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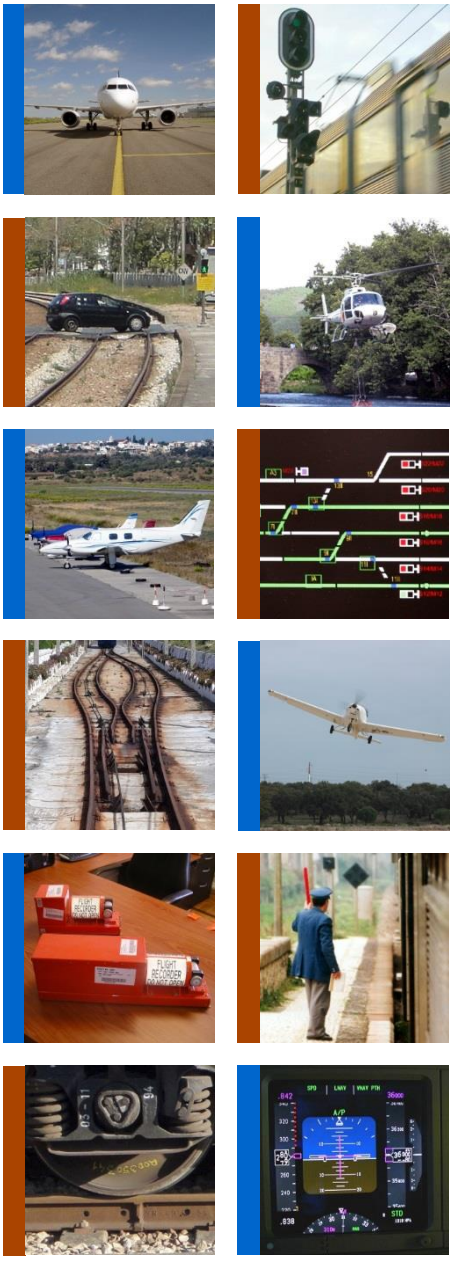
Gabinete de Prevenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviários
Office for the Prevention and Investigation of Accidents in Civil Aviation and Rail (SIA/NIB PT)



AVIAÇÃO CIVIL

LPAR – Alverca do Ribatejo – PORTUGAL

11 NOV 2018, 13:31 UTC

LOC-I por SCF-NP

CIVIL AVIATION

LPAR – Alverca do Ribatejo – PORTUGAL

2018 NOV 11, 13:31 UTC

LOC-I by SCF-NP

EMBRAER E190-100LR

AIR ASTANA / P4-KCJ

RELATÓRIO FINAL DE INVESTIGAÇÃO DE SEGURANÇA DE ACIDENTE

ACCIDENT SAFETY INVESTIGATION FINAL REPORT

[08/ACCID/2018]

REPÚBLICA PORTUGUESA
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PREFÁCIO || FOREWORD

O Gabinete de Prevenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviários (GPIAAF) é o organismo do Estado Português que tem por missão, entre outras, investigar os acidentes, incidentes e outras ocorrências relacionadas com a segurança da aviação civil e dos transportes ferroviários, visando a identificação das respetivas causas, bem como elaborar e divulgar os correspondentes relatórios.

The Office for the Prevention and Investigation of Accidents in Civil Aviation and Rail (GPIAAF) is the Portuguese State body with the mission of investigating accidents, incidents and other occurrences related to the safety of civil aviation and rail transportation, in order to identify their respective causes, as well as to produce and disseminate the corresponding reports.

No exercício das suas atribuições, o GPIAAF funciona de modo inteiramente independente das autoridades responsáveis pela segurança, de qualquer entidade reguladora da aviação civil e do transporte ferroviário e de qualquer outra parte cujos interesses possam colidir com as tarefas que estão confiadas ao Gabinete.

In the exercise of its functions, GPIAAF is fully independent from any authority responsible for safety and the regulation of civil aviation and rail transportation, as well as from any other party whose interests may conflict with the tasks assigned to this Office.

A investigação de segurança é um processo técnico conduzido com o único propósito da prevenção de acidentes o qual inclui a recolha e análise da informação, a determinação das causas e, quando apropriado, a formulação de recomendações de segurança.

Safety investigation is a technical process conducted only for the purpose of accidents prevention and comprises the gathering and analysis of evidences, in order to determine the causes and, when appropriate, to issue safety recommendations.

Em conformidade com o Anexo 13 à Convenção sobre Aviação Civil Internacional, Chicago 1944, com o Regulamento (UE) n.º 996/2010 do Parlamento Europeu e do Conselho, de 20/10/2010, e com o n.º 3 do art.º 11º do Decreto-lei n.º 318/99, de 11 de agosto, a investigação e o relatório correspondente não têm por objetivo o apuramento de culpas ou a determinação de responsabilidades.

In accordance with Annex 13 to the International Civil Aviation Organisation Convention (Chicago 1944), EU Regulation No. 996/2010 from the European Parliament and Council (20th OCT 2010) and article 11, No. 3 of Decree-Law nr. 318/99 (11th AUG 1999), it is not the purpose of any safety investigation process and associated investigation report to apportion blame or liability.

Nos termos do n.º 4 do art.º 16.º do Regulamento (UE) n.º 996/2010, e em conformidade com as secções 6.3 e 6.4 do Anexo 13 à Convenção sobre Aviação Civil Internacional, o GPIAAF remeteu, para obtenção de comentários, uma versão preliminar do relatório final às seguintes entidades:

According to section 16.4 of Regulation (EU) 996/2010 and to sections 6.3 and 6.4 of Annex 13 to the Convention on International Civil Aviation, GPIAAF sent a draft version of the final report seeking comments from the following entities:

- ANAC (Portugal)
- CENIPA - Embraer
- EASA
- NIA Kazakhstan (MIID) - Air Astana
- OGMA, S.A.
- SIA ARUBA (DCA).

- ANAC (Portugal)
- CENIPA - Embraer
- EASA
- NIA Kazakhstan (MIID) - Air Astana
- OGMA, S.A.
- SIA ARUBA (DCA).

O GPIAAF recebeu comentários da MIID, Air Astana, EASA, CENIPA/Embraer, OGMA, S.A, Aruba DCA e ANAC os quais foram devidamente analisados e, quando adotados, integrados no texto do presente relatório final.

De acordo com o Anexo 13, os comentários das diversas entidades ao projeto de relatório, considerados como não adotadas ou parcialmente adotadas, foram apensos ao relatório.

GPIAAF received comments from MIID, Air Astana, EASA, CENIPA/Embraer, OGMA, S.A, Aruba DCA and ANAC which were duly analysed and, if adopted, integrated into the text of this final report.

Following Annex 13, the non-adopted or partially adopted comments to the draft report were appended to this final report.

NOTA IMPORTANTE:

Este relatório foi preparado, somente para efeitos de prevenção de acidentes. O seu uso para outro fim pode conduzir a conclusões erradas.

IMPORTANT NOTE:

The only aim of this report is to collect lessons which may help to prevent future accidents. Its use for other purposes may lead to incorrect conclusions.

Notas para o Leitor:

Neste relatório, a representação das unidades e números é feita em conformidade com o Sistema Internacional de Unidades (SI), com o disposto nas normas da série ISO/IEC 80000 e com a norma portuguesa NP 9:1960. Nos casos especiais, em que outra unidade seja correntemente utilizada no meio aeronáutico, esta será indicada acompanhada da sua correspondência no SI.

Sempre que relevante, as abreviaturas, acrónimos e termos técnicos são explicados no glossário.

Este relatório é publicado em duas línguas, Português e Inglês. Em caso de discrepâncias entre as duas versões, prevalece o texto em Português.

Todas as referências temporais mencionadas neste relatório, salvo indicação em contrário, são apresentadas em Tempo Universal Coordenado (UTC).

Notes to the Reader:

In this report, units and numbers are normally represented accordingly to the International System of Units (SI), to the criteria in the ISO/EIC 80000 series standards and to Portuguese norm NP 9:1960. In special cases where a different unit is commonly used in the aeronautical sector, this will be preferably indicated, with the corresponding equivalence to SI.

When relevant, abbreviations, acronyms and technical terms are explained in the glossary.

This report is published in two languages, Portuguese and English. In the event of any discrepancy between these versions, the Portuguese text shall prevail.

All the times mentioned in this report, unless otherwise indicated, are given in Coordinated Universal Time (UTC).

ÍNDICE || INDEX

ÍNDICE DE FIGURAS || FIGURE INDEX

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SINOPSE || SYNOPSIS

PROCESSO GPIAAF || GPIAAF PROCESS ID **08/ACCID/2018**	*Classificação || Classification* Acidente || Accident
	Tipo de evento || Type of event SCF-NP/LOC-I Falha de sistemas da aeronave – questões de manutenção e perda de controlo em voo || Aircraft system malfunction - maintenance issues and loss of control-Inflight

OCORRÊNCIA || OCCURRENCE			
Data || Date 11-NOV-2018	*Hora || Time* 13:31 UTC	*Local || Location* NE de Lisboa, Portugal || NE of Lisbon, Portugal	*Coordenadas || Coordinates* 41°10'18,4"N 8°29'38,5"W

AERONAVE || AIRCRAFT		
Aeronave || Aircraft EMBRAER 190-100LR	*N.º de série || Serial Nr.* 19000653	*Matrícula || Registration* P4-KCJ
Categoria || Category CAT - Transporte aéreo comercial || CAT - Commercial Air Transport		*Operador || Operator* Air Astana

VOO || FLIGHT		
Origem || Origin Alverca (LPAR)	*Destino || Destination* Minsk (UMMS)	
Tipo de voo || Type of flight Voo de posição após grande manutenção || Positioning flight after heavy maintenance	*Tripulação || Crew* 03	*Passageiros || Passengers* 03
Fase do voo || Phase of flight Descolagem || Take-off	*Condições de luminosidade || Lighting conditions* Diurno || Daylight	

CONSEQUÊNCIAS || CONSEQUENCES			
Lesões || Injuries	*Tripulação || Crew*	*Passageiros || Passengers*	*Outros || Other*
Fatais || Fatal	0	0	0
Graves || Serious	0	0	0
Ligeiras || Minor	0	1	N/A
Nenhuma || None	3	2	N/A
Total	3	3	0

Danos na aeronave || Aircraft damage Substanciais || Substantial	*Outros danos || Other damage* Danos nas luzes da pista || Damage on runway lights

Uma aeronave Embraer 190-100LR, com registo de Aruba P4-KCJ, operado pela Air Astana, descolou às 13:31 UTC, no dia 11 de novembro 2018, da base militar de Alverca do Ribatejo onde realizou trabalhos de manutenção programada nas instalações da empresa de manutenção OGMA, Indústria Aeronáutica de Portugal, S.A.

O voo KC1388 tinha como destino final a base do operador no Cazaquistão, em Almaty, com escala para reabastecimento em Minsk na Bielorrússia.

A bordo seguiam três tripulantes (um comandante e dois copilotos) e três técnicos do operador.

An Embraer 190-100LR, with Aruba registration P4-KCJ, operated by Air Astana, took-off at 13:31 UTC, 11 NOV 2018, from Alverca do Ribatejo airbase, where it had undergone scheduled maintenance at OGMA, Indústria Aeronáutica de Portugal, S.A. facilities.

The flight, KC1388 had as its final destination the operator base at Almaty, Kazakhstan, with a refueling stop-over at Minsk, Belarus.

On board there were three crewmembers (a captain and two co-pilots), and three technicians from the operator.

Logo após a descolagem, com condições meteorológicas adversas, a tripulação sentiu que a aeronave não estava a responder adequadamente aos comandos. Ainda em contacto com a torre de Alverca, declararam emergência enquanto tentavam diagnosticar a causa das atitudes anormais da aeronave.

Immediately after take-off, with adverse meteorological conditions, the crew felt that the aircraft was not responding adequately to the pilot inputs. Still in contact with Alverca tower, the crew declared an emergency while trying to diagnose the cause for the abnormal aircraft attitude.

A tripulação, usando todos os recursos de controlo da aeronave nos seus três eixos, tentou imediatamente contrariar os movimentos, sem, no entanto, perceber a causa da instabilidade do voo e sem conseguir ativar o piloto automático.

The crew, using all the aircraft control resources for its 3 axis, immediately tried to counter the movements, but without understanding the cause for the flight instability and without being able to engage the autopilot.

Percebendo que estavam sem controlo efetivo da aeronave, apenas conseguiam minimizar com muito esforço, o movimento oscilatório da aeronave, tendo imposto cargas estruturais elevadas em algumas recuperações.

The crew realised that they were without effective control of the aircraft. They were only able, with considerable effort to minimize the oscillatory movements, with high structural loads involved during some recovery manoeuvres.

Ao longo de todo o voo, a tripulação debateu-se para obter o controlo da aeronave sem qualquer indicação de falha nos sistemas da mesma, apenas recebendo insistentes alertas de atitudes de voo anormais.

During the entire flight the crew struggled to gain aircraft control, having no malfunction indication from the aircraft systems, just the continuous alerts for abnormal flight attitudes.

Atendendo à criticidade da situação, a tripulação solicitou por várias vezes ao controlo de tráfego aéreo indicação de rumo para o mar com a intenção de amarar o avião, não tendo, no entanto, conseguido manter os rumos desejados para cumprir esse objetivo.

Considering the critical situation, the crew requested several times to the air traffic control for headings in order to reach the sea for ditching, not being able, however, to keep the intended course for that purpose.

Foi constatado pela tripulação que os *ailerons* estavam com um comportamento errático e, portanto, foi minimizado o comando de rolamento.

The crew realised that the ailerons were behaving erratically and therefore any command for the aircraft roll was kept to its minimum.

A situação melhorou significativamente quando a aeronave, já com o sistema de comandos de voo em modo direto, adquiriu referências visuais (VMC) com a melhoria das condições meteorológicas, no entanto sem restabelecer a operação normal e mantendo-se as dificuldades de controlo no eixo longitudinal da aeronave.

The situation improved considerably when the aircraft, already with the flight controls in direct mode, reached visual conditions (VMC) with better weather conditions, however, without restoring normal operation and maintaining the aircraft roll-axis control difficulties.

Ao ganharem algum controlo da situação voaram para Este por forma a manterem as condições visuais e começaram a seguir o plano sugerido pelo serviço de controlo de tráfego aéreo para uma aterragem de emergência num aeroporto com boas condições meteorológicas e físicas para lidar com as dificuldades de controlo reduzido da aeronave.

Having gained some control over the situation, the crew flew East in order to maintain VMC, and followed the flight plan suggested by the air traffic control for an emergency landing in a suitable airport, with good weather and physical conditions to deal with the aircraft control difficulties.

Nessa fase em que os pilotos já conseguiam manter a altitude e o rumo, e mantinham condições visuais com o terreno, juntou-se à aeronave uma parelha de caças F-16 da Força Aérea Portuguesa que ajudaram no guiamento até ao aeroporto de Beja, entretanto eleito pelo ATC como a melhor opção para a aterragem de emergência.

At that moment, when the pilots were able to keep altitude and heading, and had sufficient visual references, the aircraft was joined by a pair of F-16 fighters from the Portuguese Air Force, which assisted in guiding it to Beja airport, which had been selected by ATC in the meantime as the best emergency landing option.

Depois de duas aproximações não estabilizadas, a aeronave conseguiu aterrar em segurança na pista 19L após a terceira aproximação. A pista pretendida seria a 19R, no entanto a aeronave foi arrastada por efeito do vento para a esquerda, conseguindo finalmente aterrar.

After two non-stabilised approaches, the aircraft managed to land safely on runway 19L at the third approach. The intended runway was 19R, but due to wind drift, they finally managed to land on the left runway.

O GPIAAF foi notificado da ocorrência pouco depois do início do voo, tendo deslocado uma equipa de investigação de aviação civil para o local da aterragem de emergência com vista à recolha de evidências.

GPIAAF was notified shortly after the beginning of the occurrence flight and an investigation team travelled to the emergency landing airport for evidence gathering.

Na avaliação subsequente da condição da aeronave foi constatado que as superfícies dos *ailerons* estavam com atuação em sentido contrário ao comando dado no volante de controlo (yoke) por inversão dos seus cabos de comando em ambas as semi-asas.

During the subsequent aircraft condition assessment, it was found that both aileron surfaces were acting in the opposite direction of control yoke command, in result of control cables reversal in both semi-wings.

Tipo de ocorrência || Occurrence type

SCF-NP/LOC-I: Falha de sistema da aeronave com origem em ações de manutenção pela inversão dos cabos dos *ailerons* e consequente perda de controlo em voo.

SCF-NP/LOC-I: Aircraft system malfunction related with maintenance actions, namely the aileron cables reversal and consequent loss of control in flight.

Principais conclusões da Investigação || Investigation main conclusions

A instalação incorreta dos cabos do sistema de comandos de voo da aeronave durante as atividades de manutenção pesada, resultando numa reversão da operação do sistema dos *ailerons* da aeronave e consequente perda de controlo durante o voo, foi identificada como a causa do acidente.

The incorrect installation of the aircraft's flight control cables system during heavy maintenance activities, resulted in the aircraft's aileron system reversal operation and consequent loss of control during flight, was identified as the cause of the accident.

Contribuíram para o evento lacunas então existentes do sistema de garantia da qualidade do prestador de serviços de manutenção e falha na implementação de uma supervisão interna e

Contributed to the event, the existing gaps in the maintenance service provider quality assurance system and failure to implement an effective internal and external maintenance activities

externa eficaz das atividades de manutenção, potenciadas pelo projeto da aeronave e respetivas instruções de manutenção no que respeita à configuração do sistema de comando dos *ailerons.*

oversight, enhanced by the aircraft design and the corresponding maintenance instructions regarding the ailerons control system configuration.

Recomendações e seus destinatários || Recommendations and their addressees

As conclusões da investigação conduziram à emissão de três recomendações de segurança ao prestador de serviços de manutenção no sentido de reforçar o seu sistema de controlo produtivo, de qualidade e supervisão, bem como de uma recomendação ao fabricante da aeronave para produzir documentação guia de apoio aos operadores e prestadores de serviços de manutenção no processo de libertação das aeronaves para voo, após intervenções de manutenção complexas.

As a result of the investigation conclusions, three safety recommendations were issued to the maintenance service provider in order to strengthen its production control, quality system and oversight, as well as a safety recommendation to the aircraft manufacturer to produce guidance material to support operators and maintenance service providers in the process of aircraft release to service, after complex maintenance events.

Conforme fica patente neste relatório, o processo de supervisão no âmbito da certificação do prestador de serviços de manutenção é fundamental para minimizar o risco da existência dos fatores que resultaram no acidente. Dada a abrangência destes aspetos, entendeu a Autoridade de Investigação que uma recomendação de segurança neste domínio não seria eficaz. Contudo, perante os factos e conclusões evidenciadas no relatório de investigação, a Autoridade Nacional de Aviação Civil, no exercício das suas competências e responsabilidades, necessariamente que terá de dedicar uma especial atenção à monitorização e supervisão da organização de manutenção relativamente às lacunas identificadas neste relatório

As shown in this report, the oversight process within the scope of the maintenance service provider certification is fundamental to minimize the risk of the identified factors that resulted in the accident.

Considering the broad range of these aspects, the investigation considered that a safety recommendation in this domain would not be effective. However, in view of the facts and conclusions evidenced in the report, the National Civil Aviation Authority (ANAC), in the exercise of its competences and responsibilities, must dedicate special attention to the maintenance organization oversight and monitoring, especially over the gaps identified on the investigation.

De igual forma, a Autoridade de Aruba (DCA), dentro das suas responsabilidades e respetivo referencial de certificação, deverá supervisionar o prestador de serviços sobre as lacunas identificadas nesse domínio.

Likewise, the Aruba Authority (DCA), within its responsibilities and respective certification framework, should properly oversight the maintenance service provider on the gaps identified in that domain.

GLOSSÁRIO || GLOSSARY

ADMS	Sistema de diagnóstico e manutenção da aeronave || Aircraft Diagnostic and Maintenance System
AMM	Manual de Manutenção da Aeronave || Aircraft Maintenance Manual
OMA/AMO	Organização de Manutenção Aprovada || Approved Maintenance Organization (MRO)
ANAC	Autoridade Nacional da Aviação Civil || National Civil Aviation Authority
AP	Piloto automático || AutoPilot
ASCB	Barramento de comunicação padrão de aviónicos || Avionic Standard Communication Bus
ATA Spec 100	Sistema de numeração de capítulos pela Air Transport Association || Air Transport Association chapter numbering system
ATPL (A)	Licença de Piloto de Linha Aérea (Avião) || Airline Transport Pilot Licence (Aeroplane)
CENIPA	Centro de Investigação e Prevenção de Acidentes Aeronáuticos (SIA do Brasil) || Aeronautical Accidents Investigation and Prevention Center (SIA of Brazil)
CPL(A)	Licença de Piloto Comercial (Avião) || Commecial Pilot Licence (Aeroplane)
DVDR	Gravador digital de voz e dados (CVR+FDR) || Digital Voice and Data Recorder (CVR+FDR)
EASA	Agência da União Europeia para a Segurança da Aviação || European Union Aviation Safety Agency
EICAS	Sistema de indicação e aviso do motor à tripulação || Engine Indication and Crew Alerting System
FAA	Administração Federal da Aviação dos Estados Unidos da América || Federal Aviation Administration
FAP	Força Aérea Portuguesa || Portuguese Air Force
FCM	Módulo de comandos de voo || Flight Control Module
FCP	Painel dos comandos de voo || Flight Control Panel
FCS	Sistema de comandos de voo || Flight Control System
FHDB	Base de dados de histórico de falhas || Fault History Data Base
ft	Pé ou Pés (unidade de medida) || Feet (unit of measure) [1ft=0,3048m]
GPIAAF	Gabinete de Prevenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviários || Office for the Prevention and Investigation of Accidents in Civil Aviation and Rail (SIA PT)
h	Hora (unidade de medida) || Hour (unit of measure) [1h=3600s]
HPC	Compressor de alta pressão || High pressure compressor
IATA	Associação Internacional de Transporte Aéreo || International Air Transport Association
ICAO	Organização Internacional da Aviação Civil || International Civil Aviation Organization
IFR	Regras de voo por instrumentos || Instrument Flight Rules
IMC	Condições meteorológicas de voo por instrumentos || Instrument Meteorological Conditions

MIID	Ministério da Indústria e Desenvolvimento das Infrastruturas da República do Cazaquistão, Departamento para a Investigação de Acidentes e Incidentes || Ministry of Industry and Infrastructural Development of the Republic of Kazakhstan - Department for Investigation of Accidents and incidents (NIA of Kazakhstan)
kg	Quilograma (unidade de medida base SI) || Kilogram (SI base unit of measure)
kt	Nó (unidade de medida) || Knot (unit of measure) [1kt=1NM/h=1,852km/h]
LH	Lado esquerdo || Left hand
LPAR	Base militar de Alverca do Ribatejo || Airbase of Alverca do Ribatejo
LPBJ	Aeroporto/base militar de Beja|| Beja Airport/Military Airbase
LPPT	Aeroporto Internacional de Lisboa|| Lisbon International Airport
m	Metro (unidade de medida base SI) || Metre (SI base unit of measure)
MAC	Corda média aerodinâmica || Mean aerodynamic cord
MOM	Manual da organização da manutenção || Maintenance Organization Exposition
MSL	Nível médio das águas do mar || Mean Sea Level
N/A	Não aplicável || Not applicable
NM	Milha Náutica (unidade de medida) || Nautical Mile (unit of measure) [1NM=1852m]
NTSB	Agência dos Estados Unidos da America responsável por investigar acidentes com transportes || National Transportation Safety Board
NVM	Memória não volátil || Non-Volatile Memory
OEM	Fabricante de equipamento original || Original Equipment Manufacturer
PF	Piloto a voar || Pilot Flying
PIC	Piloto Comandante || Pilot In Command
PM	Piloto a monitorizar || Pilot Monitoring
RH	Lado direito || Right hand
RTS	Retorno ao serviço || Return To Service
s	Segundo (unidade de medida base SI) || Second (SI base unit of measure)
SB	Boletim de serviço || Service Bulletin
SIA	Gabinete de Investigação de Segurança || Safety Investigation Agency
SMS	Sistema de gestão de Segurança || Safety Management System
SOP	Procedimentos operacionais padronizados || Standard Operating Procedure
UTC	Tempo Universal Coordenado || Universal Time Coordinated
VFR	Voo com condições visuais || Visual Flight Rules
VMC	Condições Meteorológicas Visuais || Visual Meteorological Conditions
°C	Grau Celsius (unidade de medida) || Degree Celsius (Unit of measure) [1°C=273,15K]
° ' "	Coordenadas geograficas (graus; minutos; segundos) || Geographic coordinate system (degrees; minutes; seconds)

1. INFORMAÇÃO FACTUAL || FACTUAL INFORMATION

1.1. História do voo || History of the flight

A 02-OUT-2018 uma aeronave Embraer 190-100LR, com registo de Aruba P4-KCJ, operado pela Air Astana aterrou na base militar de Alverca do Ribatejo, Portugal (LPAR), com o objetivo de efetuar um pacote de trabalhos de manutenção programada nas instalações da OGMA, Indústria Aeronáutica de Portugal, S.A., uma organização de manutenção EASA Parte 145 (AMO) aprovada pela ANAC e também pela autoridade DCA de Aruba com base no reconhecimento da certificação EASA Parte 145.

On OCT 2nd 2018 an Embraer 190-100LR aircraft, Aruba registered P4-KCJ, operated by Air Astana landed at the military airbase of Alverca do Ribatejo, Portugal (LPAR), to perform a scheduled heavy maintenance work package in OGMA, Indústria Aeronáutica de Portugal, S.A., facilities, a maintenance organization EASA Part 145 (AMO) approved by ANAC and also by the Aruba DCA authority, based on the recognised EASA Part 145 approval.

Os trabalhos de manutenção pesada programada e previstos no programa de manutenção da aeronave, eram constituídos por uma inspeção básica denominada pela AMO como C2-Check (1C+2C+6YR), incluindo modificações complexas através da aplicação de vários boletins de serviço (SB), com remoção e instalação de unidades de aviónicos modulares e alguns trabalhos adicionais solicitados pelo operador e correções de anomalias decorrentes da referida inspeção básica.

The heavy maintenance work scheduled in accordance with the aircraft maintenance program, consisted of a basic inspection, named by the Part 145 as C2-Check (1C + 2C + 6YR), including complex modifications through the accomplishment of several service bulletins (SB), requiring modular avionics unit removal and installation, some additional work requested by the operator and the discrepancies correction resulting from the aforementioned basic inspection.

A 09-OUT-2018, já com a aeronave desenergizada, deu-se início à execução de um boletim de serviço (SB190-57-0038R2), que modificava o tipo de encaminhamento dos cabos de comando dos *ailerons,* com a substituição de roldanas e respetivos suportes estruturais por um passador sem contacto, por forma a reduzir o atrito dos cabos de comando naquela zona (figura 1 abaixo).

On OCTOBER 09th 2018, with the aircraft already de-energized, a service bulletin (SB190-57-0038R2) was initiated, which changed the type of routing of the ailerons' control cables, with the replacement of pulleys and respective structural supports by a non-contact support, aiming to reduce the control cable friction on that area (figure 1 below).

O trabalho estrutural, com a remoção e cravação dos suportes na longarina traseira da asa na zona do tanque de combustível, obrigava ainda à desconexão completa dos cabos de comando. Esta tarefa foi terminada a 11-OUT pelos técnicos de estruturas.

The structural work, with the removal and crimping of the supports in the rear wing spar in the fuel tank area, also required the complete disconnection of the control cables. This task was completed on October 11th by structures - SM technicians.

Um outro boletim de serviço, o SB190-27-0037R1, que consistia na substituição dos cabos de comando instalados, fabricados em aço inoxidável, por cabos em aço-carbono, foi também executado durante esta intervenção de manutenção.

Another service bulletin, SB190-27-0037R1 was accomplished, which consisted of replacing the installed stainless-steel control cables by carbon steel cables.

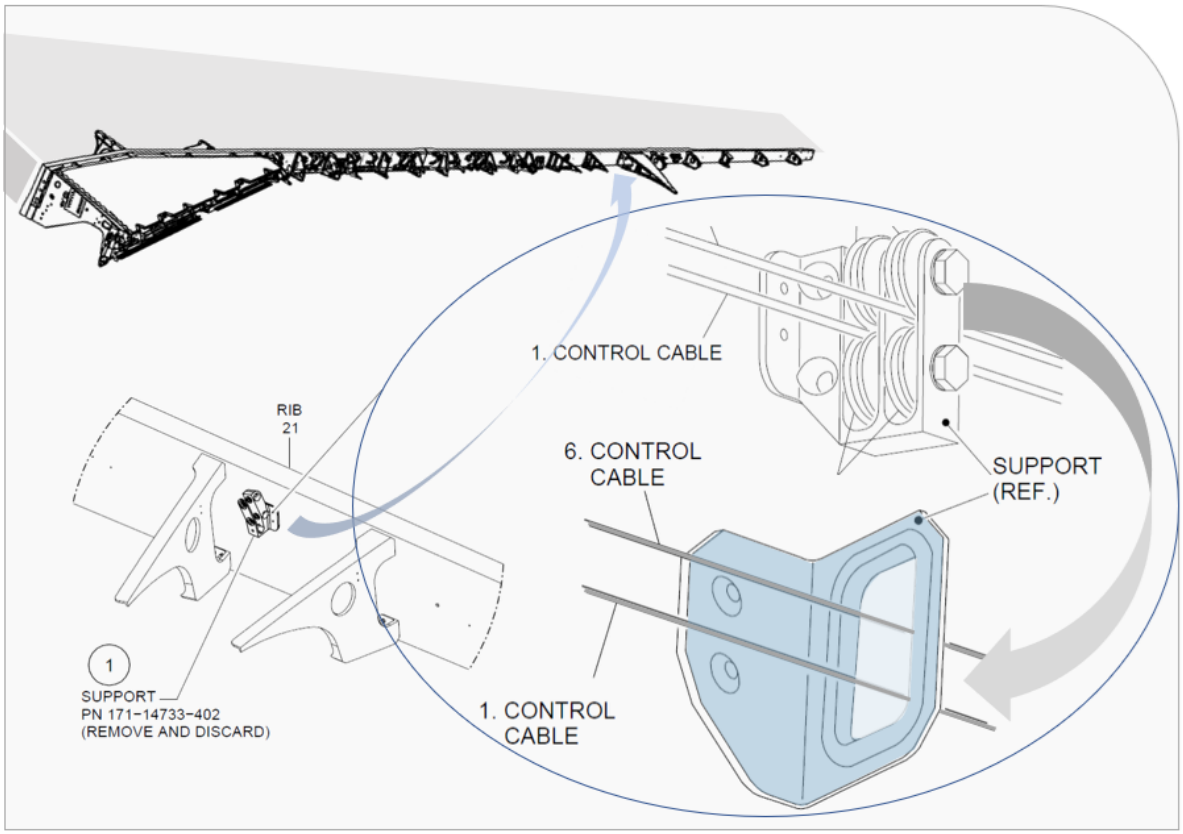

Figura 1 || **Figure 1**

Ilustração da modificação aos suportes dos cabos (SB190-57-0038R2) || Cable support modification illustration (SB190-57-0038R2)

Foram ainda realizados outros trabalhos de manutenção no sistema de cabos de comando dos *ailerons*, como lubrificações, ajustes e ensaios, onde foram detetadas pela investigação inconsistências nos registos documentais, incluindo falhas no preenchimento das cartas de trabalho referentes a datas incongruentes e inspeções independentes[1] não realizadas.

