XVII Congreso de Confiabilidad

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Congreso de
Confiabilidad

25 y 26 de noviembre de 2015. Parque Científico
y Tecnológico de Bizkaia. Zamudio (Bizkaia)

APPLICATION OF HEALTH AND USAGE MONITORING SYSTEM (HUMS) TO IMPROVE THE FLIGHT SAFETY IN A FLIGHT CONTROL ELECTRO-MECHANICAL ACTUATOR (EMA)

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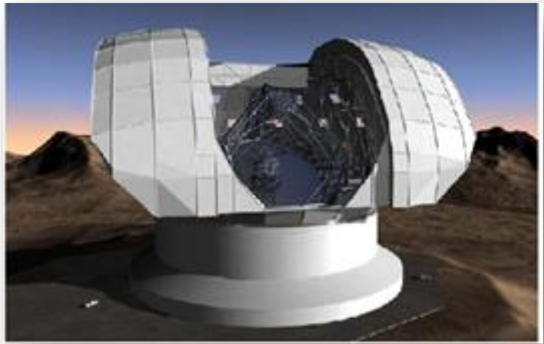
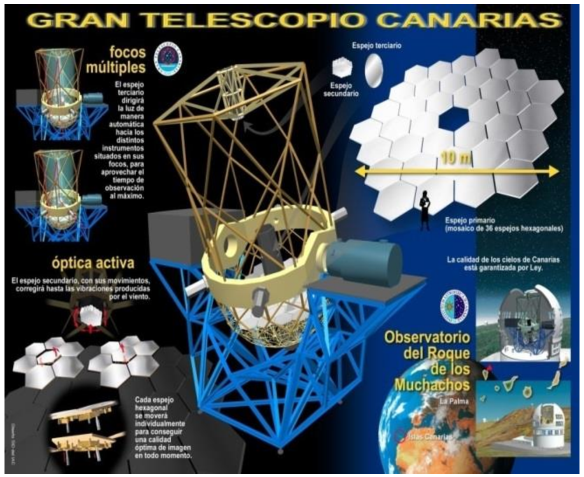
Product Support Manager

COMPAÑÍA ESPAÑOLA DE SISTEMAS AERONÁUTICOS (CESA)

- CESA - Compañía Española de Sistemas Aeronáuticos



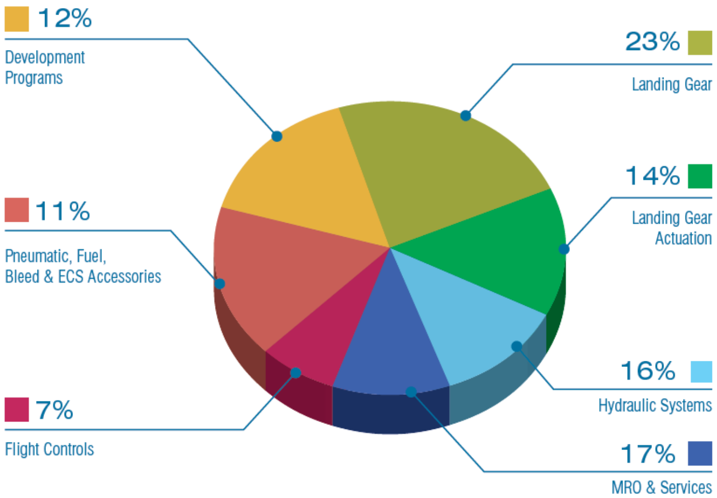
E-ELT Support System and
Position Actuator



COMPAÑIA ESPAÑOLA DE SISTEMAS AERONAUTICOS S.A.

