency curve of the actuator (Efficiency vs Number of Cycles). Once this is performed, an intentioned degradation will be tested causing failures by lubrication wear debris, increased load on actuator, etc.
Using this method and performing those tests, a faulty actuator behavior will be known allowing the prognosis of future/possible failures depending on the actuator behavior.

The HUMS strategy is based on the following points:

A. Measurement related to efficiency of system (Force/Motor current):

This information will be obtained from the same actuator in lab conditions. Then flight conditions can be simulated to characterize the disturbances that can be present in real conditions and finally several actuators should be tested to be able to establish a pattern to reduce the dispersion.

- Data obtained in endurance tests, current consumption evolution, load applied, thermal evolution of motor windings, can be used to predict the behavior of system based on its degradation within specification in service.
- Data obtained in development tests where different mechanical degradations/failures are introduced into system. Therefore, the characteristically current consumption versus load evolution is used to predict the behavior of system based on its degradation in service.
  - Ball screw friction increase due to external dust
  - Loss of grease in ball screw
  - Loss of grease in bearings
  - Overload in ball screw up to mechanical deformation of internal ball recirculation system.
  - Overload in bearings up to mechanical deformation.
  - Overheat cycling in motor
- Triaxle accelerometer installed internally into EMA. These measurements will be analyzed in order to obtain the Eigen frequencies of system in normal operating cycles. Furthermore, the frequency spectrum will be also analyzed under the failure scenario in order to check the variation obtained from the original results.

B. Life estimators depending on actuator status:

- Number of cycles counter of different operations performed by the actuators
- Behavior of actuator due to degradation of components, the system compare health monitoring with Lookup Table and can make a prognosis in real time

C. Health Monitoring: Signals from sensors:

- Double load sensor based on Wheatstone bridges of strain gages to measure the load applied by actuator
- Motor current sensor per each phase.
- Double temperature sensor integrated in motor windings
- Triaxle accelerometer
- Motor rotational position and speed measured by hall sensors or resolver.
- Actuator lineal position measured by an LVDT

D. Cycle counter in which temperature, speed, torque variables can be recorded:

- A histogram of these performances will be also saved in each operation. Main data saved will be the maximum force applied by actuator, average force during the cycle, maximum/average speed, temperature, motor current per each phase.
- A normalized cycle according to the endurance spectrum tested in order to evaluate the rate of actuator use in order to estimate the maximum

allowable number of cycles still available in actuator.

The previous four main points will be used to estimate the available cycling spectrum for the EMA. Life counter allows the comparison between the current performances and the estimated evolution. The first one is obtained in the actuator according to the proper cycling evolution of the actuator. This online calculation performed by the ECU of the actuator allows a clear evaluation of the status of the actuator in every cycle. This calculation allows a comparison against the curve obtained during the endurance test performed previously during the certification phase.

The curve obtained during the endurance test includes the results obtained from the test. Adding to this, the characteristic curves obtained from the development tests will include the different failure scenarios. As more actuators are tested the characteristic life evolution curve will reflect better the real behavior.

2.4. EMA HUMS Tests

The first step is to test the EMA to check efficiency (Force/Intensity) variation through cycles. The number of cycles will depend on the project and conditions, not reaching the end of life if not necessary.

Once some cycles have been tested, and variation of efficiency (F/I) is identified, the degradation of the actuator due to external agents will be checked (for example, by inserting sand and dust on the spindle and checking the actuator behavior).

Once several external degradation agents are tried, the behavior of the actuator against them will be characterized and HUMS will be able to anticipate the failure checking anomalous behavior in the actuator.

The main tests that shall be performed for the HUMS definitions are:

- The specified endurance test of the Elevator actuator. During this test, current consumption evolution, load applied, thermal evolution of motor windings, shall be recorded. These data shall be also post-processed to predict the behavior of system based on its degradation within specification in service.

- Several conditions could be simulated to reproduce the effects of different faults in EMA. These development tests shall be defined to test possible mechanical degradations/failures. These data shall be also post-processed to predict the behavior of system based on its degradation.

Test to be peformed are:

- Overheat cycling in motor. Any overheating of motor will demagnetize the permanent magnets of motor causing a permanent loss of efficiency. This topic causes that the actuator would require more current to produce the same external load. These higher currents would saturate the flux in the rotor laminations implying adverse implications in the control of motor performances.
- Ball screw friction increase due to external dust. These external agents as dust, ice, sand, would reduce the efficiency of the recirculation ballscrew system.
- Loss of grease in ball screw, the same effect as before could cause in ball screw by the loss of grease. This would reduce the efficiency of system. Actuator would require more current to produce the same external load.
- Loss of grease in bearings, the same effect could cause as in ball screw, the loss of grease in bearings would imply a reduction in the efficiency of system. Actuator would require more current to produce the same external load.
- Overload in ball screw up to mechanical deformation of internal ball recirculation system. Any overload in system could cause a plastic deformation in the internal ball recirculation. Therefore, actuator would require more current to produce the same external load.
- Overload in bearings up to mechanical deformation. Any overload in system could cause a plastic deformation in the internal ball recirculation. Therefore, actuator would require more current to produce the same external load.