A 26-OUT e no seguimento dos ensaios operacionais após re-energizar a aeronave, surge uma mensagem no sistema de aviso à tripulação da aeronave (EICAS), de que a aeronave não poderá ser despachada para voo por apresentar problemas no sistema de comandos de voo (FLT CTR NO DISPATCH).

Por este motivo, os ensaios operacionais de comandos de voo, entretanto deixados pendentes onde se inclui a tarefa AMM 27-10-00-710-801 –

Other maintenance works were also carried out on the aileron control cable system, such as lubrication, adjustments and tests, where inconsistencies were detected by the investigation in the maintenance records, including errors among the working cards sign-off namely inconsistencies on dates and independent inspections[1] procedures not performed.

On OCT 26th and following the operational tests after aircraft power-up, a message appeared in the engine indication and crew alerting system (EICAS) that the aircraft cannot be dispatched for flight due to problems related with the flight control system (FLT CTR NO DISPATCH).

For this reason, flight control operational tests, which had been left pending, including the AMM task 27-10-00-710-801 – "Aileron control system operational test" could not be accomplished.

[1] Inspeção independente: Inspeção a realizar em tarefas consideradas críticas com impacto em determinados sistemas críticos das aeronaves com o objetivo de avaliar a sua função e sentido de operação após a realização de trabalhos nos ditos sistemas (não confundir com dupla verificação) || Inspection to specific critical tasks on critical disturbed aircraft systems aiming the verify the function and sense of those systems (no similarities with the double check inspections).

"Aileron control system operational test", não puderam ser concluídos.

Os trabalhos de manutenção continuaram até ao dia 31-OUT, data na qual é realizado um conjunto de testes à aeronave, incluindo a colocação de motores em funcionamento e realizada a inspeção final à aeronave onde se incluem os testes de comandos de voo.

The maintenance work lasted until OCT 31st, during this time several tests were performed on the aircraft, including engines run-up and the aircraft final inspection, which included the flight control tests.

Porém, o pessoal de manutenção não identificou a inversão dos cabos de *aileron* durante as verificações operacionais posteriores, apesar das tarefas de manutenção requererem a correta confirmação da deflexão física das superfícies com os comandos do volante de controlo (*control yoke*).

However, the maintenance personnel did not identify the inversion of the aileron control cables during this late operational check, even though the maintenance instructions required them to confirm the correct surface deflections with control wheel inputs.

Após a realização dos ensaios finais da inspeção programada e mantendo-se a mensagem relativa à impossibilidade de despacho da aeronave com um problema com causas não identificadas no sistema de comandos de voo, a aeronave foi entregue pela equipa de manutenção programada ao gestor da área.

Este, por sua vez, alocou uma pequena equipa à aeronave com o objetivo de realizar a pesquisa da referida anomalia (FLT CTR NO DISPATCH).

After performing the final tests within the scheduled inspection scope and still having present the maintenance message regarding the flight controls preventing the aircraft dispatch with unidentified causes in the flight control system, the aircraft was delivered by the scheduled maintenance team to the area manager. In turn, the manager allocated a small team to the aircraft in order to carry out the investigation of the anomaly (FLT CTR NO DISPATCH).

A entrega da aeronave, com data de finalização prevista para 24 OUT, mais tarde renegociado com o operador um adiamento para 31 OUT, começa a sofrer pressões internas e externas à organização de manutenção para a entrega e retorno ao serviço. O operador, nas várias tentativas de obter respostas e a resolução do problema, disponibilizou os seus serviços técnicos, dando sugestões de possíveis problemas induzidos na aeronave durante os trabalhos de manutenção.

The aircraft final delivery date was initially scheduled for OCT 24th, later renegotiated with the operator for OCT 31st, the maintenance organization starts to suffer internal and external pressures for aircraft delivery and return to service. The operator, in the several attempts to obtain answers and the problem resolution, made available his technical services, giving suggestions of possible aircraft induced problems during the scheduled maintenance.

Após um período de pesquisa e resolução da anomalia, que decorreu até 11-NOV, envolvendo todas as áreas operacionais da AMO, operador e OEM (Embraer), a aeronave foi dada como apta para voo pela AMO. A aeronave foi preparada e posicionada para entrega à tripulação do operador, que aguardava a finalização dos trabalhos de manutenção e entrega da documentação.

After a period of troubleshooting, which ran until NOV 11th, involving all AMO operational areas, operator and OEM (Embraer), the aircraft was released for return to service by the AMO. The aircraft was prepared and positioned for the operator's delivery crew that was waiting for the maintenance work completion and documentation delivery.

Durante a realização dos preparativos operacionais pela tripulação, às 11:25 foi detetado um problema relacionado com a ventilação de um dos compartimentos de aviónicos e um dos

During operational checks and acceptance by the crew, at 11:25 a problem was detected related to the ventilation in one avionics compartment and one hydraulic system was found low , which led

sistemas hidráulicos encontrado com nível baixo, que levou a tripulação a não aceitar a aeronave, solicitando intervenção da manutenção.

Resolvidos os problemas, é iniciado um novo ciclo de preparação do voo pela tripulação seguindo os procedimentos do operador.

A aeronave realizou o táxi para o início da pista 04, após coordenação de tráfego entre os serviços ATC de Alverca e Lisboa, a tripulação inicia a descolagem às 13:30:21, sem reporte de qualquer anomalia adicional.

O Voo do evento:

A bordo, no *cockpit* seguia o piloto comandante que assumiu as funções de piloto a voar (PF) e dois copilotos, que em diferentes fases assumiram a posição de piloto a monitorizar (PM) e agindo sobre os comandos da aeronave sob ordens do PF. Na cabine e enquanto passageiros, seguiam três elementos técnicos do operador, o responsável pela gestão dos ativos técnicos do operador, um técnico de manutenção que acompanhou a realização dos trabalhos na AMO e um técnico de aprovisionamento de material.

De acordo com a informação meteorológica disponível para a base militar de Alverca, as condições atmosféricas eram caracterizadas por tetos baixos, com uma primeira camada aos 500ft, seguido de uma segunda aos 1500ft, com uma visibilidade horizontal em torno dos 2000m com chuva. O vento reportado pela torre de Alverca era de 050˚ com 7kt de intensidade.

Logo após a descolagem na pista 04 que ocorreu às 13:31:35, segundo declarações do PF à investigação, este terá tentado pela primeira vez, sem sucesso, ativar o piloto automático (AP). Às 13:32:48, ainda em contacto com a torre de Alverca e na linha de subida, a tripulação declara emergência enquanto tentavam diagnosticar a causa das atitudes de rolamento anormais da aeronave, recebendo apenas informação de falha do sistema de piloto automático (AP FAIL) sem outras mensagens associadas. Segundo os dados de voo da aeronave, às 13:33:20, a tripulação terá ativado uma primeira vez o modo direto do sistema de comandos de voo.

Em condições de voo por instrumentos, IMC e percebendo que estavam sem controlo efetivo da aeronave, contrariavam o movimento oscilatório

the crew to not accept the aircraft, requesting maintenance intervention.

Once the problems were solved, a new flight preparation cycle was initiated by the crew following the operator procedures.

The aircraft performed the taxi to runway 04 threshold, which after traffic coordination between Alverca and Lisbon ATC services, the crew initiated the take-off at 13:30:21, without reporting any additional anomaly.

Event Flight:

On board in the cockpit there were the pilot who assumed the functions of pilot flying (PF) and two co-pilots, who in different phases assumed the position of pilot to monitor (PM) and acting on the controls of the aircraft under the command of the PF. In the cabin and as passengers, followed three operator technicians, the director of technical asset management, a maintenance technician who followed the C-Check at AMO and a material supply technician (operator logistics).

In accordance with the available meteorological information for Alverca military airbase, the local atmospheric conditions were characterized by low ceilings, reported a first layer at 500ft, and a second at 1500ft, with a horizontal visibility of about 2000m with rain. The wind reported by Alverca control tower was 050˚ with 7kt.

Just after taking off on runway 04 occurred at 13:31:35, the PF declared to the investigation that he tried for the first time, without success, to activate the autopilot (AP). At 13:32:48, still in contact with Alverca tower and on initial climb heading, the crew declared emergency while trying to diagnose the cause of the aircraft's abnormal roll attitudes, receiving only autopilot system (AP FAIL) fault information, without any other associated messages.

As per aircraft flight data, at 13:33:20, the crew first activated the flight control system direct mode.

In instrument flight conditions, IMC and realizing that they were without aircraft effective control, their control inputs to counteract to the aircraft

da mesma, daí resultando a imposição de cargas estruturais elevadas em algumas das recuperações de altitude.

movement imposed high structural loads in some altitude recoveries.

Já em contacto com o controlo de tráfego aéreo da aproximação de Lisboa, atendendo à iminente perda de controlo da aeronave, a tripulação solicitou por várias vezes a indicação de rumos para o mar, tendo como objetivo a amaragem para minimização de danos na aeronave e proteção das populações numa eventual queda descontrolada da aeronave em terra.

In contact with Lisbon approach air traffic control, and given the imminent aircraft loss of control, the crew requested several times headings to the sea, with the purpose of ditching to minimize aircraft damage and to protect people on ground in the event of an uncontrolled aircraft crash landing on land.

Devido à falta de controlo efetivo da aeronave, a tripulação não conseguiu manter os rumos desejados para o mar, voando para NE como resultado das diversas manobras.

Due to the lack of effective aircraft control, the crew was unable to maintain the desired headings to the sea, flying to NE as result of the flight manoeuvres.

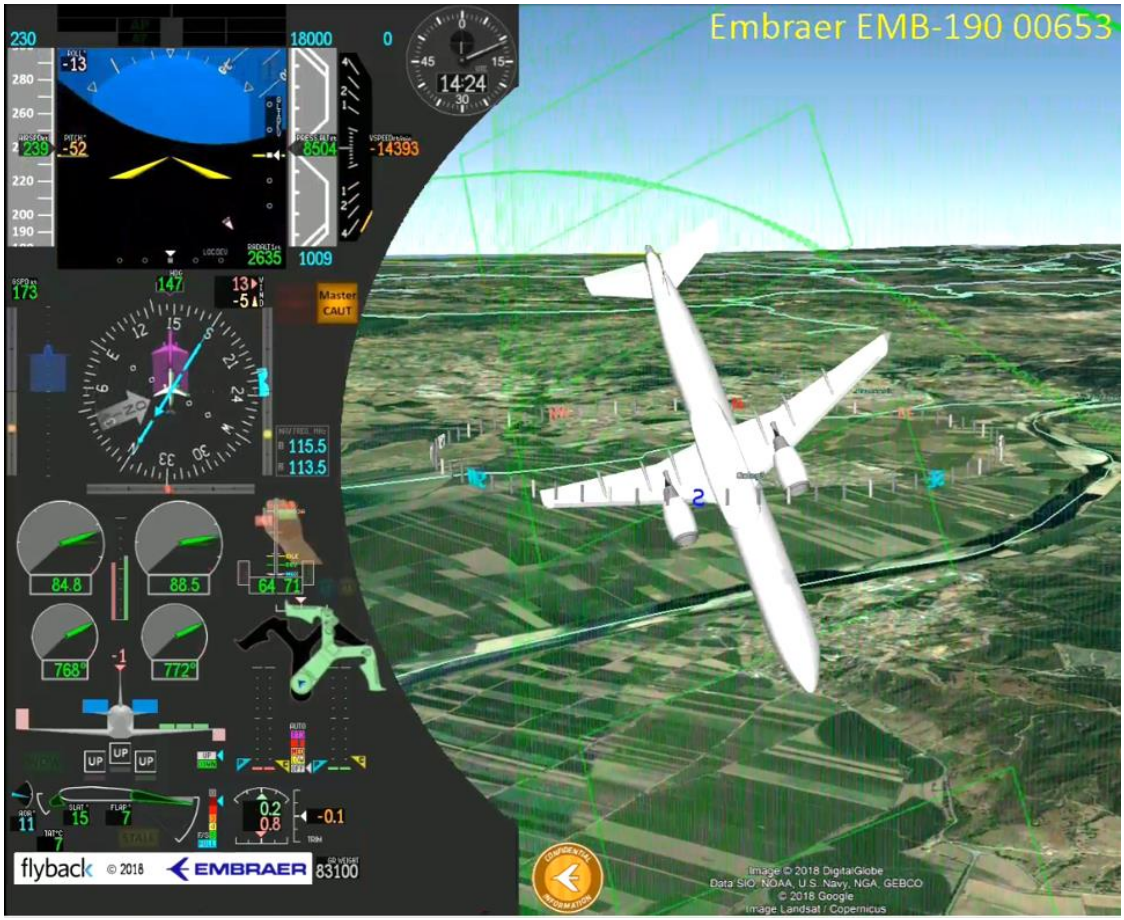

Figura 2 || **Figure 2**

Atitude anormal da aeronave – Exemplo FDR
Fonte: flyback Embraer

|| Abnormal aircraft attitude – FDR example
Source: flyback Embraer

A tripulação foi trabalhando em equipa, discutindo opções com o terceiro ocupante (copiloto em *jump-seat*) e tentando comunicar com os técnicos a bordo no sentido de formularem hipóteses e planos de ação.

The crew worked as a team, discussing options with the third occupant (jump-seat co-pilot) and trying to communicate with the technicians on board in order to formulate hypotheses and action plans.

Foi então decidido manter a posição de FLAPS 1 (*Slat* 15° e *Flap* 7°) após tentativa de recolha para a posição 0 com influência negativa no controlo em torno do eixo longitudinal. Foi também constatado o comportamento errático dos *ailerons* entre o comando dado pelo PF e a posição real das superfícies observada através da cabine e confirmado na página Sinótica de comandos de voo.

It was then decided to maintain the FLAPS 1 position (Slat 15 ° and Flap 7 °) after attempting to retract to position 0 with a negative influence on the longitudinal control axis. It was also verified the erratic behaviour of the ailerons between the given command by the PF and the real position of the observed surfaces through the cabin and confirmed in the flight controls Synoptic page.

Mesmo sem falhas de sistemas anunciadas, a tripulação, após selecionar várias vezes entre os modos direto e normal do sistema de comandos de voo, decidiu manter todo o sistema em modo direto (*elevators*, *rudder* e *spoilers*), onde o módulo de comandos de voo (FCM) é removido da cadeia de comando das superfícies de voo, passando estas a serem comandadas com relação direta aos comandos dos pilotos. Nota: No modo direto, a programação do ganho em função da velocidade do ar é removida da cadeia de comando das superfícies de voo, passando estas a serem comandadas com um ganho fixo em relação aos comandos dos pilotos.

Even without announced system failures, the crew, after switching several times between the direct and normal modes of the flight control systems, decided to keep the system in direct mode (elevators, rudder and spoilers) for entire flight, where the flight control module (FCM) is removed from flight surfaces control chain, which are then controlled in a direct proportion with the pilots' inputs on the yoke and pedals.

Note: In the direct mode the airspeed gain schedule is removed from the command path and the flight control surfaces are commanded with a fixed gain in relation to the flight crew commands.

Com uma estratégia de aprendizagem por tentativa e erro, a situação melhorou significativamente, no entanto sem restabelecer a operação normal e mantendo-se as dificuldades de controlo no eixo longitudinal da aeronave.

With a trial and error learning strategy, the situation improved significantly, however without restoring the normal operation and maintaining control difficulties in the aircraft's longitudinal axis.

Ganhando algum controlo sobre a aeronave e ao voarem para Este, a tripulação encontrou melhores condições meteorológicas assegurando a visualização do terreno que permitiu uma ação mais precisa sobre os comandos da aeronave.

Assuring some aircraft control and flying to East, the crew found better weather conditions that allowed visual cues providing better and precise action on the aircraft's flight controls.

Seguindo uma sugestão de plano traçado pelo serviço de controlo de tráfego aéreo para uma aterragem de emergência num aeroporto com boas condições meteorológicas e físicas, às 14:45 a tripulação voou para Sul para uma expectável difícil aterragem, com controlo limitado da aeronave.

Following an air traffic control service suggestion with a plan drawn for an emergency landing at a suitable airport with good weather and physical conditions, at 14:45 the crew flew South for an expected difficult landing, with limited aircraft control.

Nesta fase em que os pilotos já conseguiam manter altitude e o rumo, e mantinham condições visuais, juntou-se à aeronave uma parelha de caças F-16 da Força Aérea Portuguesa que ajudaram no guiamento até ao aeroporto de Beja, entretanto eleito como a melhor opção para a aterragem de emergência.

At that moment, when the pilots were able to keep altitude and heading, and had sufficient visual references, the aircraft was joined by a pair of F-16 fighters from the Portuguese Air Force, which assisted in guidance to Beja airport, that had been selected in the meantime as the best emergency landing option.

Feita a coordenação para uma descida e aterragem direta na pista 19R em Beja (LPBJ), as

Coordinated for a direct approach and landing on runway 19R in Beja (LPBJ), the control difficulties

dificuldades de controlo na aproximação não estabilizada evidenciaram a necessidade de descontinuar a aproximação.

in the unstabilized approach evidenced the need to discontinue the approach.

Motivado pelo desgaste físico e indisposição do PM, o PF decidiu a troca de posições dos co-pilotos, onde o co-piloto em *jump-seat* assumiu a posição de PM ajudando o PF logo após o borrego.

Because of the physical exhaustion and unwell condition of the PM, the PF decided to switch the co-pilots positions, where the jump-seat co-pilot assumed the PM position, helping the PF just after the go-around.

Depois de duas aproximações não estabilizadas, a tripulação, às 15:27, conseguiu aterrar a aeronave em segurança na pista 19L após a terceira aproximação. A pista pretendida seria a 19R, no entanto a aeronave foi arrastada para a esquerda.

After two non-stabilised approaches, at 15:27 the crew managed to safely land the aircraft on runway 19L after the third approach. The intended runway was 19R, however the aircraft drifted to the left.

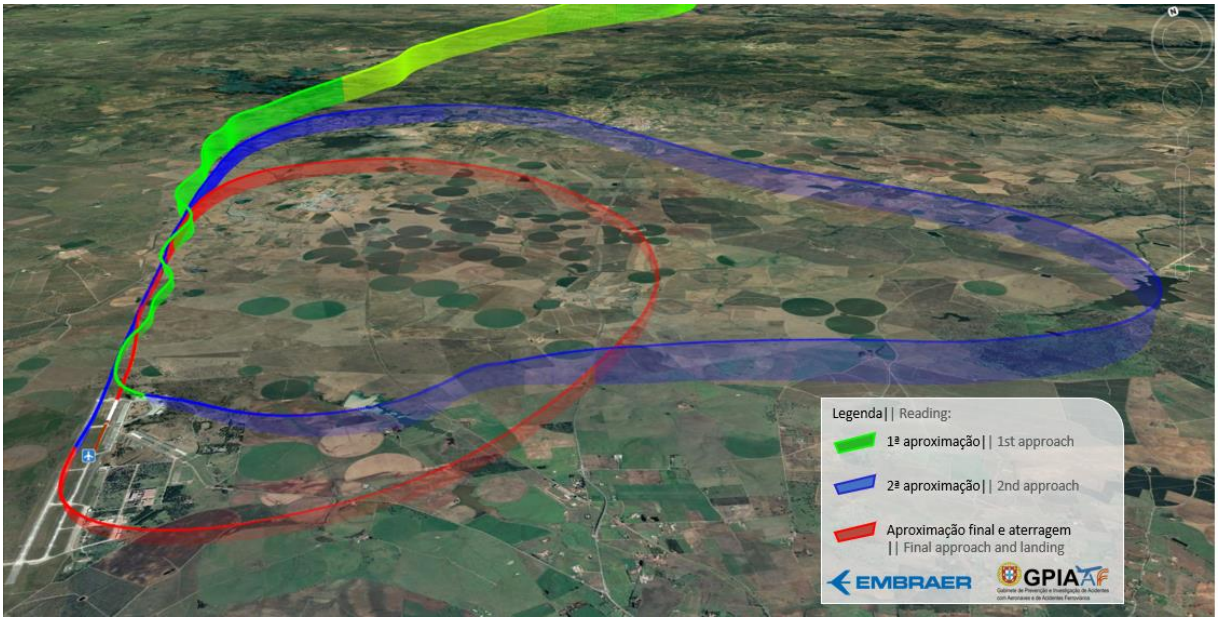

Figura 3 || **Figure 3**

Trajetória na aproximação e aterragem em LPBJ
Fonte: DVDR e google Earth

|| LPBJ approach and landing trajectory
Source: DVDR and google Earth

Nos momentos finais de desaceleração e pouco antes de a aeronave se imobilizar na pista, o EICAS apresentou a mensagem FLT CTR NO DISPATCH.

In the final deceleration moments and just before the aircraft came to stop on the runway, the EICAS presented the message FLT CTR NO DISPATCH.

1.2. Lesões || Injuries to persons

Lesões || Injuries	Tripulantes || Crew	Passageiros || Passengers	Outros || Others
Mortais || Fatal	0	0	0
Graves || Serious	0	0	0
Ligeiras || Minor	0	1	0
Nenhumas || None	3	2	0
TOTAL	3	3	0

O copiloto que assumiu as funções de PM durante grande parte do voo e até ser substituído nas suas funções pelo colega em *jump-seat*, foi o elemento da tripulação técnica que sofreu mais sintomas de enjoo e mau estar provocado pela dinâmica do voo do acidente.

Um dos passageiros, enquanto tentava comunicar com o *cockpit* e não estando sentado, num dos movimentos bruscos da aeronave, caiu e sofreu lesões no tornozelo direito, tendo sido transportado à unidade hospitalar mais próxima, com alta médica no próprio dia do acidente.

Devido às atitudes anormais da aeronave e cargas em voo, todos em voo sentiram *stress* e alguns com sintomas de enjoo. Um segundo passageiro foi assistido devido a expressar sintomas de ansiedade.

The co-pilot who assumed the PM role during most of the flight and until he was replaced in his duties by his colleague in jump-seat, was the person of the technical crew who suffered more symptoms of nausea and discomfort caused by the accident's flight dynamics.

One of the passengers, while trying to communicate with the *cockpit* and not being seated, in one of the aircraft's sudden movements, fell and suffered injuries to his right ankle sprain, and was transported to the nearest hospital and later discharged on the same day.

Because of the flight loads and the unusual aircraft attitudes, everyone on board was stressed and many felt sick. A second passenger also received attention because of stress-related concerns.

1.3. Danos na aeronave || Damage to aircraft

Durante a fase de recolha de evidências nos dias seguintes ao voo do evento, foram encontrados danos evidentes nos painéis da fuselagem, mostrando ondulações em algumas áreas. O pneu número 4 ficou danificado quando atingiu uma lâmpada delimitadora da pista durante a aterragem.

Trabalhando em conjunto com o OEM, o operador e a AMO, a investigação prosseguiu com a avaliação de danos da aeronave por forma a garantir um levantamento completo do seu estado.

As verificações de alinhamento e simetria foram realizadas pelo OEM à fuselagem, asas, estabilizador horizontal, pontas de asa, trem de aterragem e motores. O diedro da asa na nervura 26 revelou estar fora da tolerância prevista, com evidência de deformação permanente (valores: -32' para um limite de +/- 20').

Nota: ' submúltiplo de grau - minutos.

Foram encontradas deformações no revestimento de fuselagem em ambos os lados junto à zona inferior do reforço orbital na junção entre as fuselagens central II e III, ao longo das cérceas 73 e 74 e entre as cérceas 93 e 95.

During the evidence gathering on the following days, evident damage was found in the fuselage skin panels, showing waviness in some areas. Tire number 4 was damaged when it hit a runway edge lamp during landing roll-out.

Working together with the OEM, operator and AMO, the investigation followed an aircraft damage assessment procedure to completely assess the aircraft condition.

Alignment and asymmetry checks were performed by the OEM to the aircraft fuselage, wings, horizontal stabilizer, winglets, landing gear and engines. Wing dihedral on rib 26 revealed to be out of tolerance, showing a permanent deformation (values: -32’ out of +/-20’).

Note: ’ stands for degree submultiple - minutes.

LH and RH fuselage skin deformation were found close to the lower part of orbital skin joint between Center Fuselage II and III, among frames 73 and 74 and between frames 93 and 95.

Foram encontradas deformações ao longo de todo o bordo de ataque das asas. A geometria do dano é mais evidente nas regiões dianteira e traseira e mais suave nas regiões interna e externa, indicando que o dano foi causado pela deformação da asa na direção da corda.

All wing fixed leading edges were found wrinkled. The damage geometry was found sharper on forward and aft regions, and smoother on inboard and outboard regions, indicating that the damage was caused by wing bending around the wing chord direction.

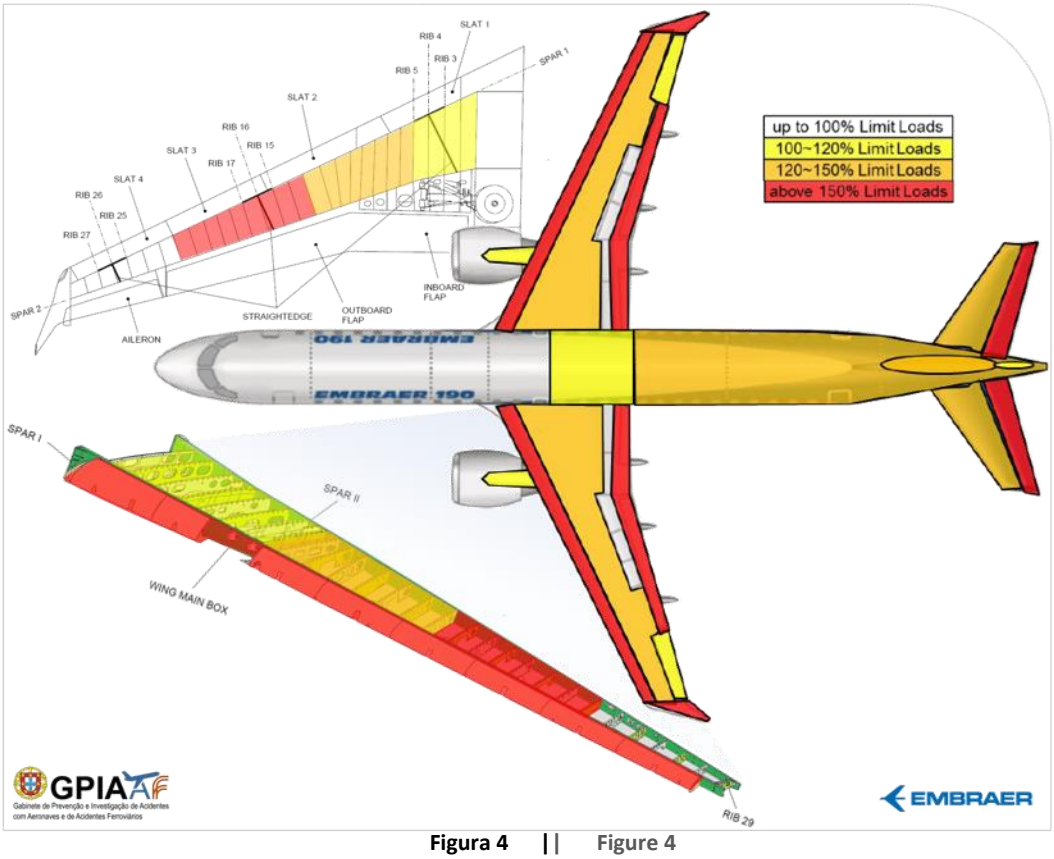

Figura 4 || **Figure 4**

Áreas da aeronave afetadas e cargas limite aplicadas durante o voo do evento || Aircraft affected areas and limit loads applied in the event flight

Durante as inspeções boroscópicas aos motores e com base no relatório de inspeção da Embraer, no motor n.º 1 foram encontrados sinais de abrasão leve nos estágios 6 e 9 do HPC, bem como evidência de fissura numa alhela do estator do 2º estágio do HPC. Relativamente ao motor n.º 2, foram também encontrados sinais de abrasão nos estágios 3, 6 e 9 do HPC.