60%	40%
AIRBUS DEFENCE & SPACE	UTC Aerospace Systems

CESA Shareholders



A330 tail boom HOIST and ERAS

CESA PRODUCTS

Cargo Door Actuator

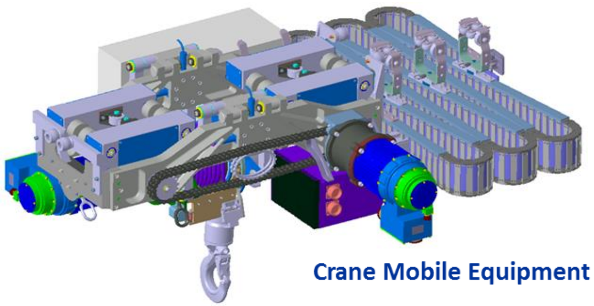
Ramp Actuator

Stabilizer Strut Actuator

Ejector Parachute Extraction System

Tow Plate

Hydraulic Reservoirs A400m
(Purchaser : Airbus Germany)



Crane Mobile Equipment

A380 Reservoir

COMPAÑIA ESPAÑOLA DE SISTEMAS AERONAUTICOS S.A.

- <u>CESA participation in European Projects</u>

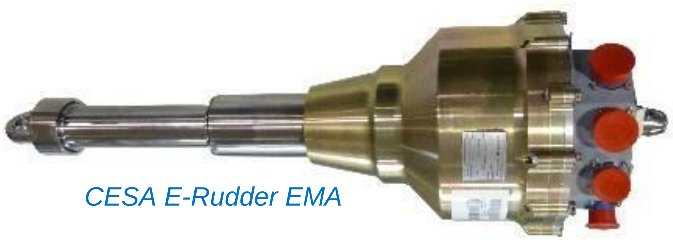
SEVENTH FRAMEWORK PROGRAMME

RESEARCH

REliability and **S**afety **E**nhanced electrical Actuation System **ARCH**itectures.

FLIGHT EMA (e-RUDDER)

Advanced Flight Control System – Design Development and Manufacturing of an Electro Mechanical Actuator with associated Electronic Control Unit and Dedicated test Bench



CESA E-Rudder EMA

ARMLIGHT

Design, development and manufacturing of an electro-mechanical actuator and test rig for **A**i**R**crafts **M**ain **L**and**I**ng **G**ear ac**T**uation systems

CESA Armlight EMA

Actuation 2015

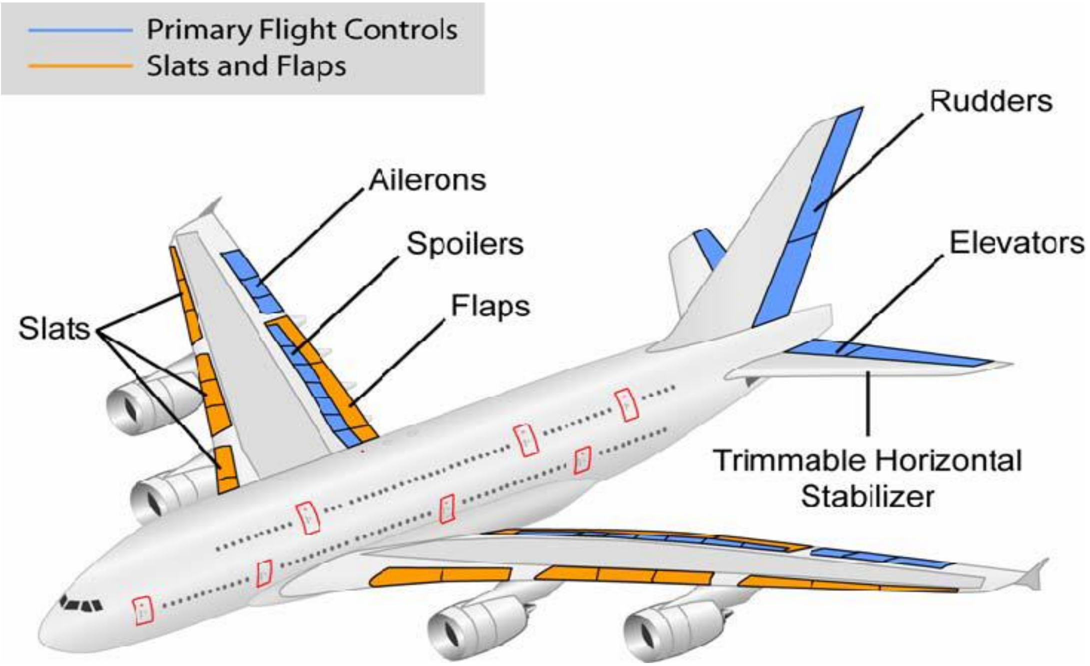
Modular Electro Mechanical Actuators for ACARE 2020 aircraft and helicopters