3. CONCLUSIONS

Implementation of HUMS allows to improve the safety, detecting earlier defects avoiding the critical failures, and enhances the maintainability of the system, improving the dispatchability of the aircraft, reducing costs of maintenance.

The proposed EMA with anti-jamming device, joined to the HUMS implementation make possible the use of EMA to perform the most critical safety aircraft functions as Landing Gear extension or Primary Flight controls (See Jiménez et Al (2016) paper).

The HUMS strategy is presented for this EMA, including the necessary variables to monitor, the sensors to be installed and the tests to be carried out.

NOMENCLATURE

A/C	Aircraft
AEC	Asociación Española para la Calidad
APU	Air Pressurization Unit
ASD	Aerospace and Defence Industries
CASA	Construcciones Aeronáuticas S.A
CESA	Compañía Española de Sistemas Aeronáuticos
EADS	European Aeronautic Defence and Space

ECU	Electronic Control Unit
EHA	Electrohydrostatic Actuator
EMA	Electromechanical Actuator
e.g.	"exempli gratia" (for example)
ES	Electrical Power System
FM	Failure Mode
FMEA	Failure Modes and Effects Analysis
FR	Failure Rate
HS	Hydraulic Power System
HUMS	Health and Usage Monitoring System
ILS	Integrated Logistic Support
LG	Landing Gear
LVDT	Linear Variable Differential Transformer
MEA	More Electrical Aircraft
PSSG	Product Services Specification Group
RAMS	Reliability, Availability, Maintainability and Safety
RAT	Ramp Air Turbine
R&D	Research and Development
RMTS	Reliability, Maintainability, Testability and Safety
SECU	System Electronic Control Unit
TBD	To Be Determined

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BIOGRAPHIES

Ricardo de Arriba Laso is RAMS & ILS Engineer at Compañía Española de Sistemas Aeronáuticos (CESA) in *Madrid* (Spain). He is a capable and versatile professional as well as dedicated and team work person who feels motivated in engineering & aeronautics. When he is not glued to his work, he spends time reading and learning new things, which feed his curiosity, and he tries not to forget playing tennis.

Ricardo grew up in *Salamanca* (Spain), where he got his High School Degree with Honors and was awarded by *Universidad de Salamanca* (Spain). He successfully graduated from *Escuela Técnica Superior de Ingenieros Industriales (Universidad de Valladolid)* and earned a position to do his M. Eng Thesis at the Aerospace Department of San Diego State University (California), where he was collaborating in DNS of Particle Laden Flows during 2011-2012 as a lab member of Prof. Guus Jacobs investigation team.

He was selected by CESA in 2012 as an intern of the RMTS & Product Support Engineering Department while he was studying CITIUS Postgraduate Program at *Universidad Autónoma de Madrid* (Spain).

During his current position at CESA, Ricardo got a Master Degree in RAMS Engineering from *Universidad de Las Palmas de Gran Canaria* (Spain), while he has been involved in all design activities of electromechanical & fluid mechanics equipment for well known aircrafts (e.g. A400M) as RAMS project leader. He is currently involved in the development of the Hydraulic Power System for a Turkish Light Helicopter, Segment Support of the E-ELT Telescope and FP7 R&D Project called RESEARCH about Flight Controls Electromechanical Actuation.

Alberto Gallego Linares is an Industrial Engineer graduated in 1993 from Polytechnic University of Madrid.

He works in CESA since 1995, first as Technical Project Leader (1995-2001) in the Design Department, then as Programme Manager (2001-2003) of equipment supplied for EADS CASA aircrafts, and from 2003 up to now, in charge of RMTS & Product Support Engineering department.

From his current position, Alberto leads the team in charge of assuring that the RAMS disciplines and ILS activities are performed along the life cycle of the product. One of his key subjects is to have effective influence in the design from the earlier development phase, establishing the Maintainability as a key design parameter, providing to the item a suitable Health Management.

In addition to the contribution of Production programmes, Alberto is involved in CESA R&D programmes, analysing the different architectures to provide alternative solutions in the future developments. He focuses on looking for methods and techniques and performing the tasks that assure links between Design, Maintainability and availability of the product for end customer.

Alberto is member of the Product Services Specification Group (PSSG), reporting group of the Services Commissions of ASD (Aerospace and Defence Industries Association of Europe).

Alberto is also member of the “Comité de Confiabilidad”, a Reliability, Availability & Maintainability group belong to AEC (Quality Spanish Association)