A concordância de borracha do *flap* interior direito foi encontrada sobreposta em relação ao *flap* exterior, evidenciando movimento relativo entre ambos como resultado das cargas aerodinâmicas aplicadas durante o voo do acidente.

As cargas experienciadas durante o voo do acidente podem ter causado na estrutura da aeronave outros danos não visíveis.

Quando as cargas limite são excedidas, a estrutura pode sofrer deformação permanente, que pode

During the engines inspections (borescope) based on Embraer Technical Support inspection report, engine #1 was found with HPC stage 6 and 9 light rubbing and HPC stage 2 crack evidence in compressor stator vane. Regarding engine #2, the HPC stage 3, 6 and 9 were also found with light rubbing.

The RH inboard rubber flap was found overlapped on the outboard rubber flap, a signature of dynamic relative movements in result of the applied aerodynamic loads experienced during the accident flight.

The experienced overloads during the accident flight may have caused other non-visible damage to the aircraft structure.

When the limit loads are exceeded, the structure may have undergone permanent deformation,

ser prejudicial à estrutura primária (por exemplo, deformação excessiva de grandes áreas) ou interferir com a operação segura (por exemplo, fricção, interferência ou bloqueio das superfícies de comando).
Da avaliação realizada à estrutura primária da aeronave pelo OEM, foi evidenciada a excedência das cargas-limite e, de acordo com a avaliação estrutural realizada com base nos pressupostos e requisitos de aeronavegabilidade 14CFR e RBAC Parte 25, §25.305 (a), foi encontrada deformação permanente na aeronave.

Os danos estruturais significativos nas semi-asas e na fuselagem levaram a investigação a alterar a classificação inicial de "incidente grave" para "acidente", seguindo as diretrizes do Anexo 13 da ICAO.
De acordo com a posição do operador, a condição da aeronave foi considerada para além do custo de reparação economicamente viável (BER).

which may be either detrimental to the structure (e.g., excessive deformation over large areas) or interfere with safe operation (e.g., friction, clash or jamming of control surfaces).

The OEM performed assessments on the aircraft primary structure showed exceedance of the limit loads, and according to the structural evaluation that was conducted based on 14CFR and RBAC Part 25 airworthiness requirements §25.305 (a), some degree of detrimental permanent deformation was found on the aircraft.

The significant structural damage in both semi-wings and fuselage led the investigation to change the initial classification of "serious incident" to "accident", following ICAO Annex 13 guidelines.

In accordance with the operator position, the aircraft condition was considered beyond economical repair (BER).

1.4. Outros danos || Other damage

Três lâmpadas de iluminação da berma direita da pista 19L foram danificadas pela roda #4 da aeronave durante a aterragem de emergência.

Three right edge lights on runway 19L were damaged by the wheel #4 during the emergency landing.

1.5. Pessoas envolvidas || Personnel information

1.5.1. Tripulação técnica de voo || Flight crew

Dos documentos fornecidos foram obtidas as seguintes referências:

The following information was obtained from the supplied documentation:

	COMANDANTE || COMMANDER	COPILOTO 1 || CO-PILOT 1	COPILOTO 2 || CO-PILOT 2
DETALHES PESSOAIS || PERSONAL DETAILS			
Nacionalidade || Nationality:	Cazaquistaneza || Kazakhstan	Cazaquistaneza || Kazakhstan	Cazaquistaneza || Kazakhstan
Idade || Age:	40	32	26
LICENÇA DE TRIPULANTE TÉCNICO || FLIGHT CREW LICENCE			
Tipo || Type:	ATPL (A)	CPL (A)	ATPL (A)
Data de emissão inicial || Date of Initial Issue:	2007-NOV-28	2014-MAY-22	2016-JAN-12
Entidade emissora || Issuing Authority:	MTC[2]	MTC	MTC
Último exame médico || Last Medical Exam:	2018-OCT-12	2017-DEC-22	2018-OCT-03
Limitações || Limitations:	VDL[3]	NIL	NIL

[2] Ministério do Transporte e Comunicação do Cazaquistão || Kazakhstan Ministry of Transport and Communication
[3] Correção para visão ao longe || Correction for defective distant vision

1.5.1.1. Qualificações || Rating

Os membros da tripulação técnica possuíam todas as qualificações técnicas no tipo da aeronave (E170/190) e autorizações válidas para efetuar o voo.

The crew technical members had all the technical qualifications in the aircraft type (E170/190) and valid authorizations to perform the flight.

1.5.1.2. Experiência de voo || Flight experience

O PIC/PF, ao serviço do operador desde 28-DEZ 2011 e com mais de 6000 horas de voo, tinha uma experiência relevante no tipo de aeronave acidentada. Dadas as condicionantes e ausência de indicação de falhas ou procedimento padrão a seguir no cenário vivenciado, a sua experiência de voo e determinação na busca de soluções foram fatores decisivos para o desfecho do evento.

The PIC/PF was at the operator's service since 28 DEC 2011 with more than 6000 flight hours. He had relevant experience in the accident aircraft type. Given the constraints and the absence of failures indication or a standard procedure to be followed in the accident scenario, his flight experience and willing searching for solutions were decisive factors for the event outcome.

O copiloto 1 que iniciou o voo em Alverca na função de PM, estava ao serviço do operador desde 2013. Era o elemento da tripulação com menos experiência de voo.

The co-pilot 1 (PM) that initiated the flight in Alverca, was at the operator's service since 2013. He was the least experienced flight crew member.

O copiloto 2 que assumiu a função de PM após a primeira aproximação a Beja, estava ao serviço do operador desde 2014, sendo a sua experiência de voo quase na totalidade no tipo E190. Demonstrando sólidos conhecimentos dos sistemas da aeronave, foi um elemento da tripulação essencial na gestão da emergência, contribuindo com sugestões ao PIC desde o início do voo e como elemento de ligação com os técnicos (passageiros) na cabine.

The co-pilot 2, which assumed the role of PM after the first approach to Beja, was at the service of the operator since 2014, and his flight experience was almost entirely in E190 type. Demonstrated significant aircraft systems knowledge, he was an essential crew member in the emergency management, contributing with suggestions to the PIC since the beginning of the flight and as a liaison with the technicians (passengers) in the cabin.

	P. COMANDANTE || PIC	COPILOTO 1 || CO-PILOT 1	COPILOTO 2 || CO-PILOT 2
Horas de voo totais || Total flight time:	6.009:00	2.692:00	3.514:00
Horas de voo no tipo || Flight time on type:	4.700:00	2.442:00	3.084:00
Últimos 90 dias || Last 90 days:	119:00	140:00	113:00
Últimos 28 dias || Last 28 days:	23:00	21:00	23:00
Últimos 7 dias || Last 7 days:	05:00	00:00	02:00
Últimas 24 horas || Last 24 hours:	00:00	00:00	00:00

1.5.2. Passageiros a bordo no voo de posição || On board passengers for the positioning flight

No voo de regresso à sua base de operação, seguiam três elementos técnicos do operador como passageiros, sendo eles o Diretor técnico pela gestão dos ativos técnicos do operador, o técnico de manutenção que acompanhou a

On board on the flight back to their base, as passengers, followed three technical operator staff, who were technical personnel from the operator, including the Director Technical Asset Management, the maintenance event supervisor

realização dos trabalhos e o gestor de aprovisionamento de material.

- Commercial Engineering and the Manager Logistics – Engineering and Maintenance.

Os três elementos evidenciaram alguma experiência para os cargos e funções que desempenhavam no operador. O conhecimento dos técnicos no tipo da aeronave E190 era limitado.

The staff evidenced some experience for the positions and functions they performed at the operator. Technicians' knowledge of the E190 aircraft type was considered limited.

Os técnicos observaram a movimentação dos *ailerons* comparativamente aos *spoilers* e passaram este facto aos pilotos, informação que foi considerada importante pela tripulação.

The staff observed that the ailerons were moving incorrectly compared to the spoilers and passed this fact to the pilots, information that was considered useful by the crew.

1.5.3. Equipa de manutenção || Maintenance team

A equipa de manutenção da Parte 145, variável em número de técnicos ao longo dos trabalhos de manutenção, rondando em média os 30 elementos de mão-de-obra direta, foi dimensão considerada suficiente pelos gestores da equipa e da área.

The Part 145 maintenance team, variable in number of technicians throughout the maintenance check, averaging 30 elements of direct labour, a number considered sufficient by both the team leaders and area managers.

Segundo os mesmos responsáveis, a equipa tinha as valências e certificações necessárias para realizar o trabalho planeado.

According to the same responsible leaders, the team had the necessary skills and certifications to carry out the planned work.

Apesar dos técnicos envolvidos diretamente no evento estarem devidamente certificados e autorizados, foram identificadas pela investigação várias lacunas na formação, conhecimentos técnicos e processuais de alguns elementos da equipa, incluindo gestão, planeamento, preparação, distribuição e controlo do trabalho com relação direta no evento de manutenção (detalhado em 1.17.2).

Although the technicians directly involved in the event are duly certified and authorized, the investigation identified several gaps within the team members in the training, technical and procedural knowledge, on roles as planning, scheduling, work distribution and control with direct contribution to the maintenance event (detailed in 1.17.2).

1.6. Informação sobre a aeronave || Aircraft information

1.6.1. Generalidades || General

O EMBRAER 190/195 é uma aeronave de corredor único, de construção predominantemente metálica, com asa baixa, cauda convencional e impulsionada por dois motores *turbofan* de elevada razão de *by-pass* montados sob as asas. Na configuração do operador atual, pode transportar até 97 passageiros em duas classes.

The EMBRAER 190/195 is a narrow-bodied aircraft, predominantly of metallic construction, with low wing, conventional tail and powered by two high by-pass ratio wing-mounted turbofan engines.
In the current operator configuration, can carry up to 97 passengers in two classes.

A família E-Jets usa a configuração de quatro assentos (2+2), com um projeto de fuselagem de "bolha dupla". A série de aeronaves E190/195

The E-Jets use four-abreast seating (2+2) configuration and have a "double-bubble" fuselage. The E190/195 series of aircraft have

tem uma capacidade para assentos semelhante às versões iniciais dos McDonnell Douglas DC-9 e Boeing 737 classic.

A família de E-Jets é considerada pela indústria como uma tecnologia intermédia entre as aeronaves de comandos de voo convencionais e as aeronaves totalmente *fly-by-wire* (FBW).

seat capacities like the initial versions of the McDonnell Douglas DC-9 and Boeing 737 classic.

The E-Jets family is considered by the industry as a mid-term technology between the conventional flight controls and the full fly-by-wire (FBW) aircraft.

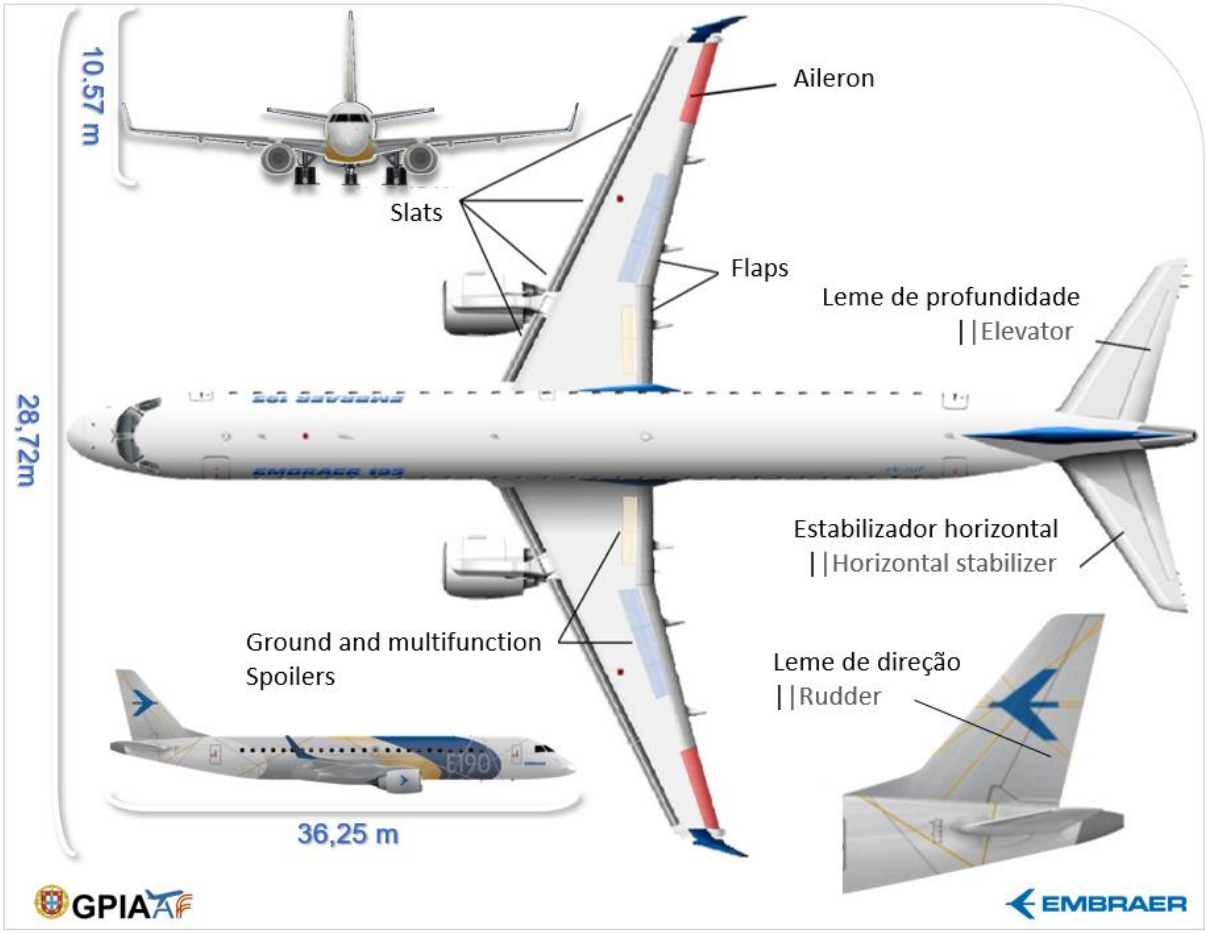

Figura 5 || **Figure 5**

Detalhe da aeronave (dimensões em m) || Aircraft detail (dimensions in m)
Fonte – Manual formação Embraer E190 | Source – Embraer E190 training manual

A aeronave é equipada com um painel de instrumentos do tipo "*glass cockpit*" que incorpora um sistema de aviónicos de bordo altamente integrado, permitindo monitorização permanente da operação da aeronave.

A glass cockpit panel is installed with a highly integrated on-board avionics system enabling the crew to monitor the aircraft's operation.

As superfícies de comando de voo são fabricadas em materiais compósitos leves, como a fibra de vidro e carbono.

A variety of lighter-in-weight composite materials like fiberglass and carbon are used on the flight control surfaces.

Além dos comandos de voo convencionais, a aeronave está equipada com um estabilizador horizontal ajustável e *spoilers* multifuncionais.

Besides the conventional flight controls, the aircraft is equipped with an adjustable horizontal stabilizer and multifunctional spoilers.

As características aerodinâmicas são incrementadas com o uso de *slats* e *spoilers* de solo.

Aerodynamic characteristics are enhanced by leading edge slats and ground spoilers.

1.6.2. Certificação || Certification

A aeronave tipo E190 foi certificado pela ANAC Brasil com base nos dados de certificação de tipo n.º EA-2005T13 em 30 de agosto de 2005.

Na EASA, a aeronave segue o padrão de projeto definido no relatório 190-100TDSD_EASA com dados de referência do certificado de tipo n.º EASA.IM.A.071.

Esses padrões de certificação, entre outros como os da FAA, garantem que a aeronave foi projetada e construída conforme os regulamentos aplicáveis. Usando o padrão da EASA apenas como referência, o padrão de certificação CS 25.671 (Geral) e respetivos AMC referem que:

(a) Cada comando ou sistema de comando deve operar com a facilidade, suavidade e demonstradamente adequados à sua função.

(b) Cada elemento de cada sistema de comando de voo deve ser projetado, ou marcado de forma distinta e permanente, para minimizar a probabilidade de incorreta instalação que possa resultar num funcionamento errático do sistema.

Especificamente, o AMC 25.671 (b) Sistemas de Controlo - Geral, refere que, para sistemas de comando que, se incorretamente instalados, colocam em risco a aeronave, o projeto deve ser tal que, em todos os pontos de separação razoavelmente possíveis, seja mecanicamente impossível instalar elementos do sistema que resulte em –

a. Uma ação não comandada,
b. Uma montagem que reverteria o sentido do comando, e
c. Interconexão não intencional dos comandos entre dois sistemas.

Para cumprir com os requisitos acima só deve ser usada a marcação para distinção, apenas em circunstâncias excecionais.

O Departamento de Aviação Civil do Ministério do turismo, transportes, setor primário e da cultura de Aruba, certificou toda a frota de aeronaves Embraer, Airbus e Boeing do operador, assumindo a supervisão do mesmo no

The E190 type was certified by ANAC Brazil using Type Certificate Data Sheet No. EA-2005T13 on 30 August 2005.

From EASA, the aircraft follows the design standard defined on report 190-100TDSD_EASA with the type-certificate data sheet No. EASA.IM.A.071.

These certification standards and others as FAA, ensures that the aircraft was designed and built as per applicable regulations. Using the EASA standard as reference only, the Certification Standard CS 25.671 (General) and related AMC states that:

(a) Each control and control system must operate with the ease, smoothness, and positiveness appropriate to its function.

(b) Each element of each flight control system must be designed, or distinctively and permanently marked, to minimise the probability of incorrect assembly that could result in the malfunctioning of the system.

Specifically, the AMC 25.671(b) Control Systems – General, refers that, for control systems which, if incorrectly assembled, would hazard the aeroplane, the design should be such that at all reasonably possible break-down points it is mechanically impossible to assemble elements of the system to give –

a. An out-of-phase action,
b. An assembly which would reverse the sense of the control, and
c. Interconnection of the controls between two systems where this is not intended.

Only in exceptional circumstances should distinctive marking of control systems be used to comply with the above.

Department of Civil Aviation of the Ministry of Tourism, transportation, primary sector and culture of Aruba certified the entire operator fleet of Embraer, Boeing and Airbus, assuring the

que diz respeito à operação destas aeronaves, usando os padrões da OACI.

operation oversight in accordance with ICAO standards,

1.6.3. Navegabilidade e Manutenção || Airworthiness and Maintenance

De acordo com os registos de manutenção, a aeronave não apresentava anomalias significativas ou relevantes antes da intervenção de manutenção. O certificado de retorno ao serviço (CRS) da aeronave foi emitido a 11 NOV 2018 contendo o detalhe dos trabalhos realizados durante a manutenção pesada.

According to the maintenance records, the aircraft did not present significant or relevant anomalies before the maintenance activities. The aircraft certificate of release to service (CRS), was issued at 11 NOV 2018, having the work details performed during the heavy maintenance check.

A aeronave estava certificada e autorizada a operar, tendo toda a documentação de aeronavegabilidade válida de acordo com a regulamentação aplicável.

The aircraft was certified and authorized to operate, with all valid airworthiness documentation as per applicable regulations.

Foram recolhidos os seguintes dados da documentação de certificação e manutenção:

The following data was collected from the certification and maintenance documentation:

Referência || Reference	Aeronave || Airframe	Motor #1 || Engine #1	Motor #2 || Engine #2
Fabricante || Manufacturer	EMBRAER	General Electric	General Electric
Tipo/Modelo || Type/Model	190 - 100LR	CF34-10E5	CF34-10E5
N.º de Série || Serial Nr.	19000653	424623	424624
Ano de construção || Year of construction	2013	2013	2013
TSN	13.152:31	13.152:31	13.152:31
Data da última Inspeção || Last Insp. Date	11.NOV.2018	11.NOV.2018	11.NOV.2018

1.6.4. Sistemas de comandos de voo da aeronave || Aircraft flight controls systems

O sistema de controlos de voo primários da aeronave consiste no sistema de controlo lateral, direcional e longitudinal. O sistema de controlo lateral atua duas superfícies de *aileron* e seis painéis de *spoiler* multifuncionais (três pares simétricos); o sistema de controlo direcional atua uma única superfície do leme de direção e o sistema de controlo longitudinal comanda duas superfícies do leme de profundidade na parte traseira do estabilizador horizontal, também ele móvel.

The aircraft primary flight control system consists of the lateral, directional, and the longitudinal control system. The lateral control system controls two aileron surfaces and six multifunction spoiler panels (three symmetrical pairs); the directional control system controls a single rudder surface and the longitudinal control system controls two elevator surfaces on the trailing edge of a movable horizontal stabilizer.

O comando das superfícies da aeronave é obtido pela ação nos comandos convencionais da coluna de controlo, manche e nos pedais do leme de direção. O sistema de comandos primários de voo utiliza as unidades eletro-hidráulicas PCU (unidades de comando de potência) para comandar os lemes de profundidade e direção, bem como os *spoilers* multifuncionais.

Control of the aircraft surfaces is achieved through conventional mechanical cockpit control columns, control yokes and rudder pedals. The primary flight control system employs electro-hydraulic PCU (Power Control Units) to control the elevators, rudder, and multifunction spoilers.

Cada um dos *ailerons* é controlado por um par de PCU hidromecânicas, que operam em configuração ativo/ativo, acionadas por cabos de comando convencionais que passam de cada manche no *cockpit* para as PCU. Para os lemes de profundidade, leme de direção e comando das superfícies dos *spoilers* multifuncionais, são utilizados comandos eletrónicos recorrendo a sensores eletromecânicos de posição instalados nas colunas de controlo. Os sensores de posição LVDT (transdutor diferencial variável linear) são usados para fornecer sinais elétricos que representam a posição dos comandos do *cockpit*. A saída elétrica do LVDT é usada para transmitir a posição de comando do *cockpit* para o sistema eletrónico associado a cada superfície de comando de voo.

The ailerons are each controlled by a pair of hydromechanical PCU, which operate in an active/active configuration, driven by conventional control cables that run from each control yoke to the PCU. For elevators, rudder and multifunction spoiler surface control, electronic controls are used by means of electromechanical position sensors mounted to the cockpit controls. LVDT (Linear Variable Differential-Transducer) position sensors are used to provide electrical signals that represent the position of the cockpit controls. The electrical output from LVDT is used to transmit the cockpit control position to the electronic system associated with each flight control surface.

O ciclo básico de 'comando para a superfície' é realizado através de eletrónica analógica incrementada pela eletrónica digital usando *software* para providenciar funcionalidades adicionais ao sistema de comandos de voo FCS (sistema de controlo de voo). O subsistema analógico de comando para a superfície fornece o que é denominado comando em modo direto. O modo direto envolve a entrada de comando do *cockpit*, onde os LVDT são usados para transmitir a posição dos comandos do *cockpit* para o circuito de controlo eletrónico analógico. O circuito de controlo analógico é denominado de ACE (eletrónica de comando do atuador).

The basic cockpit ‘controls-to-surface’ is accomplished by means of analogue electronics that is augmented by digital electronics using software to provide added functionality to the Flight Control System (FCS). The controls-to-surface analogue subsystem provides what is termed direct mode control.

Direct mode entails cockpit control input where the LVDT are used to transmit cockpit controls position into the analogue electronic control circuitry. The analogue control circuitry is referred to as ACE (Actuator Control Electronics).

O sistema de aviónicos da aeronave fornece os meios para a interface com sensores dos outros sistemas de controlo elétricos e eletrónicos da aeronave. O sistema de aviónicos integrados serve como um canal a partir do qual o FCS pode adquirir dados e sinais necessários para usar e melhorar os sinais recebidos dos comandos do *cockpit*, além de funcionalidades adicionais que normalmente não estão disponíveis nos sistemas convencionais de comandos de voo hidromecânicos acionado por cabos. O sistema de aviónicos fornece também meios para o FCS distribuir dados de comandos de voo a outros sistemas da aeronave, como o gravador de dados de voo FDR (*Flight Data Recorder*), o EICAS (sistema de informação e alerta à tripulação) e MFD (visor multifunções) para exibir informações do FCS à tripulação.

The avionics system provides the means to interface to aircraft sensors and other aircraft electrical and electronically controlled systems. The integrated avionics system serves as a conduit from which the FCS can acquire data and signals necessary for use in providing augmentation to the cockpit controls input, and additional functionalities that are not normally available in a conventional cable-driven hydro-mechanical flight controls system.

The avionics system also provides means for the FCS to distribute flight controls data to other aircraft systems such as the FDR (Flight Data Recorder), the EICAS (Engine Indication and Crew Alerting System) and MFD (Multi-Function Display) for displaying FCS information to the flight crew.

A tecnologia *Fly-by-wire* (FBW) executa os comandos de voo principais com três controladores analógicos de canal duplo independentes (P-ACE[4]) que usam comando e *feedback* por LVDT. Quatro controladores digitais (FCM) nas MAU (unidades de aviónicos modulares) incrementam os comandos do piloto por meio de uma interface de barramento CAN (*Controller Area Network*) para os controladores analógicos.

The Fly-by-wire (FBW) technology runs the primary flight controls with three independent dual-channel analogue controllers (P-ACE[4]) that use LVDT command and feedback.

Four digital controllers (FCM) in the MAU (Modular Avionics Units) augment the pilot's commands through a CAN (Controller Area Network) bus interface to the analogue controllers.

Os controladores digitais, conhecidos como módulos de controlo de voo (FCM), utilizam microprocessadores para computação. A saída dos cálculos do *software* dos FCM é limitada por *hardware* nos ACE. Os efeitos de possíveis falhas dos FCM são devidamente protegidos para não contaminar os comandos diretos dos pilotos por limitador físico em cada parâmetro gerado pelos FCM, usando as limitações de *hardware* dos ACE.

The digital controllers, known as flight control modules (FCM), utilize microprocessors for computation. Output from the FCM software computations are hardware limited in the ACE. The effects of any FCM failure is uniquely protected from overwhelming pilot control direct input by means of a hardware limiter on each FCM parameter that is used in the ACE hardware and monitor pathways.

1.6.4.1. Sistema de comando de rolagem - *ailerons* || Roll control system – ailerons

Os cabos de comando convencionais conectam os manches de controlo aos *ailerons*. As outras superfícies de comando de voo são controladas eletronicamente usando a tecnologia *Fly-by-Wire* (FBW).

Conventional control cables that run from each control wheel drive the ailerons. The other flight control surfaces are electronically controlled using Fly-by-Wire (FBW) technology.

As superfícies dos *ailerons* esquerdo e direito controlam os movimentos de rolagem (laterais) da aeronave com a atuação dos manches de comando no *cockpit* ou com os comandos dados pelo piloto automático diretamente nos cabos.

The left and right aileron surfaces control the rolling (lateral) movements of the aircraft with the actuation of the two control yokes in the cockpit or with the autopilot controls directly on the control cables.

Em relação aos *spoilers* e travões aerodinâmicos, a função do sistema de comando dos *spoilers* é incrementar o comando dos *ailerons* (*roll spoilers)*, desacelerar a aeronave durante o voo sem perda de sustentação (travões aerodinâmicos) e desacelerar e destruir a sustentação da asa após a aterragem (*ground spoilers*).

Regarding spoilers and air brakes, the function of the spoiler control system is to augment the aileron roll control (roll spoilers), slow the aircraft during flight without loss of lift (air brake), and slow the aircraft and lift damping after touchdown on landing (ground spoilers).

[4] Atuador Primário de Controlo Eletrónico (P-ACE) || Primary Actuator Control Electronics (P-ACE)

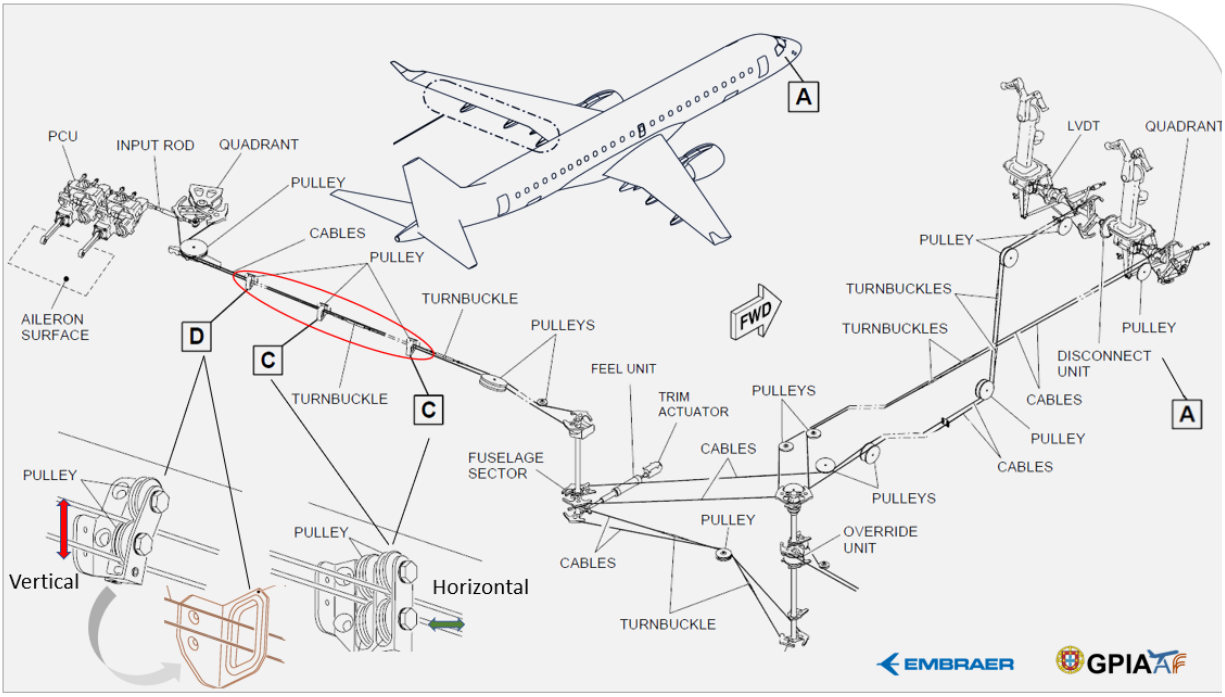

Figura 6 | | **Figure 6**

Esquemático do sistema de comando - *Ailerons* | | Aileron command system schematics

Fonte – Manual de manutenção Embraer | | Source – Embraer maintenance manual

A função de *roll spoiler* aciona os painéis multifuncionais de forma assimétrica em função da posição do manche de comando. O movimento do manche de ± 40 graus implica o movimento do painel de *spoiler* de 0 a 30 graus para cima. Existe uma faixa de trabalho do manche sem atuação que, quando movida em torno da sua posição neutra, os painéis de *spoiler* não se movem, sendo apenas movimentados os *ailerons*. A "banda morta" quando em modo DIRETO é de 5,5 graus. Essa mesma banda, no modo NORMAL, varia com a velocidade do ar e configuração dos *flaps*.