Others: *GreenAir, SuperSkySense, Fastwing, IND-Dampers, Titalum, Newtiral, POA, LAMA, ELGAR, NIPSE…*

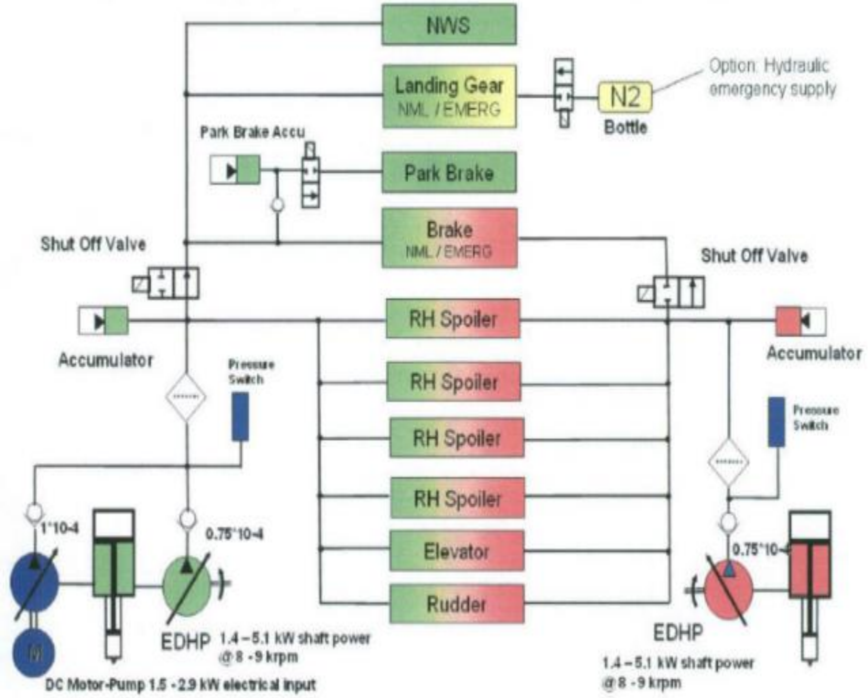
COMPAÑIA ESPAÑOLA DE SISTEMAS AERONAUTICOS S.A.

- More Electrical Aircraft (MEA): objectives for the next generation of aircrafts and helicopters => to improve the fuel consumption, the efficiency of their systems and reduce their environmental impact.

- Objective : to implement electrical actuation of control surfaces, using Electro Mechanical Actuators (EMA).



- To substitute hydraulic circuits, including pumps, reservoirs, accumulators and so on, using Electro Mechanical Actuators (EMA).



- Operation and safety issues:
  - thermal behavior,
  - power electronics optimization
  - life duration
  - mechanical jamming susceptibility

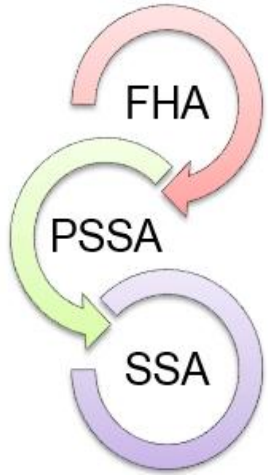
➢ AIRWORTHINESS REQUIREMENTS (CS-25.1309)

- Definition of CAT/HAZ/MAJ requirements
- No single failure will result in a Catastrophic Failure Condition;
- Each Catastrophic Failure Condition is Extremely Improbable