The roll spoiler function drives the Multi-Function Spoiler panels asymmetrically as a function of control wheel position. Control wheel movement of ± 40 degrees results in roll spoiler panel movement from 0 to 30 degrees up. There is a dead band of the control wheel, that when moved around the neutral position, the spoiler panels do not move, only ailerons move. The dead band in DIRECT Mode is 5.5 degrees. The dead band in NORMAL Mode varies with air speed and flap setting.

Os FCM fornecem a interface digital entre o FCS e os sistemas de aviónicos da aeronave. Incorporada no FCM está uma secção analógica usada para controlo e monitorização dos *spoilers* multifunção.

The FCM provides the digital interface between the FCS and the aircraft's Avionics systems. Incorporated into the FCM is an analogue section that is used for control and monitoring of the multifunction spoilers.

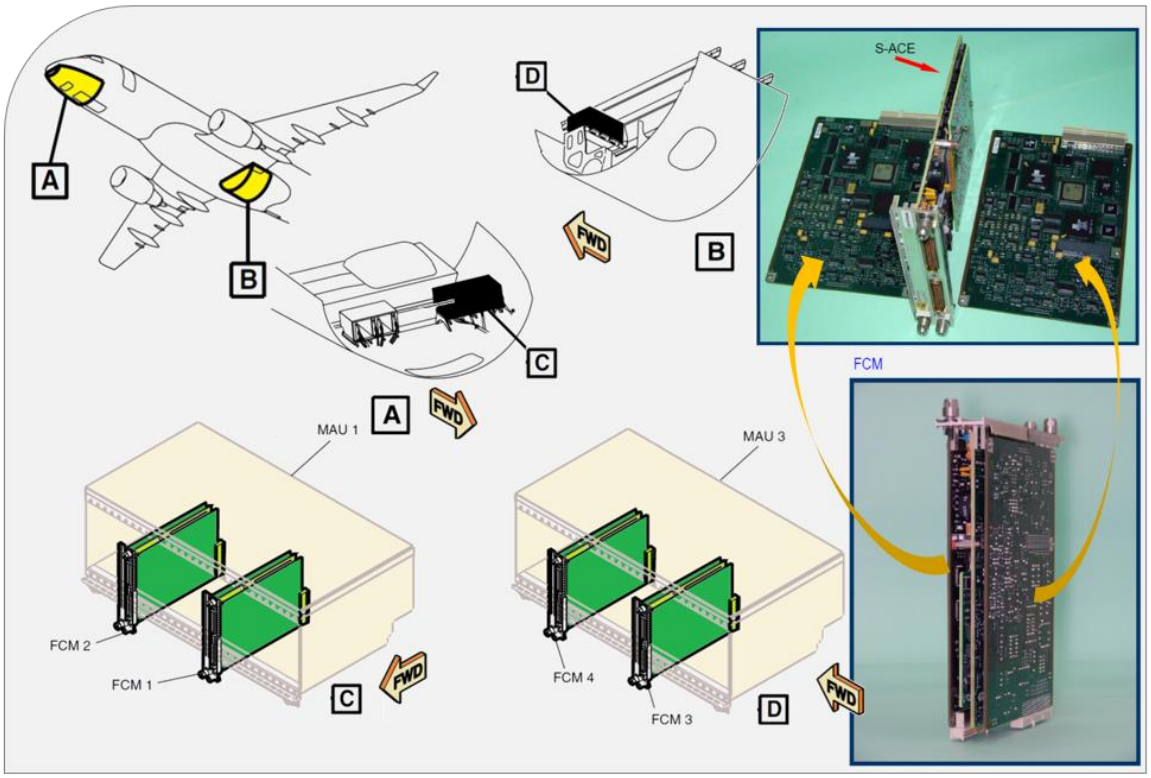

Figura 7 || **Figure 7**

Módulos de controlo de voo - FCM || Flight control modules - FCM

Fonte – Manual de formação de manutenção || Source – Maintenance training manual

O FCM é um dos módulos de *slot* duplo instalado na MAU, composto por placas de processamento digital com uma placa *mezzanine* de circuito impresso dos *spoilers* intercalada entre os dois módulos digitais. A placa do *spoiler*, denominada de *Spoiler* ACE (S-ACE), contém um circuito analógico para as funções multifuncionais de controlo e monitorização dos *spoilers*. A referida placa é segregada, ou seja, fisicamente separada em canal 'A' e canal 'B', com conectores separados e interfaces também separadas para o processamento digital do FCM associado aos canais 'A' e 'B'.

Cada canal de processamento digital do FCM contém um processador central (CPU) bem como memória de programação, memória local ou temporária (*scratchpad*) e memória não volátil (Flash, SDRAM e EEPROM, respetivamente).

O painel de comando de voo (FCP) possui três interruptores (*ELEVATORS, RUDDER e SPOILERS*) que proporcionam à tripulação a possibilidade de reiniciar (*reset*) o FCS para recuperar o modo normal após falha ou alternar para o modo direto.

The FCM is a dual slot wide MAU module comprised of two digital processing lanes with a spoiler mezzanine circuit card sandwiched between the two digital lanes. The spoiler card, which is referred to as the Spoiler ACE (S-ACE), contains the analogue circuitry for the multifunction spoiler control and monitoring functions. The mentioned card is a single card that is segregated, i.e., physically segregated into an 'A' and a 'B' lane, with separate connectors and separate interfaces to the associated FCM digital processing 'A' and 'B' lane.

Each FCM digital processing lane contains a Central Processing Unit (CPU), as well as program memory, scratchpad memory and non-volatile memory (Flash, SDRAM and EEPROM respectively).

The Flight Control Panel (FCP) has three switches (ELEVATORS, RUDDER and SPOILERS) which provide the crew with the capability of resetting the FCS (Flight Control System) to recover the normal mode from a failure or switch to direct mode.

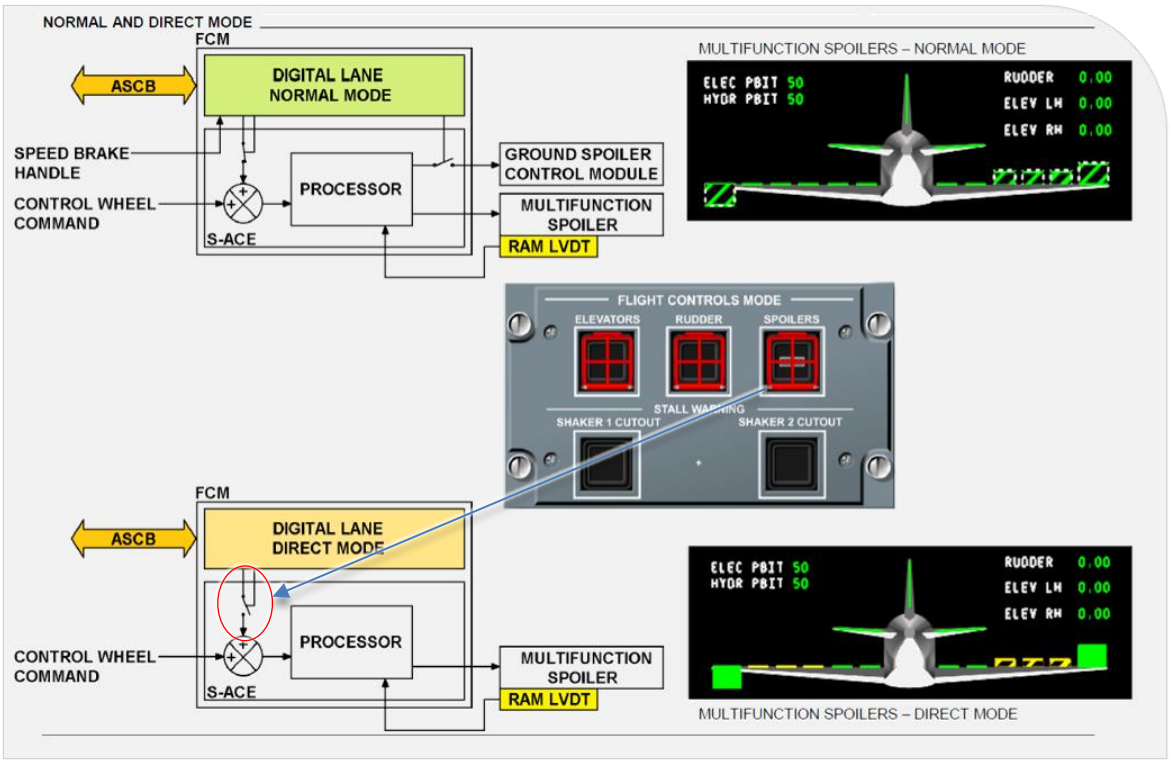

Figura 8 || **Figure 8**

Modo normal e direto de processamento de comando || Normal and direct mode command processing

Fonte – Manual de formação de manutenção | Source – Maintenance training manual

Como já referido, quando os *spoilers* multifuncionais são usados para comando de rolamento, existem dois modos operacionais: "Modo DIRETO", onde as entradas do manche são transmitidas para as superfícies com um ganho constante, e o "Modo NORMAL", onde a programação de ganho varia em função da velocidade do ar e da configuração de *flaps*. Os dados necessários para a operação no modo normal vêm do barramento de comunicação padrão de aviónicos (ASCB). A parte digital do FCM lê e grava continuamente no ASCB. O modo NORMAL inclui as funções de *software* que calculam e adicionam incrementos aos comandos dados pelos pilotos, que são implementados e controlados pelo *hardware* analógico em circuito fechado. O modo DIRETO corresponde apenas ao controlo analógico de posição por *hardware* em circuito fechado e que responde aos comandos do piloto com um ganho fixo e pré-determinado.

Recorrendo à figura abaixo, representa-se a condição normal de projeto da aeronave. O gráfico estabelece o ganho dos comandos de voo para a função de *roll spoilers* tendo em consideração a velocidade do ar e posição dos *flaps*. Pode ainda ser constatado que o ganho é

As referred above, when the Multi-Function Spoilers are used for roll control, there are two operational modes: "DIRECT Mode", where control wheel inputs are transmitted to the surfaces with a constant gain, and "NORMAL Mode", where airspeed gain scheduling is used to vary the gain as a function of airspeed and flap settings. The required data for Normal Mode operation comes from the Avionic Standard Communication Bus (ASCB). The digital portion of the FCM continually reads from and writes to the ASCB. NORMAL Mode includes the software functions calculating and adding augmentation commands to the pilots' commands, which are implemented by analogue hardware controlling and closing the loop. DIRECT Mode means only analogue closed loop position control hardware responding to the pilot commands with a fixed gain schedule.

The figure below represents the aircraft design condition. The graph establishes the flight controls gain for the roll spoilers function considering the air speed and flaps position. It

fixo em 0,5 para a condição de seleção em modo direto.

can also be seen that the gain is fixed at 0.5 for the direct mode selection condition.

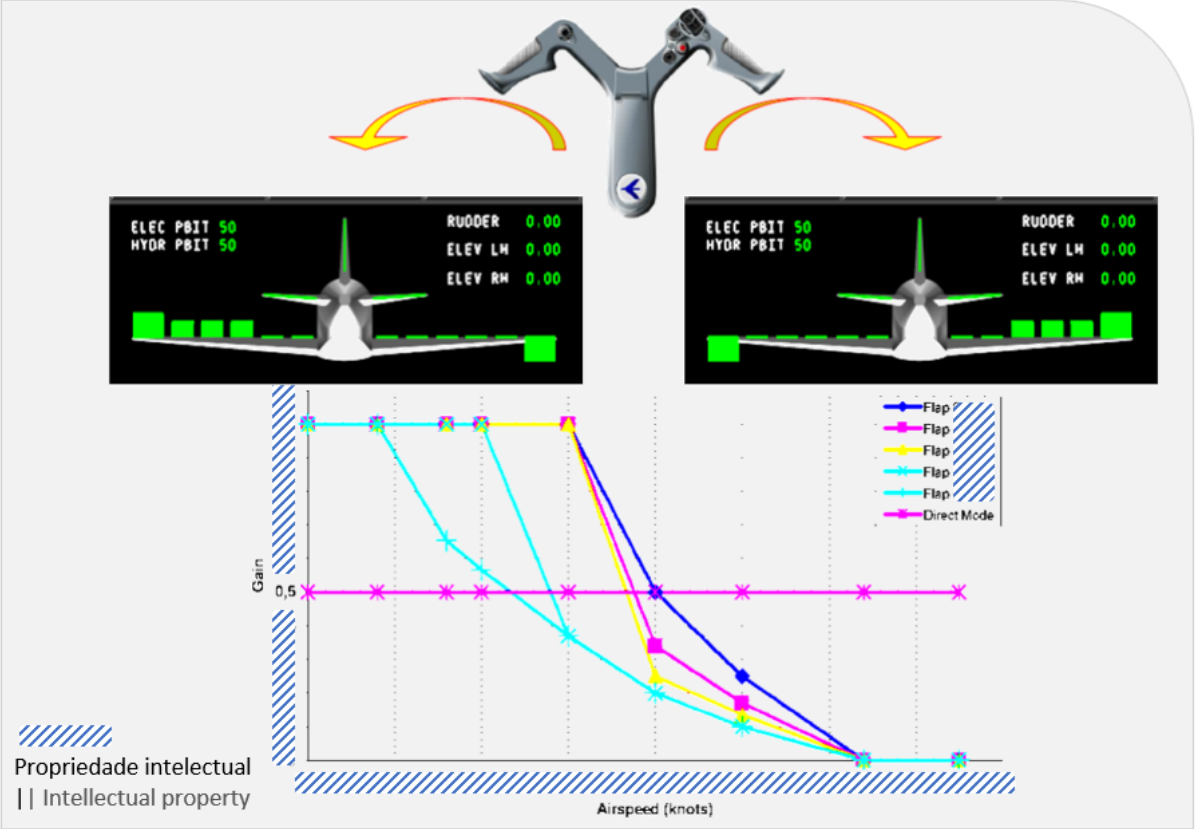

Figura 9 || **Figure 9**

Modo de incremento da função de rolamento do FCS || FCS roll augmentation mode

Fonte – Manual de formação de manutenção E190 Source – E190 Maintenance training manual

1.6.4.2. Página Sinótica - comandos de voo || Synoptic page – flight controls

A página Sinótica disponível para a tripulação ou para a manutenção, garante uma função de visualização de diferentes sistemas da aeronave, incluindo a de comandos de voo onde é representada uma aeronave, vista de trás e esquematicamente representadas, entre outras funções, a posição atual e condição dos diversos comandos de voo.

The Synoptic page available to the crew or maintenance, assures different aircraft systems visualization, including the flight controls where an aircraft is represented, seen from behind and schematically represented, among other functions, the current flight controls position and condition.

A página Sinótica de comandos de voo é utilizada nas verificações operacionais antes de cada voo pela tripulação e nas tarefas de manutenção e para a verificação da correta deflexão das superfícies no display em conjunto com a deflexão física conforme os comandos aplicados.

The flight controls Synoptic Page is used during each pre-flight by the crew and on maintenance task operational checks to verify the correct surface deflections in the display along with visual checks of the actual surface physical deflections in accordance with control inputs.

A informação para esta página é recebida através do barramento digital (ASCB) que interliga os diferentes componentes das MAU e a arquitetura integrada do sistema de aviónicos desenhada

The information to feed this page is received through a digital bus (ASCB) that connects the different components of the MAU and the integrated architecture of the avionics system

pela Honeywell, comercialmente denominada por Primus Epic.

designed by Honeywell, commercially named Primus Epic.

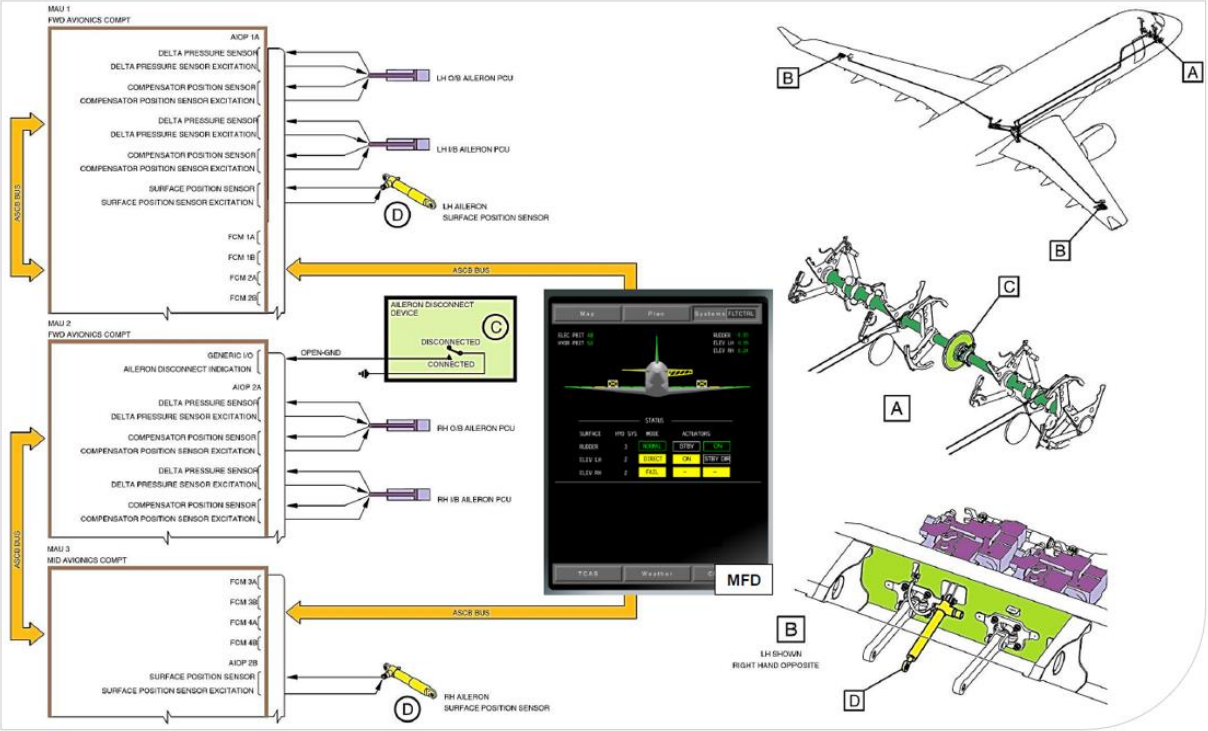

Figura 10 || **Figure 10**

Página Sinótica de comandos de voo e suas fontes || FCS Synoptic page and sources

Fonte – Manual de formação de manutenção E190 Source – E190 Maintenance training manual

1.6.5. Sistema de diagnóstico e manutenção da aeronave ADMS || ADMS - Aircraft Diagnostic and Maintenance System

A arquitetura do ADMS tem como objetivo a recolha de informações de falha, armazenar e recuperar mensagens de manutenção, correlacionar as mensagens de alerta à tripulação (CAS) com mensagens de manutenção, garantindo o interface homem-máquina na realização de tarefas de resolução de problemas. Dispõe ainda de recursos de interface adicionais nos subsistemas para auxílio nas tarefas de manutenção e ajuste.

The ADMS architecture aims to collect fault reports, store and retrieve maintenance messages, correlate the crew alerting system (CAS) messages to the maintenance messages and ensure the man-machine interface for troubleshooting tasks.

Additional maintenance and rigging interface capabilities are provided within the sub-systems.

Uma das funções do sistema e arquitetura ADMS, é usar o CMC (*Central Maintenance Computer*) como interface interativo para testar vários sistemas da aeronave, como é o exemplo dos comandos de voo.

One ADMS system and architecture functions, uses the CMC (Central Maintenance Computer) as an interactive interface for several aircraft systems test, as the flight controls system.

Por requisitos de projeto e devido às limitações do sistema de comandos de voo, em determinadas condições ou quando existem falhas detetadas, é necessário proceder a ações de manutenção. A mensagem “global” de não

As per design requirements and due to flight control system limitations, under certain conditions or when faults are detected, maintenance actions are required. The aircraft's non-dispatch “global” message for issues related

despacho da aeronave por questões relacionadas com comandos de voo (FLT CTRL NO DISPATCH) que obriga a avaliar e corrigir a causa da falha e realizar de seguida o procedimento de manutenção para retorno ao serviço (RTS), que apaga as mensagens desde que as condições que a fizeram despoletar não estejam presentes.

to flight controls (FLT CTRL NO DISPATCH), which requires proper assessment and actions to correct the root cause failure and then, perform the system return to service (RTS) reset procedure, which clears the maintenance messages provided the conditions that triggered the failure are no longer present.

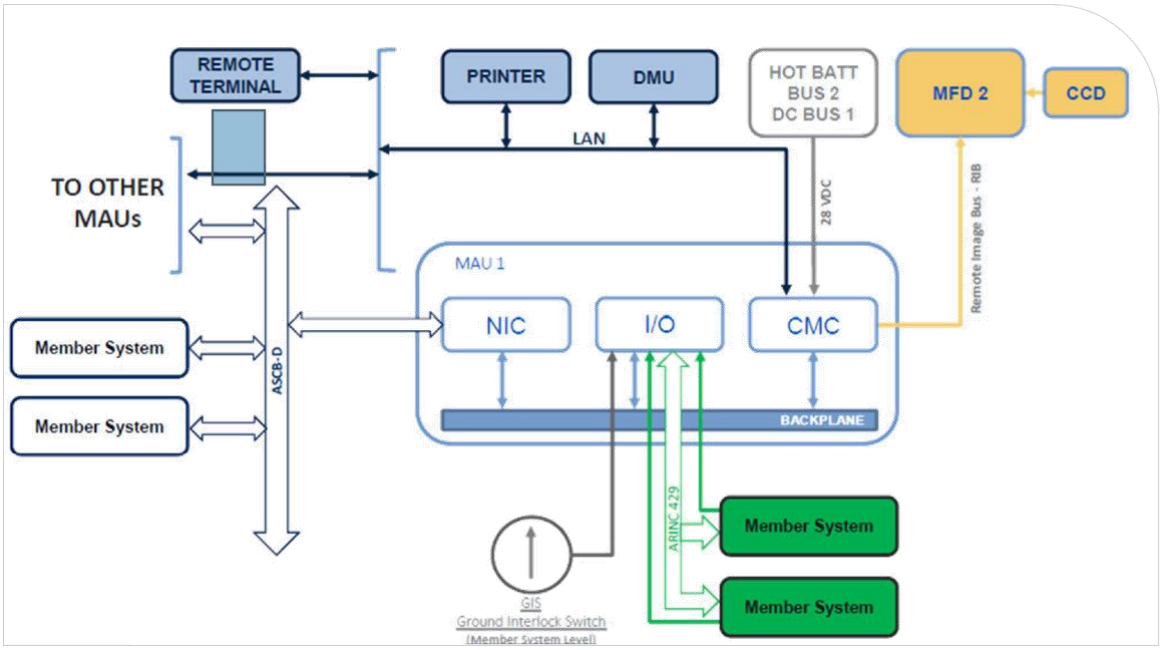

Figura 11 || **Figure 11**

Arquitetura do ADMS || ADMS architecture

Fonte – Embraer | Source – Embraer

A mensagem FLT CTR NO DISPATCH é uma mensagem global associada à monitorização da condição de todo o sistema de comandos de voo e que lhe tem associado um registo na memória não volátil acionado na exibição da mesma.

This FLT CTR NO DISPATCH annunciation is a global message that is associated with monitoring throughout the flight control system and associated with this message set a non-volatile memory latch that drives the message display.

O registo estará sempre presente mesmo depois de removida a energia da aeronave e só pode ser removida (*reset*) por uma ação de manutenção que corrija a condição que a fez espoletar.

The latch remains set even after power is cycled off and is reset only by a maintenance action that corrects the triggered condition.

A função de manutenção *fly-by-wire* (FBWMF) transmite essas informações ao CMC para exibição e recolha de dados pela equipe de manutenção.

The fly-by-wire maintenance function (FBWMF) transmits this information to the CMC for display and retrieval by maintenance personnel.

Os dados de manutenção são recolhidos e armazenados na memória não volátil (NVM) no componente membro do sistema, em que, a maioria dos dados de manutenção do sistema de comandos de voo, são armazenados nos FCM. As falhas bloqueadas (gravadas) são anunciadas no

Maintenance data is collected and stored in non-volatile memory (NVM) in the member system, that, in most of the Flight Control System maintenance data is stored in the FCM. Latched failures are annunciated on EICAS until the associated NVM memory location is cleared by

EICAS até que o local de memória da NVM associada seja limpo através de uma ação de manutenção usando a interface disponível no CMC.

means of a maintenance action through the CMC interface.

O retorno ao serviço consiste em dois processos:

The return to service consists of two process:

- Um teste de retorno ao serviço (RTS), durante o qual o sistema limpa a RAM e monitora todos os comandos que o técnico efetua em todos os comandos de voo para garantir que todos os CBIT são exercitados durante o teste.

– A Return to service (RTS) test, the system clears the RAM and monitors all command that the technician needs to cycle all controls in order to guarantee that all CBIT are exercised during the test.

- Um processo de limpeza da NVM, no qual o sistema habilitará a limpeza da mensagem EICAS FTL CTRL NO DISPATCH se, depois de todos os CBIT executados, o retorno ao serviço (RTS) passar sem falhas (página 7 de 7 do teste RTS).

– Then, after all CBIT run, if the return to service (RTS) passes without any failure, the system will be able to clean the EICAS message FTL CTRL NO DISPATCH through the NVM clearing process (page 7 of 7 of RTS test).

1.6.6. Massa e centragem || Mass and balance

De acordo com o manifesto de carga e balanceamento para o voo KC1388, a massa à descolagem da aeronave era de 41.217 kg, incluindo 552 kg de carga e 12.000 kg de combustível. O centro de gravidade foi estimado dentro dos limites estabelecidos para todas as fases do voo do acidente (15,8 to 15,4 %MAC).

According to the load and trim sheet for flight KC1388, the aircraft take-off mass was 41,217kg, including 552 kg of cargo, and 12,000kg of fuel. Its CG was estimated to be within the allowable limits for the entire accident flight (15,8 to 15,4 %MAC).

1.7. Informação meteorológica || Meteorological information

De acordo com a informação meteorológica disponível para a base militar de Alverca, as condições atmosféricas eram caracterizadas por tetos baixos, com uma primeira camada aos 500ft, seguido de uma segunda aos 1500ft, com uma visibilidade horizontal em torno dos 2000m com chuva. O vento reportado pela torre de Alverca no momento da descolagem era de 050˚ com 7kt de intensidade.

In accordance with the available meteorological information for Alverca military airbase, the local atmospheric conditions were characterized by low ceilings, reported a first layer at 500ft, and a second at 1500ft, with a horizontal visibility of about 2000 meters with rain. The wind at the take-off time was 50˚ with speed of 7kt.

O reporte meteorológico em Alverca às 13:00 e 14:00 UTC:

LPAR 11**1300**Z 04005KT 3000 RA FEW005 SCT010 BKN015 14/13 Q1010
LPAR 11**1400**Z 35005KT 2000 -RA SCT005 SCT010 BKN015 13/13 Q1010

The weather reported at Alverca at 13:00 e 14:00 UTC:

LPAR 111300Z 04005KT 3000 RA FEW005 SCT010 BKN015 14/13 Q1010
LPAR 111400Z 35005KT 2000 -RA SCT005 SCT010 BKN015 13/13 Q1010

O reporte meteorológico em Beja às 14:00, 15:00 e 15:20 UTC:

LPBJ 11**1400**Z 19017KT 9999 SCT030 BKN048 19/14 Q1011
LPBJ 11**1500**Z 20019KT 9999 SCT030 BKN048 19/14Q1010
LPBJ 11**1520**Z 20017KT 9999 SCT030 BKN048 19/13Q1010

The weather reported at Beja at 14:00, 15:00 and 15:20UTC:

LPBJ 111400Z 19017KT 9999 SCT030 BKN048 19/14 Q1011
LPBJ 111500Z 20019KT 9999 SCT030 BKN048 19/14Q1010
LPBJ 111520Z 20017KT 9999 SCT030 BKN048 19/13Q1010

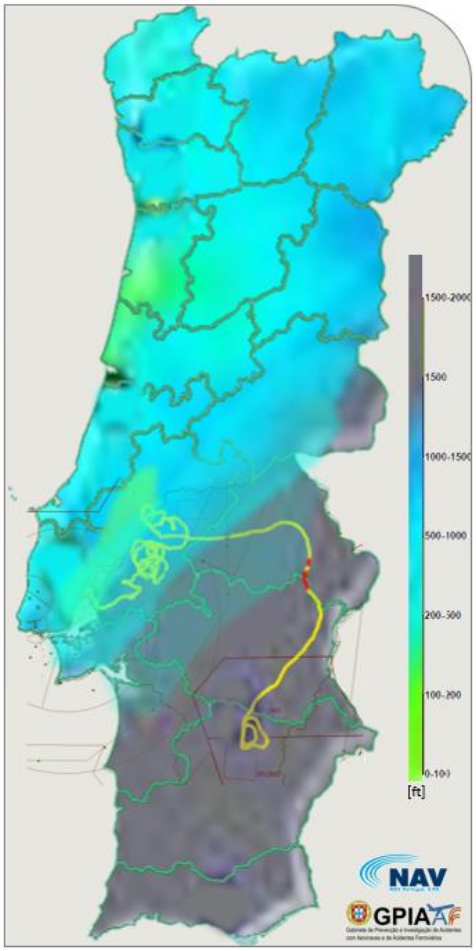

Figura 12 || **Figure 12**

Detalhe meteorológico com teto das nuvens à hora da descolagem, com o percurso da aeronave sobreposto
Fonte - ECMWF

|| Meteorological detail with cloud ceiling at take-off time, complemented by the aircraft path
Source – ECMWF

Durante o voo KC1388, Portugal continental permanecia sob a influência de duas frentes frias, provocando muita nebulosidade que cobria todo o centro e norte do continente, como indicado na figura acima.