Effect on Aeroplane	No effect on operational capabilities or safety	Slight reduction in functional capabilities or safety margins	Significant reduction in functional capabilities or safety margins	Large reduction in functional capabilities or safety margins	Normally with hull loss
Effect on Occupants excluding Flight Crew	Inconvenience	Physical discomfort	Physical distress, possibly including injuries	Serious or fatal injury to a small number of passengers or cabin crew	Multiple fatalities
Effect on Flight Crew	No effect on flight crew	Slight increase in workload	Physical discomfort or a significant increase in workload	Physical distress or excessive workload impairs ability to perform tasks	Fatalities or incapacitation
Allowable Qualitative Probability	No Probability Requirement	<---Probable---->	<----Remote---->	Extremely <-------------------> Remote	Extremely Improbable
Allowable Quantitative Probability: Average Probability per Flight Hour on the Order of:	No Probability Requirement	<-------------------> $<10^{-3}$ Note 1	<-------------------> $<10^{-5}$	<-------------------> $<10^{-7}$	$<10^{-9}$
Classification of Failure Conditions	No Safety Effect	<-----Minor------>	<-----Major------>	<--Hazardous-->	Catastrophic

Note 1: A numerical probability range is provided here as a reference. The applicant is not required to perform a quantitative analysis, nor substantiate by such an analysis, that this numerical criteria has been met for Minor Failure Conditions. Current transport category aeroplane products are regarded as meeting this standard simply by using current commonly-accepted industry practice.

➢ SYSTEM SAFETY ASSESSMENT PROCESS



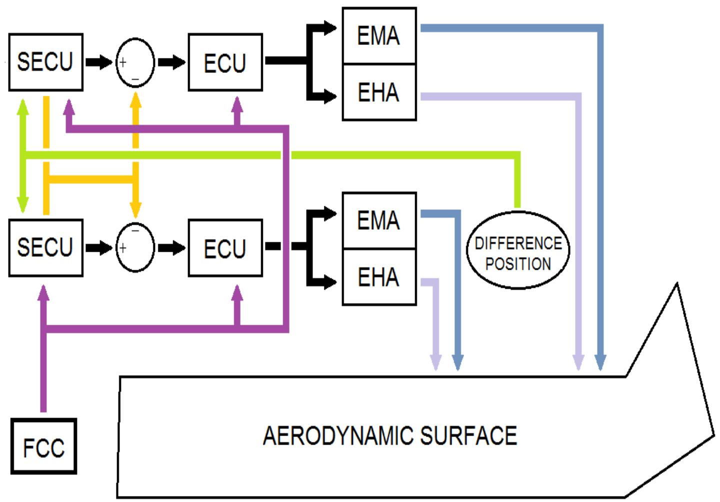
- Process according to ARP-4761
- FHA: identify functional hazards
- PSSA: architecture of system according to safety objectives
- SSA: evaluation of system to show safety objectives

➢ SYSTEM SAFETY ASSESSMENT PROCESS => FHA

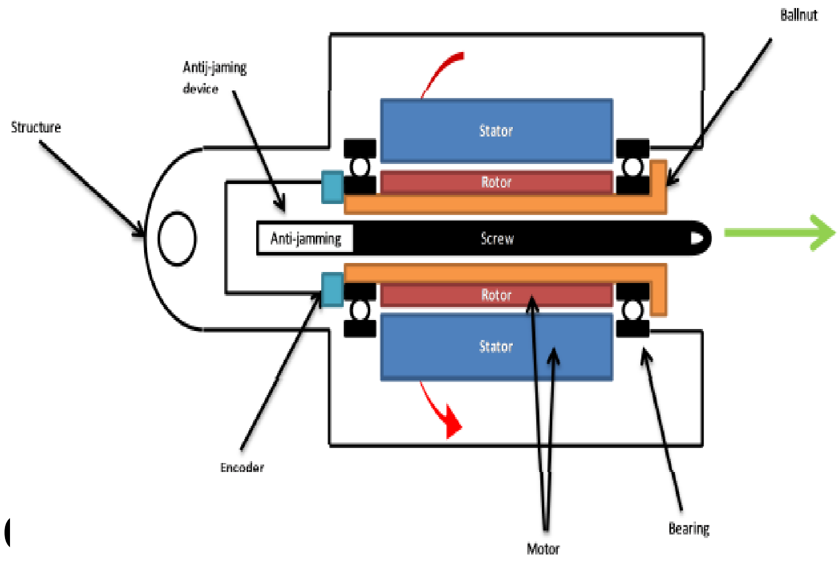
1 Function	2 Failure Condition (Hazard Description)	3 Phase	4 Effect of Failure Condition on Aircraft/Crew	5 Classification	6 Reference to Supporting Material	7 Verif.
Longitudinal stability (Pitch) Control of the Aircraft	Total loss of pitch control	Take-off / Approach and Landing	See below			
	a. Loss of both Elevators control	Take-off / Approach and Landing	No command response of the surfaces. Even detected, it can lead to loss of aircraft longitudinal stability control, and the loss of the aircraft, especially with adverse environmental conditions (cross wind).	CATASTROPHIC		FTA
		Climb / Cruise / Descent		HAZARDOUS		FTA
	b. Jamming of both Elevators	Take-off / Approach and Landing	Both surfaces stuck. Even detected, it can lead to loss of aircraft longitudinal stability control, and the loss of the aircraft, especially with adverse environmental conditions (cross wind).	CATASTROPHIC		FTA
		Climb / Cruise / Descent		HAZARDOUS		FTA
	Partial loss of pitch control	Take-off / Approach and Landing	See below			
	a. Jamming of one Elevator out of neutral	Take-off / Approach and Landing	Increase of crew workload and reduction of pitch control capabilities Excessive loads could be applied on rear fuselage, there may be some near ground flight conditions where the minimum required gradient may not be achieved and there could be a stall risk loss of aircraft longitudinal stability control, and the loss of the aircraft, especially with adverse environmental conditions (cross wind).	HAZARDOUS TO CATASTROPHIC	Additional study necessary to determine the severity. Conservative approach is kept. Depending on aircraft dynamics, it is needed to analyse if ailerons could mitigate these effects under extreme conditions	FTA

SYSTEM SAFETY ASSESSMENT PROCESS

- Result of FHA=> set of System Level Requirements
- Trade off of the different architectures (based on "no single failure principle"
- two Elevator surfaces, with two actuators each (1 EMA + 1 EHA or 2 EMA).
- Control is made by two System Electronic Controller (SECU) connected and one Electronic Controller (ECU) per Actuator