During flight KC1388, continental Portugal was under the influence of two cold fronts, triggering considerable cloudiness that covered the entire centre and north mainland, as shown in the figure above.

1.8. Ajudas à navegação || Aids to navigation

Não foram relatados quaisquer problemas com os auxílios à navegação.

No problems with any navigational aids were reported.

1.9. Comunicações || Communications

Não foram relatados problemas de comunicação entre os pilotos e os diferentes controladores de tráfego aéreo (CTA) que apoiaram o voo.

Em alguns momentos foram mantidas comunicações bilaterais entre a aeronave acidentada e o líder da patrulha de F16, tendo como objetivo o auxílio e guiamento da aeronave em emergência até ao aeroporto sugerido pelo CTA e eleito pela tripulação como adequado para a aterragem de emergência.

No communications problems were reported between the pilots and any of the air traffic controllers (ATC) who handled the flight.

For several times, bilateral communications were maintained between the event aircraft and the F16 squad leader, with the objective of assisting and guiding the emergency aircraft to the airport suggested by the ATC and elected by the crew as appropriate for the emergency landing.

1.10. Informação dos Aeroportos || Airports information

O **aeródromo militar de Alverca (LPAR)**, dispõe de uma pista com orientação 04/22 com um comprimento de 2500m por 45m de largura, recebe tráfego IFR e VFR, maioritariamente militar e para serviços de manutenção na AMO aí instalada.

Com uma localização a apenas 7NM a NE do aeroporto de Lisboa (LPPT), o tráfego em aproximação e descolagem do aeródromo militar de Alverca (LPAR) é coordenado com o aeroporto de Lisboa pelo serviço de controlo de tráfego aéreo militar de Alverca sob responsabilidade da Força Aérea Portuguesa.

Embora a tripulação do voo KZ1388 tivesse inicialmente declarado emergência ainda em contacto com o controlo de Alverca, devido ao protocolo em vigor para a referida coordenação de tráfego pela aproximação de Lisboa (Lis APP), tornou-se inevitável o procedimento de mudança de frequência pela tripulação em emergência, não desejável nestas situações com elevada carga de trabalho.

O **Aeroporto de Beja (LPBJ)**, eleito para a aterragem de emergência, é um aeródromo militar (BA11) com terminal civil, composto por duas pistas. A 19R/01L enquanto pista principal, tem 3450m de comprimento e 60m de largura. A pista secundária, 19L/01R com 3449m de comprimento e 30m de largura, é pavimentada com betão e tem uma elevação de 617ft – MSL, com as coordenadas geográficas N38°04'44.05" W007°55'56.63".

The **Alverca military aerodrome (LPAR)**, has a QFU 04/22 runway with a length of 2500m by 45m in width, receives IFR and VFR traffic, mostly military and for maintenance services at the AMO located at the Aerodrome.

With a location just 7NM NE of Lisbon airport (LPPT), the approaching and departing traffic from Alverca military aerodrome (LPAR) is coordinated with Lisbon airport by the Alverca military air traffic control service under Portuguese Air Force responsibility.

Although the flight KZ1388 crew initially declared emergency still in contact with Alverca control tower, as per protocol in force for the referred traffic coordination with Lisbon approach (Lis APP), forced the crew to a frequency change during the emergency, not desirable in these situations due to high crew workload.

Beja Airport (LPBJ), chosen for the emergency landing, is a military airport (BA11) with a civilian terminal and two parallel runways. The main runway is 19R/01L which is 3450 m long and 60 m wide. The secondary runway, 19L/01R, is 3449 m long and 30 m wide and is paved with concrete. The airport elevation is 617 feet MSL and its geographical coordinates are N38°04'44.05" W007°55'56.63".

De acordo com as informações do gestor do Terminal Civil de Beja (TCB), o "Plano de Emergência da Infraestrutura Aeronáutica da BA11 e do TCB" (PEA) não foi ativado sendo a competência atribuída ao Comandante da BA11, onde ativou o sistema primário de alarme (âmbito exclusivamente militar). A ocorrência foi tratada como uma emergência militar, motivada pela utilização e coordenação com a escolta de dois F-16 da FAP.

According to Terminal Civil Beja (TCB) manager provided information, the "BA11 and TCB Aeronautical Infrastructure Emergency Plan" (PEA) was not activated, with the event managed by the BA11 Commander attributed competencies, that ordered the primary alarm system (exclusively military). The incident was treated as a military emergency, driven by the use and coordination of the two PAF F-16s escort.

1.11. Gravadores de voo || Flight recorders

Ambos os gravadores digitais de voz e de dados de voo (DVDR) foram recolhidos no local logo após a aterragem de emergência e os respetivos dados descarregados com sucesso no dia seguinte no laboratório do GPIAAF.

Both digital voice and flight data recorders (DVDR) were removed on site, right after the emergency landing and the data successfully downloaded in the following day at the GPIAAF laboratory.

Os registos de voz do *cockpit* foram analisados em conjunto com a autoridade de investigação do departamento de investigação de acidentes e incidentes (NIA) do Ministério do Desenvolvimento da Indústria e Infraestruturas da República do Cazaquistão (MIID) para interpretação das conversações da tripulação em língua cazaque e russa.

The cockpit voice recorders data was analyzed in conjunction with the investigation authority of Department for investigation of accidents and incidents (NIA) of the Ministry of Industry and Infrastructural Development of the Republic of Kazakhstan (MIID) to understand the crew dialogues in kazakh and russian languages.

Dos dados disponíveis recolhidos das transcrições dos três canais do CVR, dada a envolvência e realidade vivida pelos tripulantes, foi possível constatar que a emergência foi gerida com relativa calma e mantido um fluxo de informação entre todos os ocupantes da aeronave.

From the available collected data from the three CVR channels transcripts, given the scenario and crew difficult experience, it was possible to verify that the emergency was managed with relative low stress and an information flow was maintained among all aircraft occupants.

Os dados de voo foram analisados e validados em conjunto com o OEM (Embraer), usando as ferramentas de interpretação adequadas. Os parâmetros gravados estavam íntegros e permitiram uma reconstituição precisa da dinâmica do voo.

Flight data were analysed and validated in cooperation with OEM (Embraer) using the appropriate interpretation tools. The recorded flight parameters were found intact and allowed an accurate flight dynamics reconstitution.

No gráfico abaixo são mostrados quatro parâmetros básicos de voo, a altitude de pressão, a velocidade vertical e a velocidade de ar calibrada, bem como as acelerações verticais. É ainda evidenciado o valor máximo registado durante todo o voo para cada um desses

The graph below shows four basic flight parameters, pressure altitude, vertical speed and calibrated air speeds, as well as vertical accelerations. The maximum recorded value throughout the flight for each of these parameters is also highlighted, showing

parâmetros, mostrando desvios significativos à normal operação da aeronave.

significant deviations from the normal aircraft operation.

Figura 13 || Figure 13

Dados básicos de voo dos DVDR || DVDR basic data

Ainda com base nos dados do FDR e cruzados com as informações do FHDB, de acordo com a análise do fabricante (Embraer), ocorreram três tentativas de acoplar o piloto automático durante o voo do evento, sendo a primeira tentativa aproximadamente às 14:22 (quase 51 minutos após a descolagem), informação que não está de acordo com as declarações da tripulação.

Also based on FDR data and crossed with FHDB information, according to OEM (Embraer) analysis, there were three attempts to engage the Auto Pilot during the event flight, being the first attempt at approximately 14:22 (almost 51 minutes after take-off), not in line with the crew statements.

1.12. Destroços e informação sobre os impactos || Wreckage and impact information

Não aplicável

Not applicable

1.13. Informação médica e patológica || Medical and pathological information

Não foi evidenciado qualquer fator de incapacitação médica dos pilotos que possa ter afetado as suas funções de condução do voo. Foram realizados testes de despiste toxicológico aos tripulantes técnicos, todos com resultado negativo.

There was no evidence of pilots' medical disability that could have affected their flight management roles. Toxicological screening tests were carried out on the technical crew, all with negative result.

1.14. Fogo || Fire

Não houve fogo.

There was no fire.

1.15. Aspetos de sobrevivência || Survival aspects

Não estando em causa os aspetos de sobrevivência atendendo ao desfecho do voo, as decisões e ações da tripulação foram determinantes para o sucesso da aterragem de emergência após as condições efetivas de perda de controlo da aeronave durante alguns instantes e em vários momentos.

Since survival aspects were not an issue considering the accident flight characteristics, the crew's decisions and actions were decisive for the emergency landing success after the aircraft complete loss of control for some moments at multiple instances.

Os esforços físicos sentidos pela tripulação, em resultado das cargas impostas à aeronave, causaram elementos de fadiga e mau estar relevantes e com impacto na condução do voo.

The imposed loads on the aircraft and the physical stress felt by the crew resulted in fatigue signs and relevant discomfort that affected the conduct of the flight.

A presença de três elementos no *cockpit* permitiu não só a discussão de possíveis soluções durante o voo, como a troca de posição dos dois copilotos na importante fase final de aterragem, permitindo uma focalização e determinação da tripulação no objetivo de conseguir uma aterragem bem sucedida.

The three crew members on the *cockpit* allowed not only the discussion for possible solutions during the flight but also the two co-pilots position change in the important final landing phase, allowing the crew to be focused and determined on the objective of a successful landing.

1.16. Ensaios e Pesquisas || Tests and Research

Foram realizados testes e inspeções de validação da condição da aeronave pela investigação e pelo OEM com o objetivo de recolher dados para uma completa compreensão da sequência de eventos das ações de manutenção e do voo do evento.

Validation tests and inspections to assess the aircraft condition were carried out by the investigation and by the OEM in order to collect data for a complete understanding of maintenance actions events and flight sequence.

1.16.1. Ensaios na aeronave acidentada || Accident aircraft performed tests

Em coordenação com o operador, com a ajuda logística dos operacionais da FAP (BA11 em Beja) e na presença e auxílio do OEM, foram realizados os seguintes testes de validação pela investigação:

- Inspeções visuais detalhadas ao sistema de comando dos *ailerons*,
- Ensaios operacionais e funcionais na aeronave acidentada com os cabos de comando na configuração do acidente,
- Ensaios operacionais e funcionais na aeronave acidentada com os cabos de comando na configuração de projeto.

Principais conclusões:

Verificada a inversão dos cabos de comando doa *ailerons* pelos seus terminais em ambos os quadrantes.

A mensagem FLT CTR NO DISPATCH deixou de estar presente após o procedimento de RTS na sequência da reposição da condição de projeto dos cabos de comando dos *ailerons* da aeronave.

In coordination with the operator, with FAP (BA11 in Beja) logistical assistance and in the presence and support from the OEM, the following validation tests were carried out by the investigation:

- Detailed visual inspection to the aileron control system,
- Operational and functional tests on the accident aircraft with the control cables in the accident configuration,
- Operational and functional tests on the accident aircraft with control cables in the project configuration.

Main conclusions:

The inversion of the aileron control cables through their terminals was verified in both quadrants.

The FLT CTR NO DISPATCH message disappeared after the RTS procedure following the aircraft aileron control cables design condition restoration.

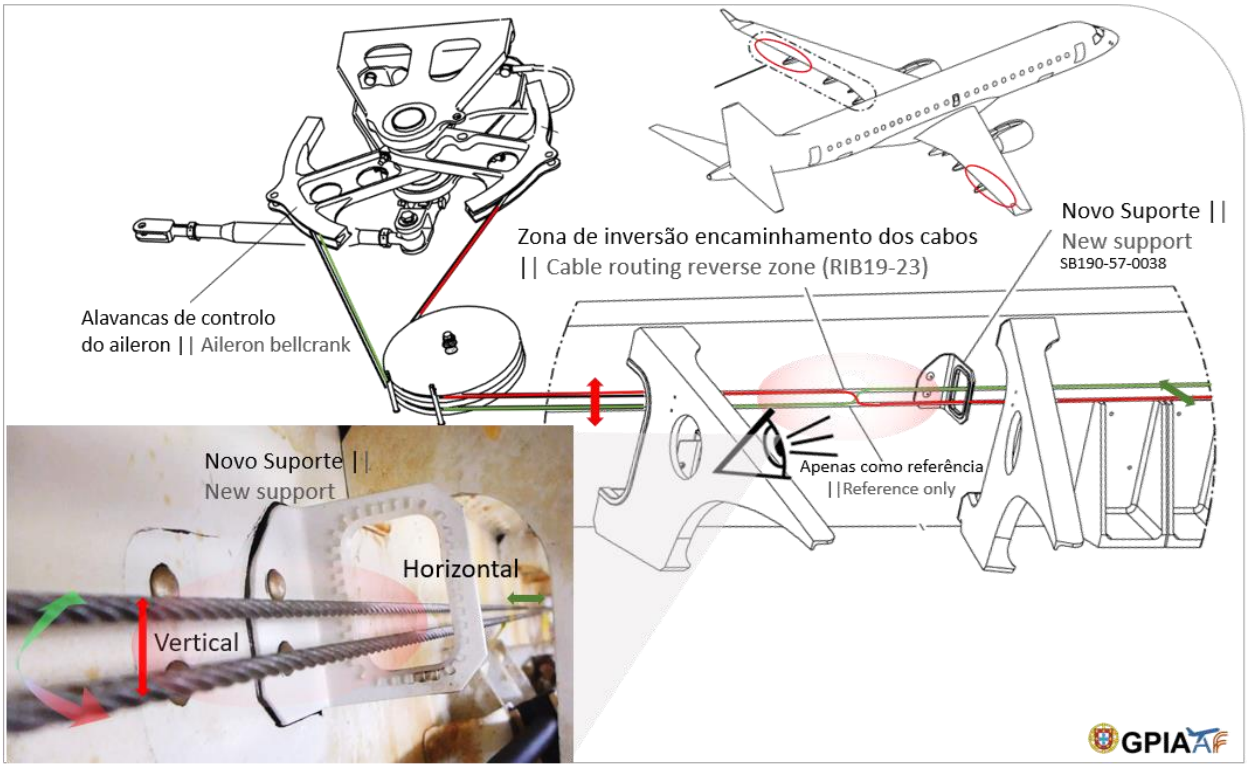

Figura 14 || **Figure 14**

Visualização do encaminhamento dos cabos de comando conforme encontrado após o voo do acidente
Fonte – AMM/SB

|| Control cables routing view as found after the accident flight.
Source – AMM/SB

1.16.2. Ensaios em aeronave aeronavegável || Tests performed in a airworthy aircraft

Com a colaboração de um outro operador de E190 e da sua própria AMO, a investigação realizou os mesmos testes de validação para ambas as configurações de voo do acidente e de projeto numa aeronave em estado aeronavegável.

In association with another E190 operator and its own AMO, the same validation tests were carried out by the investigation for both the accident and project flight configurations on an airworthy aircraft.

As principais conclusões foram em tudo semelhantes aos achados na aeronave acidentada.

The main conclusions were similar to the findings on the accident aircraft.

Adicionalmente foi confirmado que não tendo o FCS (NVM dos FCM) no seu registo prévio à inversão dos cabos de comando dos *ailerons* condição para apresentar a mensagem FLT CTR NO DISPATCH (FCND), esta não é desencadeada apenas com a inversão dos mesmos, seguida do procedimento de RTS. Neste mesmo procedimento de RTS com os cabos invertidos, foi verificado o *status* dos FCM 1, 3 e 4, apresentados a vermelho e não foi possível limpar os NVMs, conforme mostrado nas duas páginas do teste ilustrado na figura 17 referente ao voo do acidente.

Additionally, it was confirmed that with the FCS (NVM of the FCM) cleared of faults prior to the ailerons control cables inversion, i.e. without conditions to trigger the FLT CTR NO DISPATCH (FCND) message, the cable inversion only will not trigger the message, even following the RTS procedure. In this same RTS procedure after cable inversion, the FCM 1, 3 and 4 status, was shown in red, and it was not possible to clear the NVMs, as shown on the two pages of the test illustrated in figure 17 regarding the accident flight.

1.16.3. Ensaios realizados pelo fabricante || OEM performed tests

Após discussão de hipóteses com a investigação, o fabricante realizou os seguintes testes de validação nas suas instalações em Gavião Peixoto no Estado de São Paulo, Brasil, usando a aeronave E190 protótipo com número de série 190-0001 e em SJK (São José dos Campos no Estado de São Paulo – Brasil) usando o "pássaro de ferro" (Iron Bird 190).

After discussions regarding hypothesis from the investigation, the following validation tests were carried out by the OEM at its GPX facilities (Gavião Peixoto in São Paulo - Brazil), using the E190 prototype aircraft serial number 190-0001 (the iron bird), and at SJK facilities (São José dos Campos in São Paulo State – Brazil), using the Iron Bird 190.

#1. Com o objetivo de realizar a inversão dos cabos de comando dos *ailerons* para testar a possibilidade de consequentes indicações de FCND no EICAS.
Como esperado, a mensagem FCND não foi despoletada/exibida.

#1. Performing the aileron control cables inversion to test the possibility of consequent FCND EICAS indications.

As expected, the FCND message was not triggered/displayed.

2. Com o objetivo de realizar o teste de inversão dos cabos de comando dos *ailerons* e avaliar possíveis consequências durante o procedimento de retorno ao serviço do sistema de comandos de voo, sem falhas prévias registadas no sistema de comandos de voo.
Conforme esperado, a mensagem FCND não foi despoletada/exibida, sendo que foram evidenciados os marcadores a vermelho durante

#2. Performing the aileron control cables inversion test to check the possibility of consequences in the return-to-service of the flight controls system, in a condition without any previous failure in the Flight Controls System.

As expected, the FCND message was not triggered/displayed and the return to service pages shows the red bullets on the control yoke

o procedimento de retorno ao serviço, conforme descrito na figura 17 (ver página 61);

#3. Com o objetivo de realizar o teste de inversão dos cabos de comando dos *ailerons* e avaliar possíveis consequências durante o procedimento de retorno ao serviço do sistema de comandos de voo com uma falha introduzida e registada no FCS, proporcionando a exibição FLT CTRL NO DISPATCH antes da realização do procedimento RTS aos comandos de voo.

Verificou-se que o procedimento RTS não remove a mensagem FCND, mesmo após realização da ação corretiva da falha inicialmente introduzida. Como os cabos de comando dos *ailerons* permaneciam invertidos, não foi possível executar a totalidade dos CBITs e limpar os NVMs nos FCM durante o procedimento de RTS.

#4. O objetivo do último teste foi realizar a inversão dos cabos de comando dos *ailerons* avaliando as consequências no retorno ao serviço do sistema de comandos de voo, com a substituição de um FCM.

Tendo as mesmas pré-condições do teste n.º 3 com os cabos de comando dos *ailerons* invertidos e após executar as ações corretivas que despoletavam a mensagem FCND, foi substituído o respetivo FCM por um FCM com uma NVM limpa e executado o RTS. A mensagem de FCND não foi apresentada, mesmo antes de executar o RTS.

test, exactly as shown ahead on figure 17 (see page 61;

#3. Performing the aileron control cables inversion test to check possible consequences in the return-to-service of the flight controls system, in a condition with a latched failure introduced to the Flight Controls System, causing a FLT CTRL NO DISPATCH, before the flight controls system return-to-service (RTS) test was performed.

It was found that the RTS procedure did not remove the FCND message, even after performing the corrective action that initially latched the failure. As the aileron control cables remained inverted, it was not possible to fully run the CBITs and clear the NVMs on the FCM during the RTS procedure.

#4. Perform the aileron control cables inversion test with an FCM replacement, checking the consequences in the return-to-service of the flight controls system.

Having the same pre-conditions of test #3 with the inverted aileron control cables and after performing the corrective actions that latched the FCND message, the related FCM was replaced by an FCM with a cleared NVM and the RTS performed. The FCND was no longer active, even before performing the RTS.

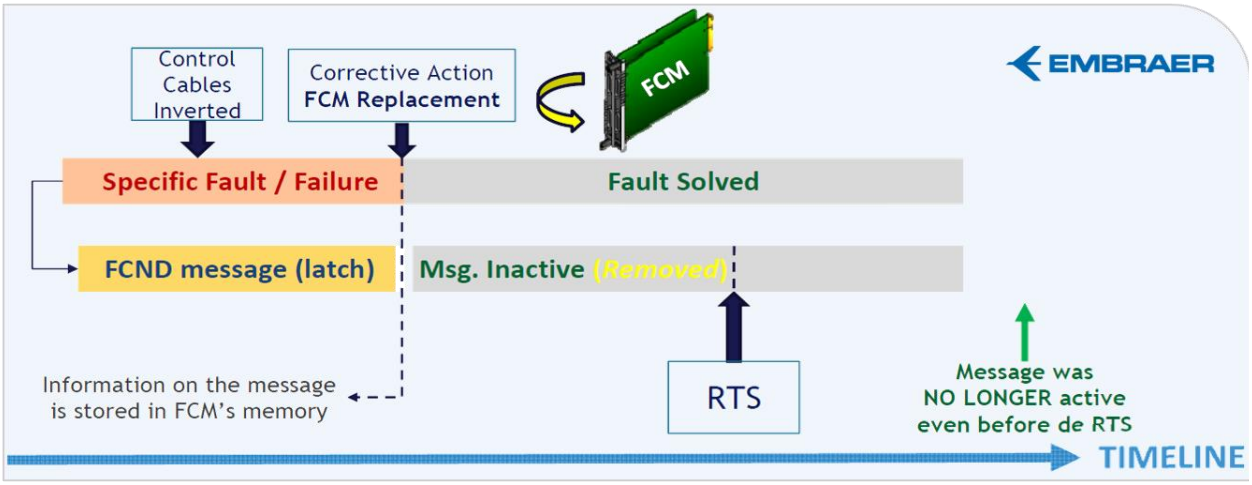

Figura 15 || **Figure 15**

Sequência de ações e resultados do teste #4 || Test #4 event sequence and findings

1.17. Informação sobre organização e gestão || Organizational and management information

1.17.1. Operador - Air Astana || Operator - Air Astana

O operador Air Astana com certificado de operador aéreo KZ-01/032, emitido pelo Civil Aviation Committee from Republic of Kazakhstan, opera um conjunto de aeronaves de fabrico ocidental, Airbus, Boeing e Embraer, onde se incluía a aeronave acidentada, com registo em Aruba através de um acordo relativo aos deveres e funções de supervisão entre o *Civil Aviation Committee of the Ministry for Investments and Development of the Republic of Kazakhstan* e o *Department of Civil Aviation of the Ministry of tourism, transportation, primary sector and culture of Aruba*.

Não dispondo à data do acidente de capacidade interna para a realização de manutenção de base à frota Embraer, o operador contratava tais serviços a diferentes organizações de manutenção, escolhendo o respetivo prestador após uma avaliação de capacidade técnica no âmbito de certificação pela autoridade de Aruba.

O processo de seleção da AMO para a realização de várias intervenções em aeronaves da frota do operador ocorreu sem que tenham sido realizadas auditorias ao sistema de manutenção e qualidade. As auditorias ocorreram já com o contrato em execução e com resultados aparentemente satisfatórios e sem não conformidades relevantes. A aeronave E190 com matrícula P4-KCJ, acidentada foi a décima segunda intervenção de manutenção do contrato baseado num princípio de Acordo Específico por Aeronave (AEA).

Não sendo uma obrigatoriedade legal, o operador não adotou a boa prática[5] de disponibilização às suas tripulações de informações ou material guia sobre as especificidades da receção e aceitação das aeronaves após intervenção relevante de manutenção. Não estavam estabelecidos mínimos meteorológicos para a realização do primeiro voo após a intervenção que precedeu o evento.

The operator, Air Astana, with air operator certificate KZ-01/032, issued by the Civil Aviation Committee from Republic of Kazakhstan, operates a set of western-made aircraft, Airbus, Boeing and Embraer, which included the accident aircraft with Aruba registration, through an agreement regarding supervisory duties and functions between the Civil Aviation Committee of the Ministry for Investments and Development of the Republic of Kazakhstan and the Department of Civil Aviation of the Ministry of tourism, transportation, primary sector and culture of Aruba.

At the time of the accident, the operator had no internal capability to perform base maintenance on the Embraer fleet, and outsourced such services to different maintenance organizations, choosing the respective provider after an assessment on its technical capability within the scope of approval of the authority Aruba.

The AMO selection process to carry out several operator's aircraft fleet services occurred without audits to the maintenance and quality system.

The audits occurred with the contract already in execution and with apparently satisfactory results and without relevant non-conformities. The E190 damaged aircraft, registered P4-KCJ was the twelfth maintenance event related to the contract based on SAA (Specific Aircraft Agreement).

Not being a legal obligation, the operator did not adopt a best practice[5] of providing its crews with information or guidance material specifying the aircraft reception and acceptance that underwent relevant maintenance works.

No meteorological minimums were established for the first flight after these heavy maintenance events.

[5] Usando o referencial EASA (Anexo V, parágrafo 6.3 do Regulamento (UE) 2018/1139), o piloto comandante deve estar satisfeito com a condição da aeronave após intervenção de manutenção || Using EASA reference (Annex V, paragraph 6.3 of Regulation (EU) 2018/1139), the pilot in command must be satisfied that the aircraft is airworthy after maintenance services.

Os procedimentos operacionais padrão do operador (SOP) na secção de procedimentos normais, 2-25 Revisão 03 de 22 FEV 2018, seguiam os SOP recomendado pelo fabricante, contendo:

"Os comandos de voo devem ser verificados quanto à liberdade de operação suave e contínua.
Uma indicação de caixa verde completa na página sinótica não é um requisito para uma verificação bem-sucedida.
O piloto sentado à esquerda seleciona a página sinótica do MFD *Flight Controls*;
. Elevator - full up, neutral, full down and neutral;
. Aileron - full left, neutral, full right and neutral;
. Rudder - full left, neutral, full right and neutral;"

Este procedimento SOP 2-25 não detalhava a questão da direção do movimento, o que não permitiu à tripulação detetar a incorreta configuração dos *ailerons*.

The operator Standard Operating Procedures (SOP) on normal procedures, section 2-25 Revision 03: 22 FEB 2018 followed the OEM recommended SOP, with:

"Flight controls should be checked for freedom of movement in a smooth and continuous manner.
A full green box indication on the synoptic page is not a requirement for a successful check.
Left seated pilot selects MFD Flight Control synoptic page;
. Elevator - full up, neutral, full down and neutral;
. Aileron - full left, neutral, full right and neutral;
. Rudder - full left, neutral, full right and neutral; "

This SOP 2-25 procedure lacked detail (control direction) which did not allow the crew to detect the misconfigured ailerons.

1.17.1.1. Ações desencadeadas pelo operador após o acidente|| Actions taken by the operator post-accident

Após o acidente e no decurso do seu processo de investigação interno, o operador desenvolveu um conjunto de ações preventivas e de mitigação, nomeadamente:

- Alteração no processo de avaliação e contratação dos serviços de manutenção de base aos prestadores de serviços de manutenção;
- Como referido, os procedimentos padrão (SOPs) da tripulação seguiam exatamente os SOP do fabricante, ainda assim foram detalhados alguns dos passos especificamente na lista de verificação pré-voo nos itens referentes à verificação da condição dos comandos de voo. A seção 2.25 prevê agora: (…)
  A cada posição correspondente alcançada de movimento ao batente/ponto neutro, o piloto sentado à esquerda declara:

  . "Elevator – Full Up, Neutral, Full Down, Neutral"
  . "Aileron – Full Left, Neutral, Full Right, Neutral"
  . "Rudder - Full Left, Neutral, Full Right, Neutral"
- Introduzida uma lista de verificação de aceitação das aeronaves após intervenção de manutenção significativa. Esta lista é disponibilizada às tripulações com o objetivo de informar os sistemas perturbados durante a manutenção.

The operator after the accident and following his internal investigation process, developed a set of preventive and mitigation actions, namely:

- Changes in the base maintenance services evaluation and contracting process of maintenance providers;
- As referred, the crew's SOPs exactly followed the manufacturer's SOP, yet some steps have been detailed specifically in the pre-flight checklist on the items referring to the flight control condition check. Section 2.25 now states:

  (…)

  As each full travel/neutral position is reached, the LSP calls out:

  . "Elevator – Full Up, Neutral, Full Down, Neutral"
  . "Aileron – Full Left, Neutral, Full Right, Neutral"
  . "Rudder - Full Left, Neutral, Full Right, Neutral"
- An aircraft acceptance checklist was introduced for use after significant maintenance intervention. The checklist informs the crews as to which systems were disturbed during the maintenance.

1.17.2. Prestador de serviços de manutenção || Maintenance services provider

A OGMA – Indústria Aeronáutica de Portugal S.A. presta serviços de manutenção e fabricação aeronáutica, sendo enquanto organização de manutenção detentora, entre outros, de certificação EASA Parte 145 (PT.145.004) e certificação do DCA de Aruba (DL-ACC-069) para trabalhos de manutenção de base na aeronave Embraer 170/190.

OGMA - Indústria Aeronáutica de Portugal S.A. provides aeronautical manufacturing and maintenance services, holding as a maintenance organization, among others, EASA Part 145 (PT.145.004) and Aruba DCA (DL-ACC-069) certification for base maintenance on the Embraer 170/190 aircraft type.

Entre um total de 1400 trabalhadores, a organização de manutenção de aeronaves civis contava, à data do acidente, com cerca de 120 técnicos de manutenção nas categorias de técnicos de certificação (*certifying staff*), técnicos de suporte (*support staff*) e não certificados (*qualified mechanics*).

Among a total of 1400 workers, the civil aircraft maintenance organization had, at the time of the accident, around 120 maintenance technicians on categories of certifying staff, support staff and non-certified qualified mechanics.

A área de manutenção de aeronaves civis presta serviços de manutenção de base aos produtos Embraer desde 1998 e especificamente no produto E170/190 desde 2005.

The civil aircraft maintenance area provides base maintenance services for Embraer products since 1998 and specifically since 2005 on E170/190 products.

O manual da organização de manutenção (MOM) está baseado no sistema normativo interno e é estruturado com procedimentos, práticas e orientações estabelecidas no seu denominado OGMA Normative System (ONS).

The maintenance organization exposition (MOM) is based on the internal regulatory system and is structured with procedures, practices and guidelines established in its named OGMA Normative System (ONS).

O referido sistema (ONS) apresenta-se globalmente bem estruturado e detalhado em procedimentos que cobrem as atividades de manutenção para as quais a organização é certificada.

This ONS system is globally well structured and detailed in procedures that cover the maintenance activities for which the organization is certified.

Já na implementação efetiva e no conhecimento desses mesmos procedimentos e normas pelos diferentes intervenientes do sistema global de qualidade, desde o operacional menos qualificado aos gestores de topo, a investigação encontrou lacunas relevantes, nomeadamente ao nível do processo de gestão e supervisão que se detalham nos parágrafos seguintes.

Relevant gaps were however identified, namely on effective implementation and knowledge of these same procedures and standards by the different personnel in the quality system, from the least qualified operational up to the top managers, the investigation found significant gaps, namely at the management and supervision processes that will be detailed in the following paragraphs.

1.17.2.1. Gestão de competências e formação || Competency management and training

Reconhecida em Portugal como uma das principais empresas aeronáuticas que contribuiu para o desenvolvimento de competências nacionais na área da manutenção e reparação aeronáutica (AMO), os dados dos últimos anos demonstram de uma alta rotatividade de pessoal associada a frequentes mudanças

Recognized in Portugal as one of the leading aeronautical companies that contributed to the development of national competences in the maintenance and repair area (AMO), the data shows a high staff turnover in recent years associated with frequent organizational changes that, as per organization management opinion,

organizacionais, o que, segundo opinião dos gestores do negócio, tem prejudicado a AMO na retenção do conhecimento técnico.

prevented the AMO from retaining the technical know-how.

O processo de atribuição de autorizações internas segue o procedimento aprovado pela autoridade nacional, e no caso de *support staff* e *certifying staff* é suportado nas competências genéricas e abrangentes pelo Regulamento (EU) 2018/1142 Anexo III, Parte 66. Os técnicos autorizados para exercer atividades de *support staff* B1 podem realizar ou supervisionar qualquer trabalho eletromecânico e/ou estrutural, em todos os sistemas mecânicos da aeronave, incluindo motores.

The process for granting internal authorizations follows the procedure approved by the national authority, and in the case of support staff and certifying staff, it is supported by the generic and wide-ranging competences of (EU) Regulation 2018/1142 annex III - Part 66. Technicians authorized to exercise support staff B1 activities may perform or supervise any electromechanical work and/or structures (sheet metal) in all aircraft mechanical systems, including engines.

Não foi evidenciada a conveniente preparação técnica e organizacional dos responsáveis da área produtiva para o âmbito das tarefas e responsabilidades atribuídas.

There was no evidence of appropriate technical and organizational preparation for the persons responsible for production within the assigned tasks and responsibilities.

Dos dados a que a investigação teve acesso, e apesar de evidenciadas tentativas de reorganização das diversas áreas produtivas após o evento, não foi possível identificar um referencial consistente no processo de avaliação e desenvolvimento de competências técnicas e consequente plano de formação.

From the data to which the investigation had access, and despite evident attempts to reorganize the different productive areas after the event, it was not possible to identify a solid standard on the technical competence and skills assessment and development process with the consequential training plan.

Não ficou clara para a investigação a identificação, pela organização, das necessidades de formação organizacional ou comportamental dos seus operacionais e gestores para fazer face às deficiências de competências e de experiência, sectorialmente reconhecidas pelos gestores intermédios.

During the investigation, it was not clear how the organisation identified the organisational or soft skills training needs to the operational staff and management, to face the recognized skills and experience deficiencies in each department assumed by the middle management.

1.17.2.2. Planeamento e preparação das atividades || Maintenance activities planning and preparation

A preparação, execução e controlo das atividades específicas (micro), bem como das ações macro de cumprimento de objetivos das atividades de manutenção estavam, à data do acidente, debaixo do controlo dos próprios executantes ou dos seus supervisores de produção (TL).

Specific micro activities setup, execution and control, as well as macro actions to fulfil maintenance activities objectives were, at the date of the accident, under staff control or their production supervisors (TL).

As interfaces entre as áreas de suporte à produção (aprovisionamento de material, planeamento e sequenciação de tarefas e área de engenharia) não eram claras quanto às respetivas responsabilidades. Embora globalmente definidas as funções de cada área, os problemas eram tratados numa base de caso a caso.

Interfaces between production support areas (material provisioning, task planning and sequencing and engineering) were unclear regarding responsibilities. Although the roles of each area were globally defined, the difficulties were treated on a case-by-case basis.

A alocação de recursos humanos e materiais à linha de produção não estava sistematizada, requerendo constantes ajustes ao planeamento das atividades com interrupções significativas do fluxo de produção e consequente realocação de recursos esporádicos ou de equipas completas, conforme verificado durante os trabalhos de implementação de modificações (SB) na aeronave acidentada ou o próprio processo de pesquisa de anomalia.

The human and material resources allocated to the production line was not structured, requiring constant adjustments to the planning activities, with significant interruptions in the production flow and the consequent staff/resources reallocation or complete team allocation, as verified during modification implementation tasks (SB) on the event aircraft or the aforementioned troubleshooting process.

1.17.2.3. Gestão e supervisão interna da atividade || Activity management and internal oversight

A supervisão das tarefas de manutenção na aeronave acidentada terá seguido os métodos habituais de trabalho aplicados pela AMO. Foram evidenciados nos documentos de trabalho importantes desvios aos procedimentos estabelecidos no normativo interno conforme aprovados pelas autoridades de certificação, os quais se exemplificarão abaixo.

The supervision of maintenance tasks on the accident aircraft followed the usual applied procedures to any other work performed by the AMO. Regarding work documentation, relevant deviations were found from the internal procedures approved by the certification authorities, as exemplified below.

A equipa estava organizada em dois turnos de trabalho, cada um com o seu chefe de equipa (TL) que era o responsável pela sequenciação, distribuição e supervisão dos trabalhos da sua equipa. Esta era constituída por técnicos de certificação, por técnicos de suporte (B1/B2) e mecânicos qualificados e não certificado com diferentes valências, embora sem especialidades formalmente atribuídas (reparações estruturais, reparações de compósitos, sistemas, aviónicos e interiores).
A passagem de turno era realizada apenas entre os TL de cada turno, sem que a informação relevante chegasse ao conhecimento de toda a equipa de uma forma consistente.

The team was organized in two working shifts, each having a team leader (TL) in charge of sequencing, distributing and supervising the tasks assigned to his team.

Each team was composed by certifying staff (B1/B2), support staff and qualified (non-certifying) technicians, with different skills (structural repair, composites repair, systems, avionics and interiors), although these skills weren't formally assigned.

Shift handover was performed only between both TL, without any relevant information reaching the rest of the team members in a consistent manner.

A classificação do tipo de supervisão das tarefas era realizada pela área da engenharia e atribuída consoante a criticidade das mesmas e conforme estabelecido na regulamentação. Era possível classificar as tarefas com execução e intervenção por um único elemento (SC), tarefas com necessidade de verificação por um segundo elemento (DC), e que adicionalmente, podem ou não ser classificadas como tarefas que requerem uma inspeção independente (*Independent Inspection*).

The tasks supervision type and classification were established by the engineering department according to their judgment and following the applicable regulation. It was possible to categorise the performed tasks as single check (SC), tasks that need double check by a second technician (DC), which in addition may or may not be classified as tasks that require an independent inspection.

O Regulamento (EU) N.º1321/2014 relativo à aeronavegabilidade continuada das aeronaves,

The (EU) Regulation No. 1321/2014 on the continuing airworthiness of aircraft and

produtos aeronáuticos, componentes e aprovação de organizações de manutenção e pessoal aeronáutico, estabelece pelos requisitos do seu Anexo II EASA Parte 145.A48 o conceito de *independente inspection*, sendo considerado um importante método de captura de erros.

O âmbito de uma inspeção independente é garantir a correta instalação, bloqueamento e sentido de operação de um determinado sistema que foi perturbado. Ao inspecionar os sistemas de comando que foram sujeitos a manutenção, a pessoa independente qualificada deve considerar os seguintes pontos de forma independente:

(1) todas as partes do sistema que foram desconectadas ou perturbadas devem ser inspecionadas quanto à instalação e correto bloqueamento;
(2) o sistema, como um todo, deve ser inspecionado quanto ao movimento completo e livre em toda a sua extensão;
(3) os cabos devem ser corretamente tensionados com a adequada separação dos batentes secundários;
(4) a operação do sistema de comando deve ser observada, como um todo, para garantir que os comandos estejam a operar no sentido correto;
(5) se diferentes sistemas de comando estiverem interconectados e que se possam afetar entre si, todas as interações devem ser verificadas em toda a sua extensão nos comandos aplicáveis; e
(6) o *software* que faz parte de uma tarefa crítica de manutenção deve ser verificado, por exemplo: versão, compatibilidade com a configuração da aeronave.

Uma inspeção independente é uma inspeção realizada por uma "pessoa independente qualificada" sobre uma tarefa realizada por uma "pessoa autorizada", tendo em consideração:

- a "pessoa autorizada" é a pessoa que executa a tarefa ou a supervisiona, e que assume a responsabilidade total pela conclusão da tarefa de acordo com os dados de manutenção aplicáveis;
- a "pessoa independente qualificada" é a pessoa que realiza a inspeção independente e atesta a conclusão satisfatória da tarefa e que não foram encontradas deficiências. A "pessoa

aeronautical products, parts and appliances, and on the approval of organisations and personnel involved in these tasks, establishes per EASA requirements on its Annex II, Part 145.A.48, the independent inspection concept as an important error capture method.

An independent inspection should ensure correct assembly, locking and sense of operation of a particular system that has been disturbed. When inspecting control systems that have undergone maintenance, the independent qualified person should consider the following points independently:

(1) all those parts of the system that have actually been disconnected or disturbed should be inspected for correct assembly and locking;
(2) the system, as a whole, should be inspected for full and free movement over the complete range;
(3) cables should be tensioned correctly with adequate clearance at secondary stops;
(4) the operation of the control system, as a whole, should be observed to ensure that the controls are operating in the correct sense;
(5) if different control systems are interconnected so that they affect each other, all the interactions should be checked through the full range of the applicable controls; and
(6) software that is part of the critical maintenance task should be checked, for example: version, compatibility with aircraft configuration.

An independent inspection is an inspection performed by an 'independent qualified person' of a task carried out by an 'authorised person', taking into account that:

- the "authorised person" is the person who performs the task or supervises the task and they assume the full responsibility for the completion of the task in accordance with the applicable maintenance data;
- the "independent qualified person" is the person who performs the independent inspection and attests the satisfactory completion of the task and that no deficiencies

independente qualificada" não emite um certificado de retorno ao serviço, portanto, não é obrigatório possuir privilégios de certificação;

- a "pessoa autorizada" emite o certificado para retorno ao serviço ou assina a conclusão da tarefa após a inspeção independente ter sido realizada satisfatoriamente;
- o sistema de cartas de trabalho usado pela organização deve garantir o registo da identificação de ambas as pessoas e os detalhes da inspeção independente, conforme necessário e antes da emissão do certificado de retorno ao serviço ou da assinatura para a conclusão da tarefa.

A AMO tinha definido no seu normativo interno o conceito de inspeção independente, cujos conteúdos e procedimentos sofreram alterações ao longo dos anos. Contudo, nenhum dos técnicos entrevistados pela investigação conhecia o âmbito e a filosofia deste procedimento de deteção do erro.

Analisado o protocolo de manutenção da aeronave acidentada referente aos trabalhos realizados, foi possível verificar que as tarefas classificadas com o requisito de inspeção independente, não foram realizadas segundo os procedimentos estabelecidos na regulamentação.

Nomeadamente, os trabalhos de supervisão das atividades de tarefas críticas dos sistemas relevantes para o acidente, foram em grande parte assinados pelos chefes de equipa (TL) de ambos os turnos. Apesar das suas autorizações e certificações internas serem válidas para a realização dos trabalhos, o nível do seu conhecimento técnico e carga de trabalho associada à gestão da equipa, deixaram dúvidas à investigação quanto à exequibilidade de tais tarefas em número e complexidade apenas pelos dois elementos.

Foi constatado pela investigação que o processo produtivo realizado à aeronave acidentada foi em tudo semelhante, nas suas debilidades, a outros processos de manutenção anteriores. A investigação recolheu informações sobre a existência de fragilidades de controlo efetivo do processo de produção e que estas eram transversalmente conhecidas dentro da

have been found. The 'independent qualified person' does not issue a certificate of release to service, therefore they are not required to hold certification privileges;

- the "authorised person" issues the certificate of release to service or signs off the completion of the task after the independent inspection has been carried out satisfactorily;
- the work card system used by the organisation should record the identification of both persons and the details of the independent inspection as necessary before the certificate of release to service or sign-off for the completion of the task is issued.

The AMO had defined the concept of independent inspection in its internal normative, whose contents and procedures have changed over the years. However, none of the technicians interviewed by the investigation knew the scope and philosophy of this error detection procedure.

Analysing the event aircraft maintenance protocol regarding the performed work, it was possible to verify that the tasks classified with the independent inspection requirement were not accomplished according to the procedures established in the regulation.

Namely, critical maintenance tasks relevant to the accident, requiring a close oversight, were mainly signed off by both production shift leaders (TLs).

Despite their valid internal authorizations and certifications to carry out the work, the depth of their technical knowledge and workload associated with the team management, raised doubts to the investigation regarding the feasibility of such number of complex tasks, just from the two team leaders.

It was found by the investigation that the production process carried out on the event aircraft was similar, in its weaknesses, to other previous maintenance processes.

The investigation also found weaknesses in effective production control process and that were known across the organization.

organização. Alguns exemplos diretamente relacionados com o evento:
- falta de planeamento e sequenciação de tarefas,
- fecho documental sem tarefas inteiramente terminadas,
- inspeções independentes assinadas sem terem sido realizadas no seu âmbito e extensão.

Some examples directly related to the event:

- lack of tasks planning and sequencing,

- document closure without full completed tasks,

- independent inspections signed without having been carried out in their scope and extension.

O sistema de supervisão interno previsto no regulamento (EU) N.º 1321/2014 não reconheceu estas fragilidades e não desenvolveu ações de mitigação ou alerta para as fragilidades identificadas no processo produtivo.

The internal oversight system provided in (EU) regulation No. 1321/2014 did not recognize these weaknesses and did not take mitigation actions or alert to the identified weaknesses in the production process.

1.17.2.4. Sistema de gestão da segurança e cultura de reporte || Safety management system and report culture

Não sendo à data do evento um requisito regulamentar, a AMO dispunha de um departamento de segurança operacional com procedimentos escritos sobre o seu funcionamento e âmbito de atuação.

Not being a regulatory requirement at the date of the event, the AMO had a safety department with written procedures on its operation and scope.

Embora existam evidências de algum trabalho feito na divulgação de boas práticas no domínio da cultura de reporte e algumas ações de formação que abordam o tema, sobretudo no pós evento e ao longo de 2019, a investigação observou na organização evidências de práticas de reporte de ocorrências e tratamento das mesmas em estado embrionário com poucos efeitos práticos na mudança de cultura dos seus operacionais, revelando uma falta de comprometimento da gestão de topo nestas matérias.

The investigation had access to evidence that some work has been done on reporting culture best practices dissemination, along with some training sessions to address the topic, especially in the post-event and throughout 2019, practices for reporting and occurrences handling were observed in the organization, however at primary stages with few practical effects on the employees culture change, revealing a lack of commitment by top management in these matters.

Dos dados a que a investigação teve acesso, o número de reportes voluntários e sobretudo os de ocorrências de segurança operacional são diminutos e de âmbito incipiente.

From the data to which the investigation had access, the number of voluntary reports and, mainly, those of safety concern occurrences are few and incipient in the scope.

No processo de entrevistas realizadas nos diversos níveis hierárquicos da empresa, foram constatadas falhas no entendimento e implementação do conceito de gestão de segurança operacional (SMS), incluindo ao nível das lideranças. Durante a recolha de dados, não foram demonstradas práticas de aplicação na empresa dos princípios de cultura justa[6].

From interviews conducted of personnel at different organization hierarchical levels, flaws were found on the safety management (SMS) philosophy understanding and implementation, including at leaders' level. During data gathering by the investigation, the just culture[6] practices were not demonstrated to be applied in the company.

[6] Uma atmosfera de confiança na qual as pessoas são incentivadas a fornecer informações essenciais relacionadas com segurança operacional, sendo também claras quanto à linha que deve ser traçada entre comportamento aceitável e o inaceitável. (James Reason 1997) || An atmosphere of trust in which people are encouraged for providing essential safety-related information, but in which they are also clear about where the line must be drawn between acceptable and unacceptable behavior. (James Reason 1997)

1.17.3. Sistema de supervisão externa e auditoria || External oversight and auditing system

Os trabalhos de manutenção na aeronave acidentada foram realizados sob a certificação da autoridade de Aruba. O processo de certificação e supervisão por esta autoridade é sobretudo baseado nas certificações prévias da organização como a certificação EASA Parte 145 e FAA 14CFR Part 145.
Embora a certificação Aruba DCA esteja assente em processos de auditoria de certificação inicial e continuada, a autoridade de Aruba não levantou ao prestador de serviços questões pertinentes ou relevantes sobre o seu processo produtivo seguindo a legislação aplicável.

The maintenance work on the accident aircraft was carried out under Aruba authority certification. The certification and supervision process by this authority is mainly based on previous organization certifications such as EASA Part 145 and FAA 14CFR Part 145.

Although Aruba DCA certification is based on initial and continuing certification audit processes, the Aruba authority did not raise any pertinent or relevant questions to the service provider about its production process, following the applicable regulation.

A certificação nos requisitos europeus (EASA) é realizada por delegação de competências e responsabilidades na Autoridade Nacional da Aviação Civil, ANAC. No processo de certificação continuada de 2018 do prestador de serviços foram levantadas não conformidades, sendo uma delas relacionada com a verificação de tarefas críticas (*Independent Inspection*). Não se constataram consequências efetivas na alteração do procedimento ou como este era entendido na organização.

EASA certification is carried out by delegating powers and responsibilities to the civil aviation national authority, ANAC. In the 2018 service provider continuous certification process, non-conformities were raised, one of which was related to the critical task supervision (Independent Inspection). No evidences of effective consequences in the procedure update or how it was effectively implemented in organization.

Pelo artigo 85 da regulamentação base (UE) N.º 2018/1139 do Parlamento Europeu e do Conselho de 4 de julho 2018, é requerido à Agência Europeia de Segurança da Aviação (EASA) que conduza inspeções de padronização por forma a monitorizar as autoridades nacionais competentes sobre o cumprimento do regulamento e suas regras de implementação, reportando à Comissão.
Já no primeiro trimestre de 2019, a EASA no decurso da auditoria ao licenciamento, certificação, autorizações e obrigações de aprovação realizada à ANAC e usando o prestador de serviços de manutenção envolvido no acidente como parte da amostra, foram identificadas um conjunto de situações, das quais se destaca de relevante para as lacunas encontradas pela investigação no referido prestador de serviços de manutenção, a aprovação do MOM da Parte 145 pela ANAC com deficiências, onde se incluem falhas de informação referente às autorizações internas do pessoal de certificação (CS) e de suporte (SS) para exercer as respetivas funções.

Articles 85 of the Basic Regulation (EU) No. 2018/1139 of the European Parliament and of the Council of 4 July 2018, require the European Union Aviation Safety Agency (EASA) to conduct standardisation inspections, in order to monitor the application by Competent Authorities of this regulation and of its implementing rules, and to report to the Commission.

During 1Q-2019, when performing the audit for licensing, certification, authorizations and approval obligations carried out to ANAC, EASA using the Part 145 service provider involved in the accident, as part of the sample, a set of shortcomings were found which stands out as relevant to the gaps found by the investigation in the aforementioned maintenance service provider, the approval of the Part 145 MOM by ANAC with deficiencies, which includes lack of information regarding the internal authorizations of the certifying staff (CS) and support staff (SS) in their corresponding functions.

1.18. Informação adicional || Additional information

1.18.1. Sequência de eventos de manutenção para a inversão dos cabos dos *ailerons* || Maintenance event sequence for the aileron cable transposal

Na fase inicial de modificações da intervenção de manutenção programada, especificamente durante a execução do boletim de serviço (SB190-57-0038R2), que modificava o tipo de encaminhamento dos cabos de comando dos *ailerons,* com a substituição de roldanas externas, em ambas semi-asas e respetivos suportes estruturais por um passador sem contacto, houve a necessidade de desconexão completa dos cabos de comando. Terá sido este o precursor da necessidade da remoção simultânea dos cabos.

In the initial modification phase of the schedule maintenance check, specifically during the service bulletin (SB190-57-0038R2) accomplishment, which modified the ailerons control cables routing type, with the replacement of outer pulleys, from both semi-wings, and the respective structural supports by a contactless frame, it was required to completely disconnect both control cables. This was the trigger condition for the cables simultaneous removal.

Após término do trabalho estrutural, os técnicos que tinham removido os cabos procederam à sua instalação temporária, pois segundo indicação dos chefes de equipa (TL), havia a necessidade da Equipa de Sistemas (equipa especializada em trabalhos sobre comandos de voo) proceder à substituição dos mesmos para dar cumprimento a um outro boletim de serviço, o SB190-27-0037R1, que consistia na substituição dos cabos de comando instalados fabricados em aço inoxidável por cabos em aço-carbono. Foram também aqui detetadas inconsistências documentais.

After finishing the structural work, the technicians who had removed both cables proceeded with a temporarily installation, as per team leaders (TL) instructions, there was a need to another team (flight controls specialized team) intervention as per another service bulletin accomplishment, the SB190-27-0037R1, which consisted of replacing the installed control cables manufactured in stainless steel with carbon steel cables. Documentary inconsistencies were also found here.

A referida substituição dos cabos foi registada como tendo sido realizada a 17-OUT, e conforme requerido pelo SB, foram registados o valor da temperatura ambiente e o valor da tensão aplicada aos cabos.
Contudo, nesta data a aeronave ainda se encontrava numa configuração que de acordo com o manual de manutenção da aeronave (AMM), inviabilizava a execução desse trabalho dado encontrar-se sem corrente elétrica necessária para a realização dos testes operacionais.
Não foram elaboradas cartas de trabalho adicionais para posterior realização ou finalização do trabalho.

The referred cable replacement was recorded as accomplished on OCT 17th, and as per SB instructions, the ambient temperature and cables applied tension were recorded.

However, on that date, the aircraft remained in a configuration that made it impossible to perform this work, as per aircraft maintenance manual (AMM) without electrical power to perform the required operational tests.

No additional working cards were raised for subsequent work to be carried out or for proper completion.

A reconexão temporária dos cabos nos quadrantes das PCU foi realizada por pessoal sem experiência relevante na tarefa. Estes técnicos seguiram as instruções do manual de

The temporary reconnection of the cables in PCU quadrants was carried out by personnel without relevant experience. These technicians followed the maintenance manual instructions, although they found them complex and difficult to follow.

manutenção, apesar de as considerarem complexas e de difícil seguimento.

Dias depois, os cabos foram substituídos, um a um e sem remoção completa dos mesmos, em conformidade com o referido no manual de manutenção (remoção e instalação). A tarefa foi realizada por pessoal experiente e que não detetou problemas na configuração dos mesmos.

Estando a aeronave nessa fase dos trabalhos sem energia elétrica, não foram realizados os testes de verificação de correta operação dos *ailerons* imediatamente após a finalização da tarefa de substituição dos cabos, conforme requerido no SB.

Aquando da reenergização da aeronave e durante a execução dos testes operacionais, a aeronave apresentou uma mensagem de FLT CTRL NO DISPATCH devido a uma falha no sistema de FCS. No entanto, devido à inversão dos cabos que havia ocorrido sem ter sido detetada, não foi possível executar o ciclo completo de retorno ao serviço dos comandos de voo, executando os cinco CBIT dos sistemas de comandos dos *ailerons* e limpar as NVM dos FCM.

Days later, the cables were replaced, one at a time and without complete removal, as required by the maintenance manual instructions (removal and installation). This task was performed by experienced personnel who did not detect any problems in the configuration.

As the aircraft was in this configuration without applied power, the operational tests to check the ailerons correct operation were not immediately performed after completing the cable replacement task, as required in the SB.

After the aircraft power-up and during the operational checks, a FLT CTRL NO DISPATCH was triggered due to a failure in the FCS. However, due to the non-detected aileron control cables inversion, it was not possible to fully perform the reset cycle on the flight controls return to service procedure, exercising the five CBIT of the ailerons control systems and cleaning the NVMs on the FCMs.

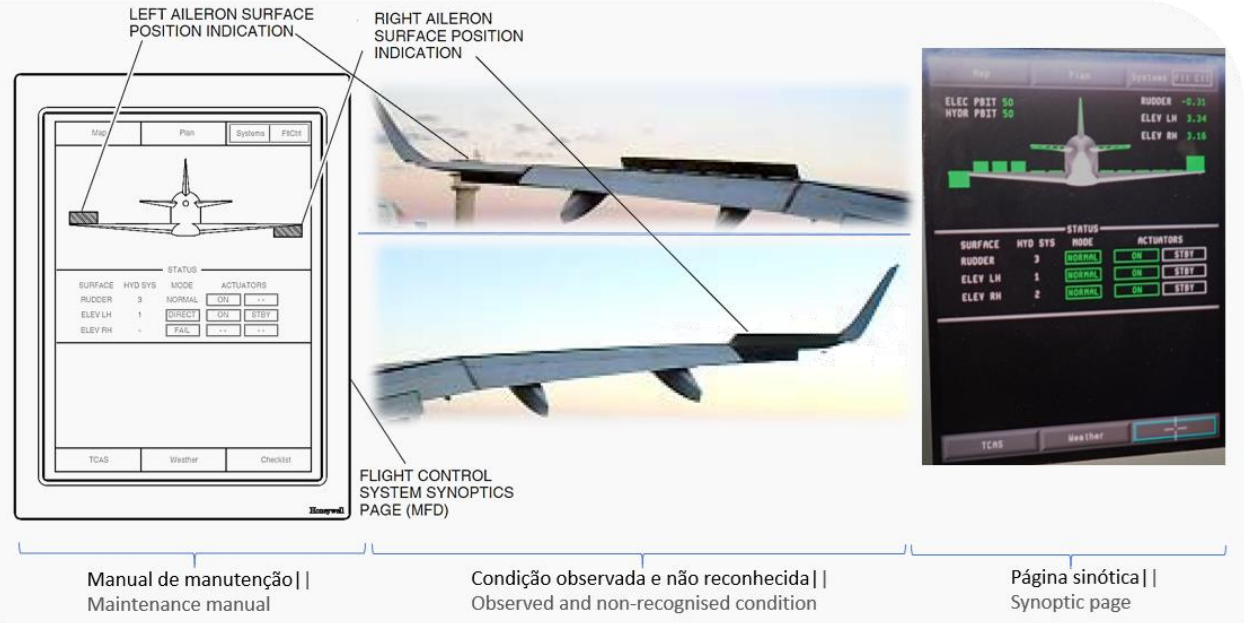

Figura 16 || Figure 16

Ilustração da posição física dos *ailerons*, conforme tarefa de manutenção à data do evento || Maintenance task procedure illustration for the physical aileron status at event time

Entre outros, os testes operacionais de comandos de voo preconizados no AMM, incluem uma verificação física do correto movimento dos *ailerons*, com a comparação da indicação dada pela página Sinótica, a posição física das

Among others, the flight control tests include a ailerons correct movement physical check as per AMM, in comparison to the indication given in the Synoptic page, the actual physical position of

superfícies de controlo (*ailerons* e *spoilers*) e o comando aplicado (*yoke*).

A nova equipa dedicada à resolução da anomalia contava com elementos da produção, engenharia e o próprio gestor da área. Mais tarde, a 5 NOV e após vários contactos com o serviço de suporte técnico do fabricante, a Embraer, foi despachado um representante técnico localizado em Amesterdão na Holanda para ajudar a resolver o problema e despachar a aeronave para voo.

Em todo o processo de pesquisa da anomalia, foram detetadas e corrigidas pela equipa várias discrepâncias técnicas, eventualmente induzidas durante a inspeção programada e/ou durante o próprio processo de pesquisa da anomalia.
Alguns dos técnicos envolvidos nesta fase não eram funcionários da AMO e não eram conhecedores do seu sistema normativo interno.