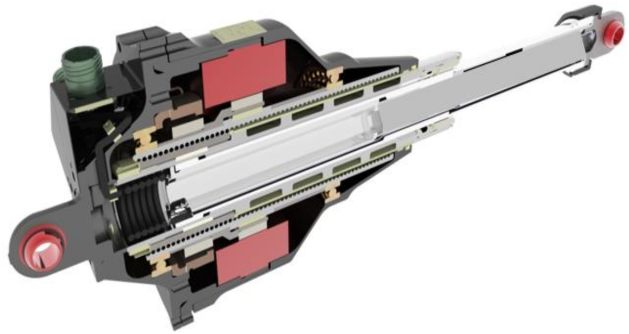


➢ SYSTEM SAFETY ASSESSMENT PROCESS => PSSA



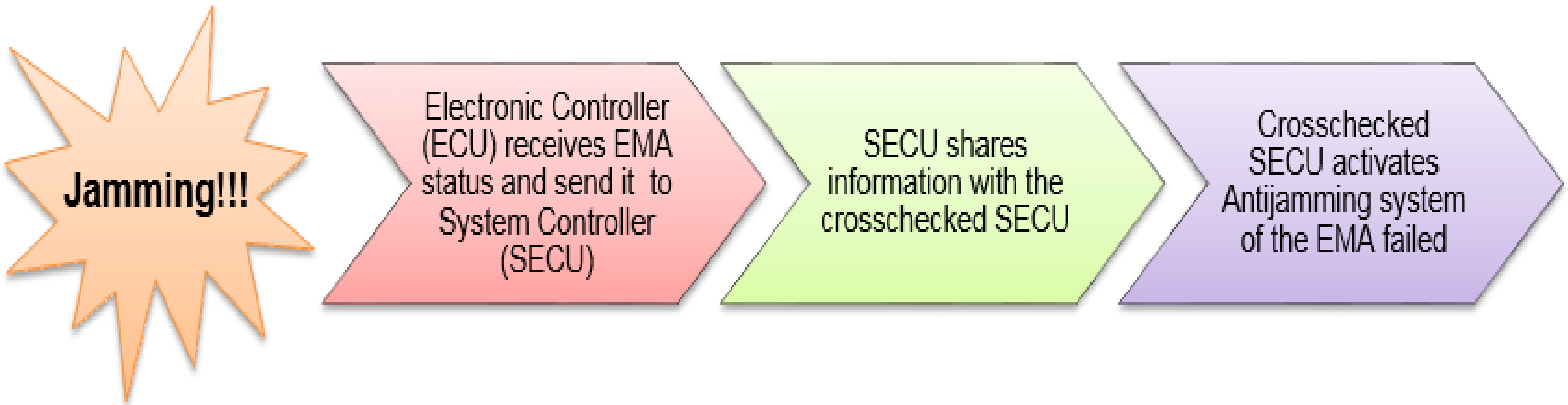
- Fault Tree Analysis
- Common Cause Analysis
- Definition of Development Assuranc
- Definition of scheduled maintenance safety-related tasks
- Definition of requirements at equipment level

SYSTEM SAFETY ASSESSMENT PROCESS => SSA



- Fault Tree Analysis
- Common Cause Analysis
- FMEA/FMES at system item
- Definition of Development Assurance Level for System Items
- Validation of Failure Condition Classifications
- Verification of the Safety requirements identified in the FHA

- SAFETY CHALLENGE (From SERVOHYDRAULIC ACTUATOR to EMA)
  - Critical issue: jamming of EMA mechanical items
  - Single failure leading to CAT effect.
  - CESA solution: anti-jamming system => assuring the free movement of the Flight Surface governed by the redundant



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  - Single failure leading to CAT effect.
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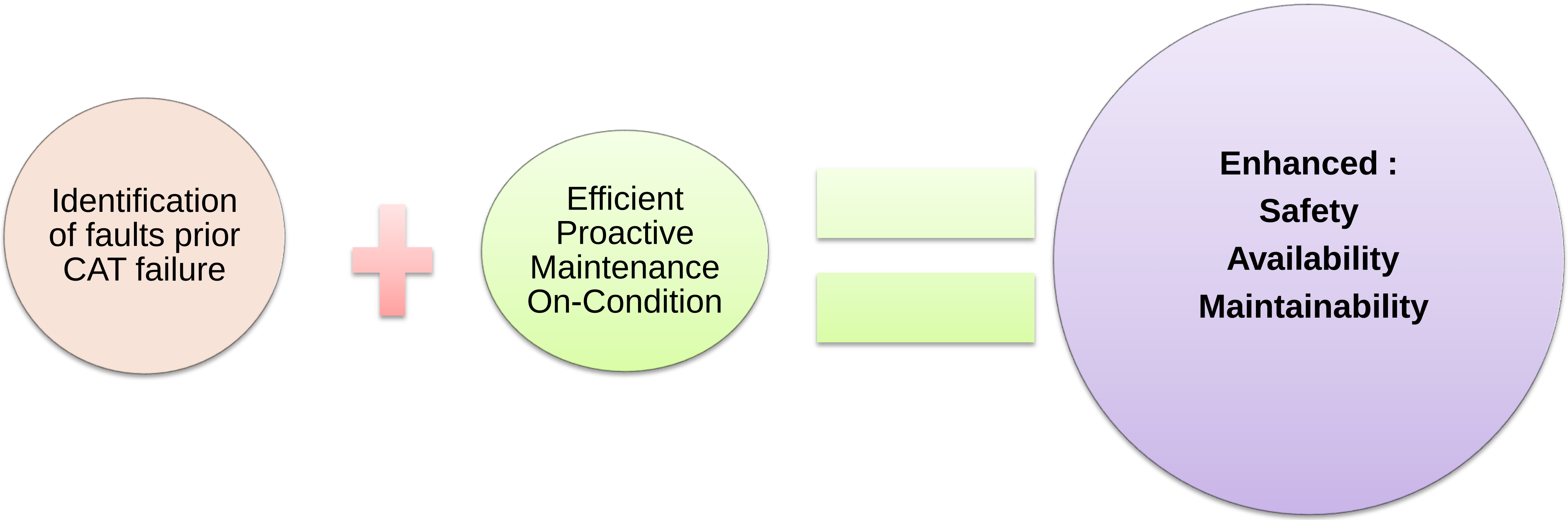
HUMS CONCEPT