Os itens e ações considerados pela investigação como mais relevantes e com algum tipo de relação com a anomalia apresentada na aeronave pela mensagem de FLT CTR NO DISPATCH, são os abaixo elencados de forma resumida. Alguns dos componentes substituídos correspondem a itens de outras posições da mesma aeronave ou de outra aeronave por indisponibilidade de *stock* na AMO para a pesquisa da anomalia:

- Mensagem de *Ground Spoiler Fail*, que levou à substituição do FCM3 e PSEM2 com carregamento dos respetivos *softwares*;

- Detetados danos em pinos elétricos da *Backplane* da SPDA e substituída a mesma;

- Substituído o P-ACE1 com procedimentos de ajuste e retorno ao serviço executados;
- FCM1 detetado com suposto defeito, substituído e carregado *software* sem sucesso na resolução da anomalia, sendo que no final do dia 5 NOV, mantém indicação de possíveis problemas nos FCM1, 2 e 4;

- Dia 6 NOV, substituição do FCM 3 por um novo, FCM 1 e 4 oriundo de outras posições, FCM2 de outra aeronave, substituídos P-ACE2 e 3, substituídos PSEM2 e DC *Power Module* do Slot#3 da SPDA#1, efetuados vários carregamentos de *software*, a mensagem mantinha-se;

- Dia 8 NOV, detetados e resolvidos problemas no ajuste do leme de direção;

the control surfaces (ailerons and spoilers) and the applied input (yoke).

The new team that included maintenance, engineering and the area manager himself, was fully dedicated to the troubleshooting. Later, on NOV 5th and after several contacts with the manufacturer's technical support service, Embraer, a technical representative located in Amsterdam, Netherlands, was dispatched to help solve the problem and dispatch the aircraft for flight.

Throughout the troubleshooting process, several technical discrepancies were detected and corrected by the team. It is likely that those discrepancies were induced during the scheduled maintenance and/or during the troubleshooting process itself. Some of the technicians involved in this phase were not AMO employees and were not familiar with its internal quality system.

Below, in summary format, are listed the considered items/actions by the investigation as most relevant and related with the discrepancy presented in the aircraft by the FLT CTR NO DISPATCH message. Some of the replaced components were items with origin in other positions of the same aircraft or from another aircraft due to lack of stock in the AMO for troubleshooting purposes:

- Ground Spoiler Fail message, which led to the replacement of FCM3 and PSEM2 with related software loading;

- SPDA Backplane electrical pins damage detected and replaced;

- P-ACE1 replaced with proper with proper rigging and return to service procedure performed;

- FCM1 detected with suspected defect, unsuccessful replacement and software loaded – at the end of NOV 5th, indication remains of possible issues with FCM1, 2 and 4;

- NOV 6th, replacement of FCM 3 with a new one, FCM 1 and 4 from other positions, FCM2 from another aircraft, replaced P-ACE2 and 3, replaced PSEM2 and DC Power Module from SPDA #1, Slot#3, several software loads performed, the message remained;

- NOV 8th, detected and solved rudder adjustment issues;

- Dia 9 NOV, substituído FCM1 e FCM4, sendo o status no final do dia: FCM1, 3 e 4 novos e o FCM2 oriundo de outra aeronave, condição que garantiu a eliminação da mensagem de FLT CTR NO DISPATTCH;

- Dia 11 NOV, na manhã do dia do acidente, foi instalado o FCM2, último componente a ser substituído e efetuados os carregamentos de *software*. Após seis sequências de *power-down/power-up*, a mensagem de FLT CTR NO DISPATCH não terá reaparecido no seguimento da realização do procedimento de verificação e retorno ao serviço (RTS) do sistema de comandos de voo.

- NOV 9th, FCM1 and FCM4 replaced, with the following status at the end of the day:
FCM 1, 3 and 4 new and FCM 2 coming from another aircraft, condition that ensured the FLT CTR NO DISPATCH message clearing;

- NOV 11th, in the morning of accident day, FCM2 was installed, the last component to be replaced and software loaded.

After six power-down/power-up sequences, the FLT CTR NO DISPATCH message did not reappear following the flight controls system return to service (RTS) procedure.

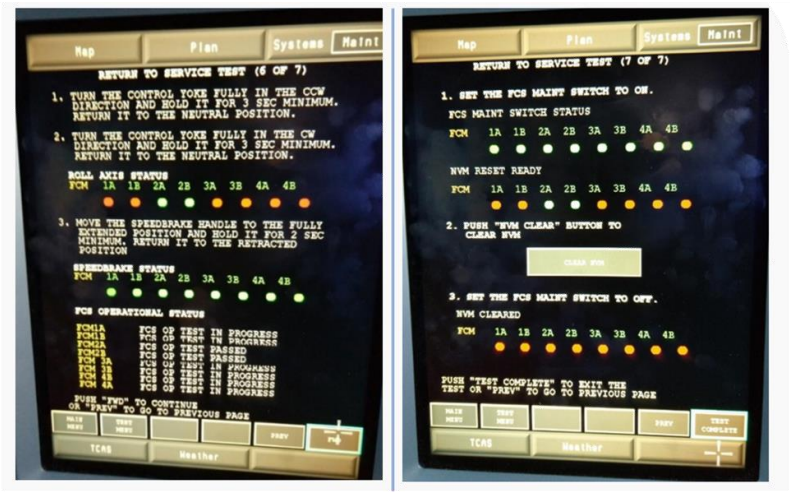

Figura 17 || Ilustração do teste dos FCM e condição das respetivas NVMs antes do voo do acidente

Figure 17 || FCM test and respective NVMs condition illustration, before the accident flight

Neste último procedimento realizado na manhã do voo do acidente, confirmando que a mensagem de FLT CTR NO DISPATCH tinha desaparecido do EICAS. A página de estados de manutenção dos FCM apresentavam a configuração acima ilustrada, onde apenas o FCM2 apresentava o estado a verde após o ensaio. Os módulos de memória (NVM) dos restantes FCMs não passavam no teste e as respetivas NVMs não aceitavam *reset* no último passo (7 de 7) do procedimento de RTS, no entanto o sistema da aeronave assumia como concluído.

Esta sequência de eventos levou a que não fosse possível limpar a mensagem de FLT CTR NO DISPATCH até ter sido substituído o módulo de comando com registo de falha na memória.

In this last performed procedure on the morning of the accident flight, confirmed that the FLT CTR NO DISPATCH message had disappeared from EICAS. The FCM maintenance status page presented the configuration shown in the above figure, where only the FCM2 presented the green status after the test (RTS). The others FCM memory modules (NVM) did not successful pass the test and the respective NVMs did not accept the reset during last step (7 of 7) of the RTS procedure, however the aircraft system assumed as completed.

This sequence of events established the conditions that make the FLT CTR NO DISPATCH message clearance not possible, until the control module with recorded fault on its memory was replaced.

Durante a fase de pesquisa de anomalias (desde 31-OUT a 11-NOV), ao proceder à substituição dos FCM com as respetivas memórias que tinham, entretanto registado falhas decorrentes das normais configurações da aeronave durante os trabalhos de manutenção, o registo da falha foi eliminado pela arquitetura do sistema e conforme descrito em 1.6.5 (Sistema de diagnóstico e manutenção da aeronave - ADMS).

During the troubleshooting phase (since 31-OUT to 11-NOV) when replacing the FCM with the respective memories, that in the meantime had registered failures due to normal aircraft configurations during maintenance activities, the failure record was eliminated as explained in the system architecture described in 1.6.5 (ADMS – Aircraft Diagnostic and Maintenance System replacement).

Nenhum dos técnicos envolvidos no processo de resolução da anomalia durante as inúmeras tentativas de remoção da mensagem através do procedimento de RTS com movimentação das superfícies de comando de voo, se apercebeu do movimento invertido dos *ailerons* (por observação visual direta dos mesmos ou através da página Sinótica) em relação ao comando dado no volante de controlo (*control yoke*).

None of the involved technicians in the troubleshooting process during the several attempts to remove the message through the RTS procedure with positive flight control surfaces movement, noticed the erroneous ailerons movement (by direct observation or through the Synoptic page) in respect to the given command in the control yoke.

1.18.2. Suporte técnico do fabricante – EMBRAER || OEM – EMBRAER technical support

1.18.2.1. Publicações técnicas da aeronave || Aircraft technical publications

A AMO é um centro de serviços aprovado pelo fabricante da aeronave. Os serviços de manutenção executados na aeronave acidentada usaram as publicações técnicas adequadas e aplicáveis e, quando necessário, com o suporte técnico do fabricante, nomeadamente na fase de pesquisa de anomalias. Foram encontradas inconsistências em algumas das instruções técnicas utilizadas, nomeadamente nas tarefas relacionadas com os cabos de comando dos *ailerons*.

The AMO is an OEM approved service centre. The performed maintenance services on the accident aircraft were carried out with the appropriate and applicable technical publications and, when necessary, with the OEM technical support, namely during the troubleshooting phase. Inconsistencies were found in some of the technical instructions used, namely in tasks related to aileron control cables.

As inconsistências nas tarefas de remoção e instalação dos cabos dos *ailerons* evidenciavam uma descrição e sequenciação de sub-tarefas com compreensão complexa e com elevado potencial de confusão. As figuras, sem recurso a diferenciação gráfica do correto encaminhamento dos cabos foram consideradas como confusas tanto pelos executantes como por outros técnicos experientes no modelo da aeronave e chamados pela investigação para dar a sua opinião.

The inconsistencies in the aileron cables removal and installation tasks exhibited complex understanding on description and sub-tasks sequencing and with a high potential for misunderstanding. The figures, without graphical differentiation usage for proper highlight cable routing, were considered to be confusing by the involved technicians and other experienced staff on the aircraft type as well, called upon the investigation to express their opinion.

No manual de manutenção foram identificadas figuras que pretendem representar os mesmos componentes, contudo com representações inversas, como é o caso da tarefa de ajuste dos cabos comparativamente à tarefa de instalação dos mesmos (ver figura seguinte). É de notar que

In the maintenance manual, figures were identified that intend to represent the same components with inverse representations, as is the case with the cable adjustment task compared to the installation task, as shown on the following figure. It should be noted that the

a tarefa de instalação dos cabos fazia referência a figuras com a representação correta dos componentes, contudo com limitações no formato de apresentação.

referenced figures contained in the cables installation task contained correct components representation, however with presenting format limitations.

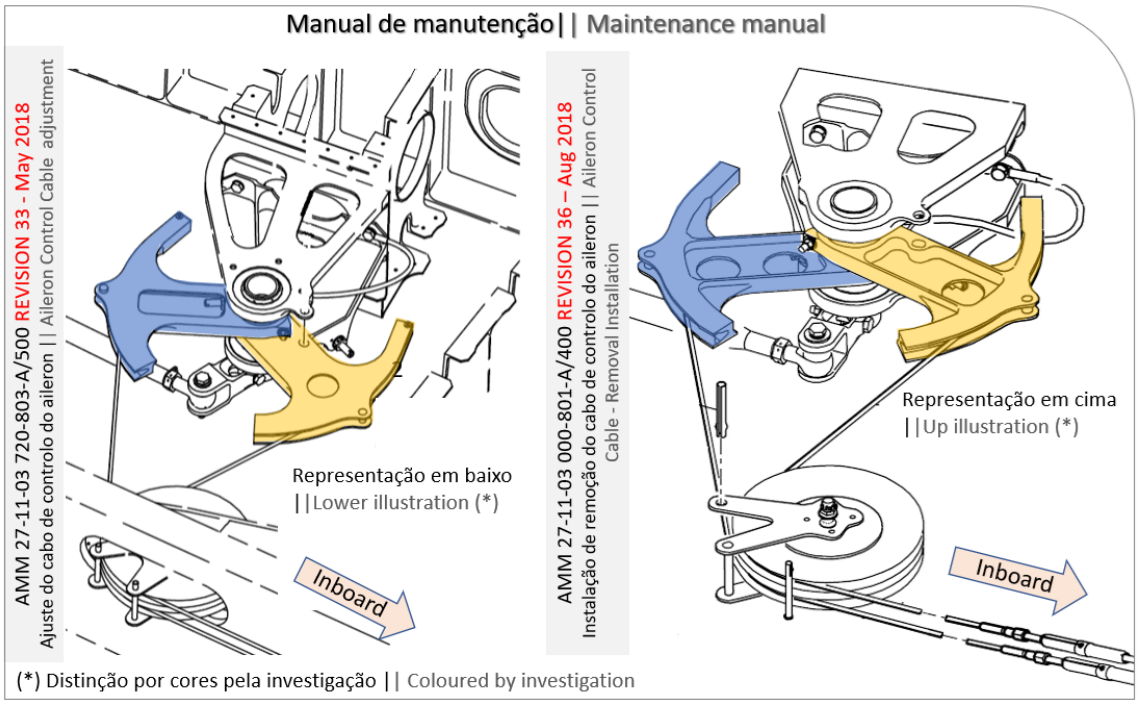

Figura 18 || **Figure 18**

Diferenças de representação técnica de componentes || Technical view of components - differences
Fonte - AMM | Source - AMM

Relativamente ao documento de trabalho de modificação do suporte das roldanas dos cabos, o boletim de serviço SB190-57-0038R2, referia a necessidade da desconexão completa de ambos os cabos de comando na zona da longarina traseira de ambas as semi-asas para instalação dos novos passadores (figura 1). Este procedimento colocava em causa a configuração de projeto da aeronave pela facilidade de reinstalação incorreta, não cumprindo com as especificações de certificação enumeradas em 1.6.2 acima.

Regarding the working document for the cables pulley support replacement, service bulletin SB190-57-0038R2, mentioned the need for a complete disconnection of both control cables in the rear wing spar area on both semi-wings aiming the new frame installation (figure 1). This procedure jeopardises the aircraft project configuration and facilitates an incorrect reinstallation, not complying with the certification specifications listed in 1.6.2 of this report.

1.18.2.2. Serviço de suporte técnico prestado || OEM provided technical support

O fabricante, enquanto responsável por garantir o suporte do produto para que o operador assegure a aeronavegabilidade continuada, oferece um serviço de suporte técnico aos seus clientes e centros de serviço para garantir a operação eficiente das suas aeronaves.

The manufacturer, while ensuring product support for the operator that in turn ensure the aircraft continued airworthiness, offers a technical support service to its customers and service centres to ensure the efficient operation of its aircraft.

A AMO, após as identificadas dificuldades em lidar com a suposta falha de comandos de voo,

The AMO, after the identified difficulties in dealing with the supposed flight controls failure,

durante o processo de pesquisa de anomalia recorreu a este serviço do fabricante com inúmeras interações promovidas pelo seu departamento de engenharia.

Após vários dias e com a pressão para a entrega da aeronave ao operador, o fabricante após solicitação da AMO, decide enviar um representante técnico (FTR) com o objetivo de resolução do problema em proximidade.

Por definição do fabricante, um representante técnico de campo (FTR) é alocado à base do cliente, durante o período de tempo previamente contratado. Um FTR deve auxiliar e aconselhar o cliente em questões de manutenção e engenharia da aeronave, atuando como uma ligação entre o cliente e o fabricante, a Embraer.

Atendendo à (não detetada) configuração da aeronave fora das condições de projeto, o suporte prestado pelo fabricante levou às ações de pesquisa de anomalia realizadas durante os 11 dias. Tais ações foram suportadas em procedimentos por tentativa, seguindo pistas emanadas pelo sistema ADMS e interpretadas pela engenharia do fabricante.

Em todo este processo de pesquisa de anomalia, em nenhum momento foi questionado pelo fabricante ou pela AMO se a aeronave ainda mantinha as condições de certificação inicial, dada a extensão da intervenção com a substituição em massa de componentes primários do sistema de comandos de voo.

Embora todas as ações de substituição de componentes estivessem cobertas por instruções do manual de manutenção e dentro do âmbito de certificação da AMO, a sua execução conjunta e a sua sequência não foram avaliadas quanto a eventuais necessidades de testes adicionais e de validação da condição final da aeronave após grande intervenção, com necessidade ou não de aprovação pela autoridade local, neste caso DCA.

É importante referir que a disposição técnica do fabricante, caso existisse, não seria uma aprovação para a aeronave retornar ao serviço, no entanto, poderia ser usada para apoiar o operador a fazê-lo. Se as disposições técnicas contidas no documento exigirem aprovação adicional da autoridade reguladora local, serão

during the troubleshooting process, resorted to this service from the manufacturer with several interactions promoted by its engineering department.

After several days and with the pressure to deliver the aircraft to the operator, the manufacturer, after AMO request, decided to send a technical representative (FTR) with the purpose of solving the problem in close contact.

By definition, a field technical representative (FTR) is dispatched to customer's base, during a previously contracted period of time. An FTR shall assist and advise customer on aircraft maintenance and engineering matters by acting as a liaison between customer and OEM, Embraer.

Considering the aircraft's (not detected) configuration not in compliance with design specifications, the support provided by the manufacturer led to the troubleshooting actions carried out for 11 days. Those actions were supported and based in tentative procedures, following clues originated by the ADMS system and interpreted by the manufacturer's engineering.

In all this troubleshooting process, at no time was questioned, either by the manufacturer or the AMO, whether the aircraft still maintained the initial certification conditions, given the extent of the maintenance intervention with massive flight control system primary components replacement.

Although all actions for replacing those components were covered by instructions in the maintenance manual and within the scope of AMO certification, their combined accomplishment and their sequence were not assessed for possible additional requirements for testing and final aircraft condition validation after major intervention, whether or not it needs local authority approval, DCA on the case.

It must be referred that an OEM technical disposition, if issued, would not be an approval for the aircraft to return to service, however, may be used to support the operator to do so. If the technical disposition contained in the document requires additional approval from the local regulatory authority, appropriate measures need to be taken to obtain such approval.

necessárias medidas apropriadas para obter essa aprovação.

A AMO possuía um procedimento para a inspeção final e entrega de aeronave após intervenção de manutenção. Contudo não se mostrou eficaz na deteção da configuração da aeronave.

The AMO had a procedure for the final inspection and aircraft delivery after a maintenance activity. However, it was not effective in detecting the aircraft misconfiguration.

1.18.2.3. Ações desenvolvidas pelo fabricante pós-acidente || OEM post-accident actions

Dentro das suas responsabilidades, a engenharia de manutenção do fabricante deve assegurar o desenvolvimento do produto através dos procedimentos de manutenção, boletins de serviço, validação de procedimentos, suporte e desenvolvimento das publicações técnicas aplicáveis à aeronave.

Within its responsibilities, the manufacturer's maintenance engineering must ensure product development through maintenance procedures, service bulletins, procedures validation, support and development of technical publications applicable to the aircraft.

Após o evento e no decorrer da investigação, o OEM realizou importantes alterações nas instruções e procedimentos aprovados, como é exemplo a alteração da tarefa de substituição dos cabos dos *ailerons,* onde passou a usar instruções mais claras e recorrendo a coloração das figuras com implicação no SB de substituição dos mesmos cabos, o SB 190-57-0038 *aileron control cables - fairleads and grommet replacement* e na tarefa de verificação da posição dos *aileron*s.

After the event and during the investigation, the OEM made important changes to the approved instructions and procedures, such as changing aileron control cables replacement task adding clearer instructions and using figure colouring on SB 190-57-0038 aileron control cables - fairleads and grommet replacement related instruction, the SB for cable material replacement and also on the operational task to check the ailerons position.

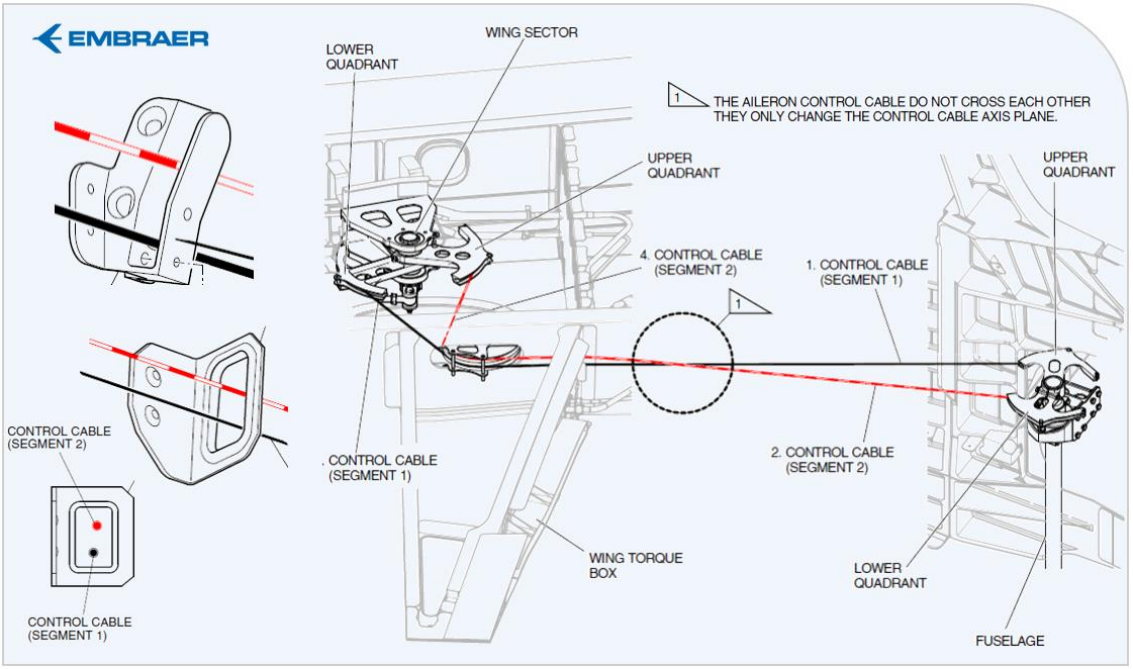

Figura 19 ||
Figura exemplificativa das alterações preconizadas na tarefa de manutenção de substituição dos cabos
Fonte – AMM 27-11-03 Rev. Out 2019

Figure 19
Illustrative picture with changes in the revised cable replacement maintenance task
Source – AMM 27-11-03 Rev. Out 2019

O SB 190-57-0038 foi revisto para estar harmonizado com o AMM, onde a revisão 3 do mesmo já está disponível com procedimentos nos quais não é necessária a remoção simultânea dos dois cabos de comando dos *ailerons*.

O fabricante desenvolveu, em complemento à representação gráfica visual também melhorada no manual de manutenção, uma nova página de CMC como ajuda à execução do teste operacional dos *ailerons* pelo AMM 27-10-00-710-801-A, que consta no novo *software* a ser carregado nas aeronaves e que garante uma validação da condição efetiva das posições relativas entre o comando dado no volante de controlo (*yoke*) e a posição física das superfícies dos *ailerons*.

Este novo recurso disponível para ser incluído no CMC, além da verificação visual e da verificação na página Sinótica, se instalado, ajudará o técnico na realização do teste operacional do sistema de comando dos *ailerons*.
A solução recorre a *software* com linguagem de programação em "baixo nível" (*software* para uso apenas em manutenção), e, portanto, sem necessidade de processo de certificação, que através do código **0** para "Falha"; código **1** para "Passa" e código **2** para "Aguarda Comando", informa o técnico da posição dos *ailerons* em relação ao comando realizado na coluna de controlo.

The SB 190-57-0038 was revised to be harmonized with AMM and the revision 3 is already available with procedures where is not required to remove both aileron control cables at the same time.

The manufacturer developed, in addition to the visual graphic representation also improved in the maintenance manual, a new CMC page as an aid to the operational test of the ailerons by AMM 27-10-00-710-801-A, which is included in the new software to be loaded onto the aircraft and which assures a validation of the effective condition of the relative positions between the command given in the control yoke and the actual position of the aileron surfaces.

This new feature already available to be included to the CMC in addition to the visual check and Synoptic check, if installed, aids the mechanic to do the Aileron Control System Operation Test.

The solution uses "low-level" programming software (software used in maintenance only), and therefore, without the certification process requirements, trough the code **0** for "Failure"; code **1** for "Pass" and code **2** for "Waiting for Command", informs the technician of the ailerons position in relation to the control column command.

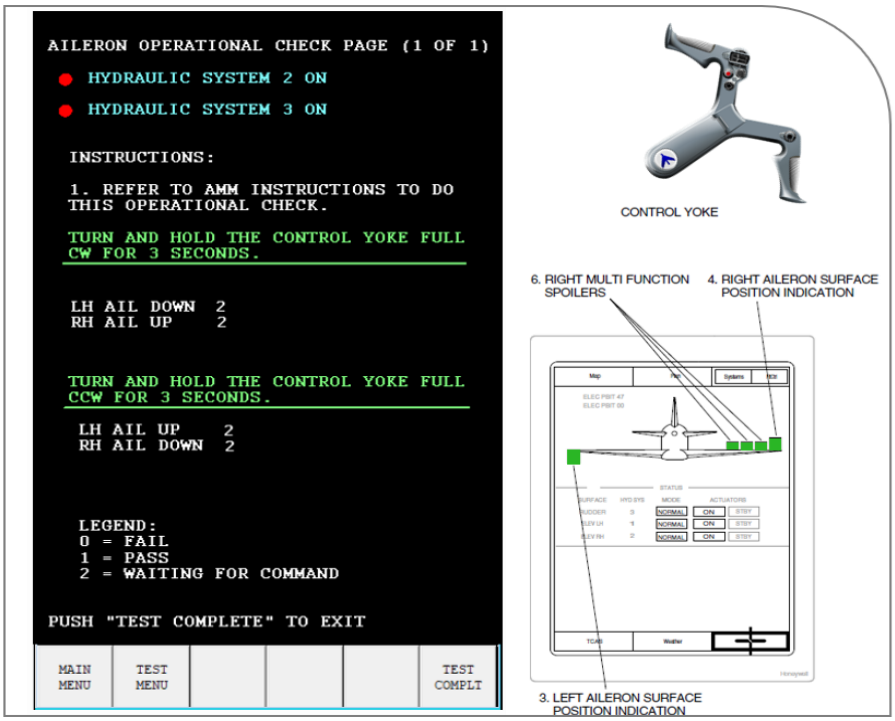

Figura 20 || **Figure 20**
Nova página CMC de verificação operacional dos *ailerons* || New CMC page for aileron operational check
Fonte – Nova revisão do AMM Source – New AMM revision

1.18.3. Outros acidentes relacionados com manutenção em comandos de voo|| Other maintenance flight control related accidents

Apresentam-se de seguida sumariamente quatro eventos com exemplos de ações de manutenção diretamente relacionadas com sistemas de comandos de voo que levaram a acidentes ou incidentes graves. A inclusão destes eventos no presente relatório de investigação tem o propósito de consubstanciar as lições aprendidas nos referidos eventos e a sua relação com os achados no presente caso e analisados no capítulo 2.

Below are briefly presented four events with examples of maintenance actions directly related to flight control systems that led to accidents or serious incidents. The inclusion of these events in the present investigation report has the purpose of consolidating the lessons learned in the referred events and their relationship with the findings in the present case and analysed on chapter 2.

1.18.3.1. Voo 9446 da Colgan Air, Yarmouth, Massachusetts || Colgan Air Flight 9446, Yarmouth, Massachusetts

A 26 AGO 2003, o voo 9446 da Colgan Air, efetuado num Beech 1900D, com matrícula N240CJ, acidentou-se na água perto de Yarmouth no Massachusetts, EUA. Os dois tripulantes faleceram e a aeronave ficou substancialmente danificada. O voo de reposicionamento, realizado sob as regras FAA 14 CFR Parte 91, descolou do Aeroporto Municipal de Barnstable, Hyannis, Massachusetts, para o Aeroporto Internacional de Albany (ALB), Albany, New York.

On August 26th, 2003, Colgan Air flight 9446, using a Beech 1900D, registered N240CJ, crashed into water near Yarmouth, Massachusetts, USA. The two flight crewmembers were killed, and the aircraft was substantially damaged. The repositioning flight, which was conducted under 14 CFR Part 91, departed Barnstable Municipal Airport, Hyannis, Massachusetts, for Albany International Airport (ALB), Albany, New York.

Logo após a descolagem, a tripulação declarou emergência, reportando um problema no compensador de profundidade. A aeronave atingiu uma altitude de cerca de 1100ft MSL. A tripulação solicitou autorização para aterrar numa pista específica, sendo autorizada pelo controlador para usar qualquer das pistas. Nenhuma outra transmissão rádio foi recebida da tripulação.

Shortly after take-off, the flight crewmembers declared an emergency and reported a trim problem. The aircraft had reached an altitude of about 1100ft MSL. The flight crew requested to land on a specific runway, and the controller cleared the flight to land on any runway. No further transmissions were received from the flight crew.

A investigação do NTSB[7] ao acidente revelou, entre outros achados, que a ilustração do tambor dianteiro do cabo do compensador do leme de profundidade era mostrada invertido na seção 27-30-04 do manual de manutenção do Beech 1900D. A 22-OUT-2003, a Raytheon Aircraft Company reviu o procedimento de ajuste do cabo do compensador do leme de profundidade para evidenciar a correta ilustração das peças.

The National Transportation Safety Board's investigation[7] of this accident revealed, among other findings, that the illustration of the forward elevator trim tab cable drum appeared backward in section 27-30-04 in the Beech 1900D AMM. On October 22nd, 2003, Raytheon Aircraft Company revised its Beech 1900D AMM elevator trim tab cable rigging procedure to show the correct illustration for the forward elevator trim tab cable drum.