- HEALTH MONITORING:
  - diagnosis and isolation of faults
  - Monitor internal parts to deliver feedback to SECU/ECU
  - Definition of sensors and variables to measure by means of FMEA
- USAGE (PROGNOSIS)
  - Usage module integrates models able to predict failures in critical items

Benefits of HUMS



Health & Usage Monitoring strategy for EMA

Measurement of System Efficiency

- Development and endurance test data recorded to get an "Ideal Efficiency" curve implemented in Control System
- Simulation of degradations: loss of grease, overload in bearings, dust in ballscrew
- Frequency spectrum

Life estimation

- Comparison of health monitoring with "Ideal Curve"

Health Monitoring from Sensors

- Load,
- current,
- temperature,
- Motor rotational position
- Actuator lineal position

Cycle counter with variables record

- Histogram of performance recorded in each operation
- Normalized cycle to be tested to estimate the maximum number of remaining cycles of the actuators

➢ Health & Usage Monitoring strategy for EMA

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➢ Health & Usage Monitoring strategy for EMA

Health Monitoring from Sensors

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- current,
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➢ Health & Usage Monitoring strategy for EMA

Life estimation

- Comparison of health monitoring with “Ideal Curve”
- To analyse to be able to predict the increase (or reduction) of life of equipment.
- To analyse the possibility to include comparison in real time

➢ Health & Usage Monitoring strategy for EMA

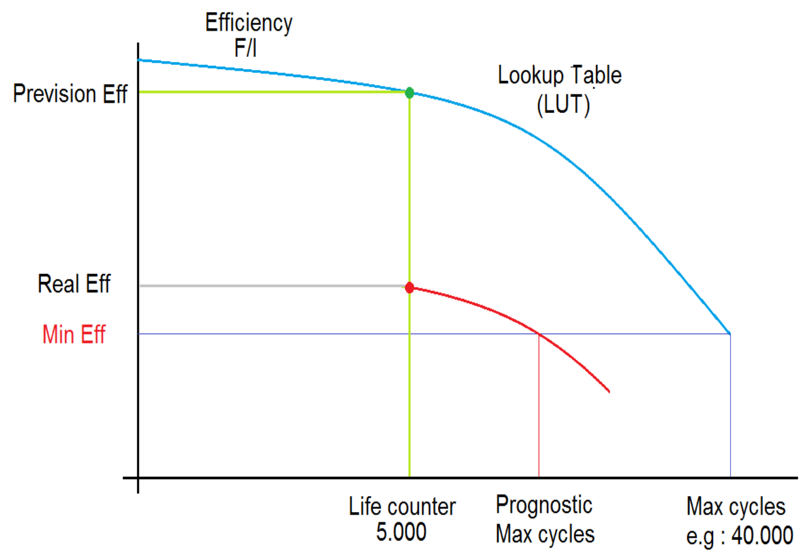
Cycle counter with variables record

- Histogram of performance recorded in each operation
- Normalized cycle to be tested to estimate the maximum number of remaining cycles of the actuators

• HUMS implementation in SECU

Test correlations / mathematical algorithms

Health Monitoring
- Load
- Motor Current
- Temperature
- Vibration
- Position



Prognosis

Remaining Useful Life Prediction