[7] Informação adicional sobre este acidente (NYC03MA183) pode ser encontrada na página do NTSB na internet || Additional information about this accident, NYC03MA183, can be found on the National Transportation Safety Board's (NTSB) Web site

1.18.3.2. Voo 17 da Emery Airlines, Rancho Cordova, California || Emery Airlines Flight 17, Rancho Cordova, California

A 16 FEV 2000, o voo 17 da Emery Airlines, usando um McDonnell Douglas DC-8-71F, com matrícula N8079U, despenhou-se num parque de automóveis logo após a descolagem, enquanto tentava regressar ao Aeroporto Sacramento Mather, em Rancho Cordova na Califórnia, EUA para uma aterragem de emergência. O voo 17 era um voo de carga programado de Sacramento para o Aeroporto Internacional James M. Cox Dayton em Dayton no Ohio, EUA. Os dois pilotos e o engenheiro de voo faleceram e a aeronave foi destruída.

On February 16th, 2000, Emery Airlines flight 17, a McDonnell Douglas DC-8-71F, N8079U, crashed in an automobile salvage yard shortly after take-off while attempting to return to Sacramento Mather Airport, Rancho Cordova, California, USA for an emergency landing. Flight 17 was a scheduled cargo flight from Sacramento to James M. Cox Dayton International Airport, Dayton, Ohio. The two pilots and the flight engineer were killed, and the aircraft was destroyed.

A investigação do NTSB ao acidente determinou que o parafuso que ligava a manivela direita da ferragem de controle do leme de profundidade da aeronave ao encaixe do tirante foi incorretamente fixado e inspecionado durante a recente inspeção tipo D à aeronave (manutenção de base realizada a cada 12 anos) ou em ações de manutenção subsequentes. A Tennessee Technical Services, prestador de serviços de manutenção à Emery Airlines, realizou a última inspeção D da aeronave do acidente entre 27 de agosto e 17 de novembro de 1999.

The NTSB investigation of this accident determined that the bolt attaching the accident aircraft's right elevator control tab crank fitting to the pushrod was improperly secured and inspected during either the aircraft's most recent D inspection (heavy maintenance accomplished every 12 years) or subsequent maintenance. Tennessee Technical Services, an Emery Airlines maintenance contractor, performed the accident aircraft's last D inspection between August 27 and November 17, 1999.

Oito dias após a conclusão da inspeção D, um piloto relatou um aumento nas forças da coluna de comando. O pessoal de manutenção da Emery descobriu que os amortecedores esquerdo e direito do leme de profundidade estavam invertidos, e o diário de manutenção indicava que o pessoal de manutenção reposicionou os amortecedores para as suas posições corretas. O pessoal de manutenção da Emery poderá ter intervencionado o parafuso no encaixe da manivela da guia de controle enquanto solucionava o problema relatado.

Eight days after the D inspection was completed, a pilot reported increased control column forces. Emery maintenance personnel found that the left and the right elevator dampers were reversed, and the maintenance logbook indicated that the maintenance personnel moved the dampers to their correct positions. Emery maintenance personnel could have come in contact with the bolt at the control tab crank fitting while troubleshooting the reported problem.

O NTSB[8] determinou que a causa provável do acidente foi a perda do controle de arfagem, resultante da desconexão do comando do compensador direito do leme de profundidade. A desconexão foi causada pela falha na fixação e inspeção adequada ao parafuso de fixação.

The NTSB[8] determined that the probable cause of the accident was a loss of pitch control resulting from the disconnection of the right elevator control tab. The disconnection was caused by the failure to properly secure and inspect the attachment bolt.

[8] Para mais informação ver o relatório NTSB NTSB/AAR-03/02 || For more information, see National Transportation Safety Board Report NTSB/AAR-03/02

1.18.3.3. Perda de controlo durante a descolagem no voo 5482 da Air Midwest || Loss of control during take-off of Air Midwest flight 5481

A 08-JAN-2003, a Air Midwest efetuava o voo 5481, um voo regular para o Aeroporto Internacional Greenville – Spartanburg na Carolina do Sul, EUA, com um Raytheon (Beechcraft) 1900D, que se despenhou logo após a decolagem da pista 18R no aeroporto internacional de Charlotte-Douglas. Os 2 tripulantes e 19 passageiros a bordo da aeronave foram feridos fatalmente, uma pessoa no solo sofreu ferimentos leves e a aeronave foi destruída pelas forças de impacto e por um incêndio após a queda.

On January 8, 2003, an Air Midwest scheduled passenger flight 5481 to Greenville - Spartanburg International Airport, South Carolina, a Raytheon (Beechcraft) 1900D, crashed shortly after take-off from runway 18R at Charlotte-Douglas International Airport. The 2 flight crewmembers and 19 passengers aboard the aircraft were killed, 1 person on the ground received minor injuries, and the aircraft was destroyed by impact forces and a post-crash fire.

O NTSB[9] determinou que a causa provável do acidente foi a perda de controle de arfagem da aeronave durante a descolagem. A perda do controle resultou do ajuste incorreto do sistema de controle do leme de profundidade e adicionalmente pela posição do centro de gravidade traseira, considerado substancialmente para além dos limites traseiros certificados para o modelo.

The National Transportation Safety Board[9] determines that the probable cause of this accident was the aircraft's loss of pitch control during take-off. The loss of pitch control resulted from the incorrect rigging of the elevator control system compounded by the aircraft's aft center of gravity, which was substantially aft of the certified aft limit.

Os fatores contributivos para o acidente foram:

1) falta de supervisão da Air Midwest dos trabalhos executados na estação de manutenção de Huntington, West Virginia;
2) procedimentos e documentação de manutenção da Air Midwest;
3) programa de massa e centragem da Air Midwest à data do acidente;
4) falha do inspetor de garantia de qualidade da Raytheon Aerospace em detetar o incorreto ajuste do sistema de comando do leme de profundidade;
5) os pressupostos no uso de médias de massa e centragem contidos no material guia da Administração Federal de Aviação (FAA) em vigor à data do acidente; e
6) a falta de supervisão da FAA sobre o programa de manutenção da Air Midwest e seu programa de massa e centragem.

Contributing to the cause of the accident were:

(1) Air Midwest's lack of oversight of the work being performed at the Huntington, West Virginia, maintenance station;
(2) Air Midwest's maintenance procedures and documentation;
(3) Air Midwest's weight and balance program at the time of the accident;
(4) the Raytheon Aerospace quality assurance inspector's failure to detect the incorrect rigging of the elevator control system;
(5) the Federal Aviation Administration's (FAA) average weight assumptions in its weight and balance program guidance at the time of the accident; and
(6) the FAA's lack of oversight of Air Midwest's maintenance program and its weight and balance program.

1.18.3.4. Incidente grave Airbus A320 - controlo de rolamento || Airbus A320 roll control serious incident

A 20-MAR-2001 um Airbus A320, descolou do aeroporto de Frankfurt/Main, Alemanha com

An Airbus A320 on 20 March 2001, departed from Frankfurt/Main airport, Germany for a flight to

[9] Para mais informação ver o relatório NTSB NTSB/AAR-04/01 || For more information, see National Transportation Safety Board NTSB/AAR-04/01

destino a Paris, França, com 115 passageiros e 6 tripulantes a bordo. Imediatamente após a decolagem, a aeronave assumiu um ligeiro ângulo de rolamento para a esquerda. O comandante que era o piloto a voar, tentou corrigir a atitude com um comando ligeiro no *sidestick* para a esquerda. Ainda assim, aumentou continuamente o rolamento até aproximadamente 22°. O comandante informa: "Não posso fazer mais nada", o co-piloto assumiu os comandos referindo "Eu tenho o controlo" e pressionou o botão *TAKE OVER PUSH BUTTON*.

Paris, France, having 115 passengers and 6 crew members onboard. Immediately following the lift-off, the aircraft assumed a slight bank angle to the left. The commander, who was the pilot flying, tried to correct the attitude by a slight input on the left sidestick. However, the bank angle increased continuously up to approx. 22°. With the commander's call out: "I can't do anything more ", the first officer took over the controls with the words "I have control" and pressed the TAKE OVER PUSH BUTTON.

Controlado pelo piloto automático, o avião subiu para nível de voo FL 120, onde a tripulação analisou cuidadosamente o sistema de comando. Com uma ação do lado esquerdo (comandante), a aeronave - após uma breve oscilação e uma pequena variação do ângulo de rolamento correspondente à ação executada – repentinamente reage contrariamente. O *sidestick* do lado direito (co-piloto) funcionava normalmente.

Controlled by the autopilot, the aeroplane climbed to flight level FL 120 where the crew cautiously analysed the control system. With an input on the left sidestick the aircraft - after a short shaking and a brief bank angle corresponding to the input - suddenly reacted contrary. The right-hand sidestick functioned normally.

A tripulação decidiu não prosseguir com o voo e regressar a Frankfurt. O co-piloto assumiu os comandos e aterrou com segurança a aeronave em Frankfurt. O avião foi então entregue à organização de manutenção.

The crew decided to not continue the flight but to return to Frankfurt. The First Officer took over the controls and safely landed the aeroplane in Frankfurt. The aeroplane was then handed over to the maintenance organisation.

Antes deste voo, a aeronave esteve na organização de manutenção durante dois dias a realizar trabalhos de manutenção. Nos vários voos realizados anteriormente, foram reportados problemas num dos dois computadores (ELAC) que controlam, entre outros, o ângulo de rolamento. Na substituição do computador, foi encontrado no conector do ELAC1 um pino elétrico dobrado, que não pôde ser reparado. Foi então substituído o conector do ELAC1 com as respetivas ligações elétricas. Neste processo, dois pares de fios foram conectados invertidos, o canal de comando e o canal monitorização.

Prior to this flight, the aircraft had already been at the maintenance organisation for two days for repair purposes. On several previously conducted flights had problems occurred on one of the two elevator aileron computers (ELAC), which control, among other things, the bank angle. When the computer was replaced, a bent pin, which could not be repaired, was found on the plug of the ELAC no. 1. Therefore, the whole plug of the ELAC no. 1 was replaced and rewired. Two pairs of wires were connected inverted, the Command Channel and the Monitor Channel.

O BFU[10] concluiu que o incidente grave ocorreu devido à inversão de dois pares de fios durante os trabalhos de reparação do conector do computador ELAC1 e, o erro não foi reconhecido pela tripulação de voo durante a verificação dos comandos de voo.

The German Federal Bureau of Aircraft Accident Investigation, BFU[10] concluded that the serious incident was due to the fact that during repair work on the plug of the Elevator Aileron Computer (ELAC) no. 1 two pairs of wires had been connected inverted, and the error was not recognized by the flight crew during the "FLIGHT CONTROL CHECK".

[10] Para mais informação ver o relatório do BFU 5X004-0/01 abril 2003 || For more information, see BFU Serious Incident report 5X004-0/01 April 2003

1.19. Técnicas de investigação úteis ou eficazes || Useful or effective investigation techniques

O âmbito da investigação detalhou as seguintes áreas:

- Análise dos aspetos técnicos da aeronave Embraer 190, número de série 19000653, com matrícula P4-KCJ, nomeadamente e em detalhe a análise do sistema de comandos de voo;
- Análise dos documentos da aeronave (operações, manutenção, aeronavegabilidade e fabrico);
- Análise de procedimentos de manutenção da aeronave tipo E190-100 e respetivos documentos de suporte;
- Pesquisa e análise de dados dos dispositivos eletrónicos a bordo;
- Recolha e análise de dados do prestador de serviços de manutenção relativo à contratação, formação e gestão de pessoal, constituição das equipas de manutenção, sistema de reporte de e tratamento de ocorrências;
- Procedimentos de suporte do OEM à AMO;
- Recolha e análise de dados de supervisão da atividade do prestador de serviços de manutenção pelas autoridades de certificação;
- Análise de aspetos operacionais executados pela tripulação durante o voo do evento.

The investigation scope detailed the following areas:

- Technical aspects analysis of Embraer 190 aircraft, serial number 19000653, with registration number P4-KCJ, namely and in detail the analysis of the flight controls system;
- Analysis of the aircraft documents (operations, maintenance, airworthiness and manufacture);
- Maintenance procedures analysis for aircraft type E190-100 and related support documents;
- Data research and analysis of onboard electronic devices;
- Part 145 service provider data collection and analysis regarding the staff hiring, training and management, maintenance team's constitution, occurrence reporting system and management;
- OEM to AMO support procedures;
- Data collection and analysis for activity oversight to the maintenance service provider by the certification authorities;
- Operational aspects analysis regarding crew performance during the event flight.

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2. ANÁLISE || ANALYSIS

Neste capítulo são analisados os aspetos relevantes da investigação, dando especial ênfase aos serviços de manutenção e às condições latentes envolvidas no evento.

In this chapter the relevant aspects of investigation are analysed, emphasizing the maintenance services and the latent conditions involved in the event.

Dado o número de fatores envolvidos no evento e elevada complexidade nas relações entre estes, a investigação seguiu um método de análise sistémico com base no modelo de gestão de risco de [Rasmussen, 1977].

Given the number of involved factors on the event and high complexity in the relations between them, the investigation followed a systemic analysis method based on the [Rasmussen, 1977] risk management framework.

Seguindo esse método sistémico, por definição, os erros pressupõem-se como sendo ambos causas e consequências.

Following this systemic method, the errors are assumed to be both consequences and causes.

A identificação de eventuais erros humanos é apenas um ponto de partida, não um fim ou conclusão. Sendo o objetivo a aprendizagem com o erro e diminuir as possibilidades da sua recorrência, o contexto organizacional que envolveu as ações da pessoa ou da equipa, incluindo equipamentos, procedimentos, outras pessoas, ambiente e gestão, será devidamente considerado.

Identifying possible human errors is just a starting point, not an end or conclusion. Being the aim to learn from the errors and to lessen the chances of it happening again, the organizational context that surrounded the person or team's actions, including equipment, procedures, other people, the environment and management need to be considered.

Nesta perspetiva, a simples remoção de uma causa raiz de um sistema não impedirá que o acidente se repita. É necessária uma abordagem holística, na qual as deficiências de segurança de um sistema como um todo devem ser identificadas e resolvidas.

From this perspective, simply removing a root cause from a system will not prevent the accident from reoccurring. A holistic approach is required whereby safety deficiencies throughout the entire system must be identified and addressed.

Este evento que terminou num acidente, sem consequências últimas de perda de vidas humanas, proporcionou valiosas oportunidades tanto ao OEM para melhorar o seu produto como à AMO para repensar a gestão dos riscos envolvidos nos serviços prestados.

This accident event, without the ultimate consequences of the loss of life, provided valuable opportunities to both the OEM to improve the product and to the AMO to rethink the risk management on the provided services.

2.1. Serviços de manutenção e reparação (AMO) || Maintenance and repair services (AMO)

A AMO iniciou um programa de implementação de um sistema de gestão de segurança operacional (SMS) em 2013, que desde então, e apesar de a investigação reconhecer as várias tentativas, estas, limitaram-se à elaboração de um manual e de um conjunto de procedimentos. Conforme discussão à frente em 2.1.2, não foi

AMO started a program to implement a safety management system (SMS) in 2013, and since then, and despite the investigation recognized several attempts, these were nothing more than a written manual and procedures set-up. As it will be discussed below in 2.1.2, it was not possible for the investigation to measure the practical

possível à investigação mensurar resultados práticos ou reconhecer as necessárias mudanças culturais para a implementação de tal processo.

É certo que a implementação de um SMS à data do evento não era ainda requerida pela EASA, estando, no entanto, prevista a sua implementação após 2020 conforme *rulemaking task* RMT.0251 previsto no Plano Europeu de Segurança operacional da Aviação (EPAS) 2020-2024.
Os objetivos da nova regulamentação são claros, obrigando a introduzir princípios de gestão da segurança operacional por implementação do anexo 19 da OACI e que fomentem uma cultura organizacional para uma gestão eficaz da segurança e para um reporte eficaz de ocorrências, em conformidade com o Regulamento (UE) N.º 376/2014 da Comissão. A adoção de práticas como as descritas no "145.A.200 Sistema de gestão" e respetivo material guia (GM) do Regulamento (UE) N.º 1321/2014 serão em breve uma imposição legal.

A ausência de implementação efetiva de um sistema integral de gestão de segurança operacional terá deixado a AMO exposta a riscos operacionais significativos. Devido à ausência de dados, a condição do risco das operações de manutenção com as diversas atividades não estava a ser devidamente avaliada e se as diversas ações críticas estariam a ser conduzidas num nível de risco tolerável.

É consensual entre os especialistas nesta matéria que a gestão do erro deve ter em consideração dois aspetos:

- Reduzir a probabilidade de pessoas cometerem erros,

- Garantir que o sistema está preparado para lidar com os erros quando eles ocorrerem.

O uso do termo "erro humano" não significa que haja um problema com uma ou várias pessoas e, segundo *Reason*[11], quando não se trata de uma ação deliberada para produzir um efeito indesejado, o erro é sempre uma consequência e não uma causa, resultando de fatores organizacionais e do contexto em que as ações são realizadas.

results or even recognize the necessary cultural changes for the implementation of such a process.

It is true that the SMS implementation was not required by EASA at the date of the event, however, it is expected to be implemented after 2020 as foreseen in the rulemaking task RMT.0251 on European Plan for Aviation Safety (EPAS) 2020-2024.

The objectives of the new regulations are clear, forcing the introduction of safety management principles by implementing ICAO Annex 19 and fostering an organizational culture for effective safety management and effective incident reporting, in accordance with Regulation (EU) no. 376/2014 of the Commission. The adoption of such practices as those described in 145.A.200 Management System and respective guidance material (GM) of Regulation (EU) No 1321/2014 will soon be a legal requirement.

The absence of an effective safety management system implementation may have left the Part 145 exposed to significant operational risks. Due to the lack of maintenance data, the risk condition of the maintenance operation was not being properly assessed and whether the various critical actions were being carried out at a tolerable risk level.

There is a consensus among the error management experts, that error management must take into account two basic aspects:

- Reducing the probability that people will make errors,

- Making sure that the system is prepared to deal with errors when they occur.

The use of the term "human error" does not mean a problem with people and as per *Reason*[11], when it is not a deliberate action to produce an unwanted effect, the error is always a consequence and not a cause, resulting from organizational factors and the context in which the actions are carried out.

[11] REASON, James – Human Error. UK, Cambridge: [1990]

Embora os erros possam trazer eventos e consequências indesejadas, estes também podem oferecer valiosas oportunidades para identificar e implementar melhorias no sistema, desde que a organização ou sistema envolvidos estejam preparados para tal.

Desta forma, o erro humano ocorrido na realização dos trabalhos de substituição dos suportes dos cabos, levou a investigação a explorar os aspetos sistémicos que lhe estiveram subjacentes.

No decorrer do processo de investigação foram identificados na organização fatores relevantes (abaixo listados) para o evento e tratados nos subcapítulos seguintes.

Although errors can lead to unwanted events and consequences, it can also provide valuable opportunities to identify and implement system improvements, provided the organization or system involved are prepared to do so.

In this way, the human error that occurred during the cable support replacement, led the investigation to explore the systemic aspects that underlie it.

During the investigation process the relevant factors to the event (listed below) were identified in the organization and will be discussed on the following subchapters:

Figura 21 || **Figure 21**

Cadeia de fatores identificados || Identified involved factors

2.1.1. Avaliação de competências e adequação à tarefa || Competence assessment and task suitability

A avaliação de competências é obrigatória na regulamentação EASA Parte 145.

O requisito 145.A.30 (e), AMC 145.A.30 (e) e GM2 145.A.30 (e) exige, entre outros, que o pessoal do planeamento, técnicos de manutenção, equipas de serviços especializados, supervisores e equipas de certificação, sejam avaliados dentro das organizações quanto às suas competências por avaliação prática "em

Competence assessment is mandatory in EASA Part 145.

The requirement 145.A.30 (e), AMC 145.A.30 (e) e GM2 145.A.30 (e), establish amongst others that planners, mechanics, specialized services staff, supervisors and certifying staff are assessed for competence by 'on the job' evaluation and/or by examination relevant to their particular job

ambiente de trabalho" e/ou exame relevante para a sua função em trabalhos específicos, antes de ser permitido o trabalho sem supervisão.

role within the organisation before unsupervised work is permitted.

Uma gestão eficaz de competências deve garantir que cada um e que todos os funcionários cumpram todos os pré-requisitos para a realização efetiva do trabalho que lhes é confiado.

Effective competence management should ensure that each and every employee has all the prerequisites to deliver effectively the work which they need to do.

Operacionais com conhecimentos e experiência limitada normalmente levam mais tempo para executar uma determinada tarefa e esse será o melhor resultado ou, na pior situação, as suas ações podem aumentar o risco do erro e este pode contribuir para incidentes ou acidentes.
A formação e treino de todo o pessoal com exposição de produção é apenas o ponto de partida. A implementação de programas efetivos de avaliação e formação de competências em manutenção de aeronaves, obriga a uma abordagem que envolva o indivíduo, a equipa, a organização, o ambiente e o trabalho ou tarefa específica e num determinado momento.

Employees who lack knowledge and experience will typically take longer to perform a given task and this will be the best outcome or, in the worst outcome case, it may increase the risk of an error or mistake becoming an incident or accident.

Training provision for all staff that have a production exposure is a starting point only. When implementing real aircraft maintenance competence assessment & training programs the approach needs to cover the person, the team, the organization, environmental and the required job in a defined time frame.

O AMC1 145.A.30 (e) Requisitos de pessoal, previsto no regulamento (UE) n.º 1321/2014, refere que a competência deve ser definida como uma habilidade mensurável ou padrão de desempenho, conhecimento e entendimento, tendo em consideração a atitude e o comportamento.

The AMC1 145.A.30 (e) Personnel requirements from (EU) No 1321/2014 states that competence should be defined as a measurable skill or standard of performance, knowledge and understanding, taking into consideration attitude and behaviour.

A competência deve ser aferida pela avaliação de:
— desempenho no trabalho e/ou teste de conhecimentos por pessoal adequadamente qualificado, e
— registos de formação básica, organizacional e/ou de aeronave tipo e diferenças, e
— registos de experiência.
A validação do acima exposto pode incluir uma verificação de confirmação pelas organizações que emitiram esses documentos. Como resultado dessa avaliação, a qualificação de um indivíduo deve determinar:
— qual nível de supervisão contínua que será necessária ou se o trabalho não supervisionado será autorizado,
— quando for determinado que é necessária formação adicional.

Competence should be assessed by evaluation of:
— on-the-job performance and/or testing of knowledge by appropriately qualified personnel, and
— records for basic, organisational, and/or product type and differences training, and
— experience records.

Validation of the above could include a confirmation check with the organisation(s) that issued such document(s). As a result of this assessment, an individual's qualification should determine:
— which level of ongoing supervision would be required or whether unsupervised work could be permitted,
— whether there is a need for additional training.

Um registo dessa qualificação e avaliação de competência deve ser mantido atualizado.

A record of such qualification and competence assessment should be kept.

O GM2 145.A.30 (e) define o procedimento de avaliação de competência e o AMC 145.A.35 (a) (1), relativamente ao pessoal de certificação e suporte, refere que um indivíduo que possui uma licença Parte 66 com um averbamento de tipo/grupo relevante, ou uma qualificação nacional no caso de componentes, não significa por si só que esse titular esteja qualificado para ser autorizado como pessoal de certificação e/ou pessoal de suporte. A organização é responsável por avaliar a competência do titular quanto ao âmbito de manutenção a ser autorizado.

AMC 145.A.35(a) (3), refere algumas tarefas especiais de manutenção podem exigir treino e experiência específicos adicionais, incluindo, entre outros:

- resolução de problemas aprofundada;
- ajustes muito específicos ou procedimentos de teste;
- calibração e ajuste detalhado; (…)
- inspeções extensas/reparação estrutural de determinado sistema; (…)

Estudos, *Williamson and Feyer* (1990), apontam que o tipo de erro expectável numa determinada tarefa parece estar intimamente relacionado com a frequência com que a tarefa é executada. Por definição, pode-se esperar que os erros baseados em regras ou no conhecimento sejam predominantes quando a tarefa é pouco comum, tornando-se menos comuns com a execução continuada da tarefa. Por outro lado, os desvios e lapsos, com origem nas habilidades são relativamente incomuns em tarefas pouco frequentes, contudo, podem tornar-se problemáticos em tarefas executadas de forma rotineira.

Por estes motivos, as organizações de manutenção devem garantir que os departamentos técnicos de formação recebem *feedback* regular sobre incidentes recorrentes de manutenção, com o objetivo de incluir nos programas de formação alertas e estratégias que evitem esses eventos.

GM2 145.A.30(e) defines the competence assessment procedure and the AMC 145.A.35(a) (1) specifically for certifying staff and support staff, states, a person holding a Part 66 licence with the relevant type/group rating, or a national qualification in the case of components, does not mean by itself that the holder is qualified to be authorised as certifying staff and/or support staff. The organisation is responsible to assess the competence of the holder for the scope of maintenance to be authorised.

AMC 145.A.35(a) (3), some special maintenance tasks may require additional specific training and experience, including but not limited to:

— in-depth troubleshooting;

— very specific adjustments or test procedures;

— rigging; (…)

— extensive structural/system inspection and repair; (…)

Studies, *Williamson and Feyer* (1990), point out that the type of error which can be expected on a given task appears to be closely related to the frequency with which that task is performed. By definition, rule-based or knowledge-based mistakes can be expected to be particularly prevalent when the task is unusual, but to become less common on tasks which are performed frequently. Skill-based slips and lapses, on the other hand, are relatively uncommon on unusual tasks but may become problematic on tasks which are performed routinely.

For these, maintenance organisations should ensure that engineering training departments receive regular feedback on recurring maintenance incidents in order to include alerts and strategies in the training programs to avoid these events.

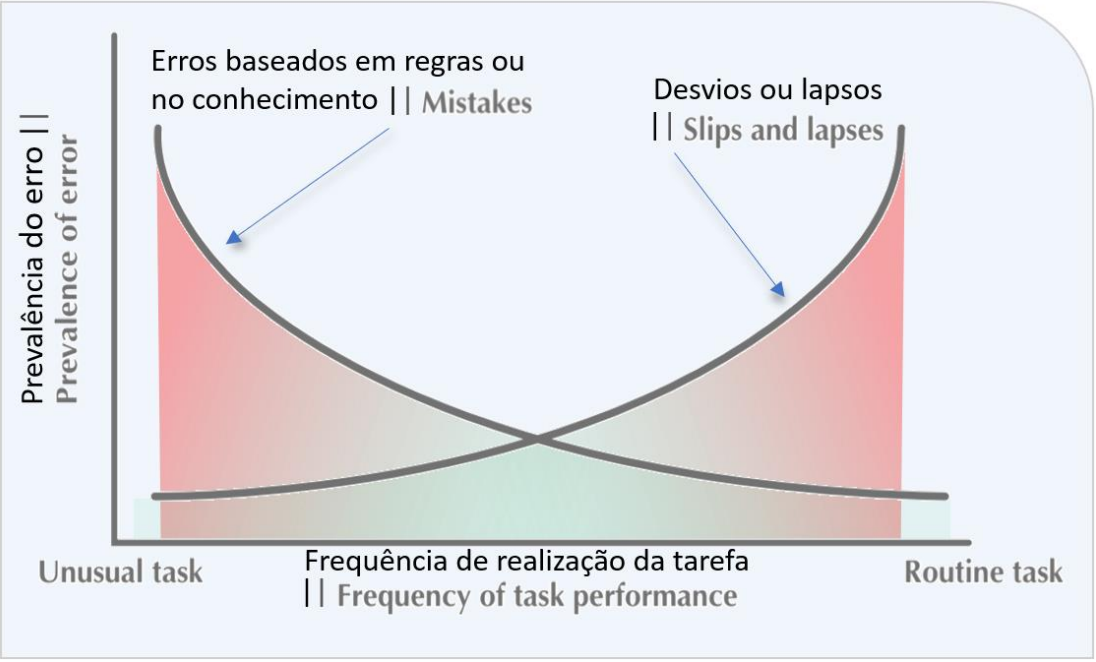

Figura 22 || **Figure 22**

Frequência de realização da tarefa e a prevalência dos tipos de erros
Fonte: HF in airline maintenance ATSB (BASI) junho 1997

|| Task frequency and the prevalence of error
Source: HF in airline maintenance ATSB (BASI) June 1997

Similarmente, os gestores das organizações de manutenção devem garantir que recebem *feedback* regular e estruturado sobre os eventos/incidentes de manutenção, com particular ênfase para as falhas com causas subjacentes a competências ou procedimentos ou falhas latentes que promovem esses eventos/incidentes.

Similarly, maintenance organisations managers should ensure that they receive regular, structured feedback on maintenance events/incidents, with particular emphasis on the underlying competency or procedural conditions or latent failures which promote such events/incidents.

Deve ser ministrada formação continua e regular de reciclagem aos técnicos de manutenção, com foco nos aspetos e procedimentos da AMO. Essa formação, se bem enquadrada, pode ajudar a reduzir a frequência de eventos/incidentes relacionados com possíveis entendimentos errados dos procedimentos internos.

Regular refresher training should be offered to maintenance engineers with particular emphasis on company procedures. Such training, with proper framework, could help to reduce the frequency of events/incidents related with possible misunderstandings of company procedures.

As evidências e indícios recolhidos pela investigação relativamente às avaliações de competência da AMO, sugerem que estas foram realizadas numa perspetiva de conformidade legal. Tal significa que existe um sistema implementado, mas que está apenas construído enquanto procedimento administrativo e suportado nos requisitos mínimos da legislação, distante da oportunidade de prover as melhores práticas de avaliação e formação eficazes de competência em manutenção de aeronaves.

The evidence gathered by the investigation regarding AMO competency assessments suggests that these assessments were carried out from a perspective of legal compliance. This means that there is a system in place, but it is only built as an administrative procedure supported on legal minimum requirements, far from the opportunity of delivering best practice which ensures effective aircraft maintenance competence assessment and training.

A sequência de eventos durante as atividades de manutenção programada (até 31 OUT) e em alguns momentos da fase de pesquisa de anomalias (1 a 11 de NOV) demonstraram falta de solidez de conhecimentos técnicos da equipa no produto E190, bem como fragilidades na organização e condução dos trabalhos de manutenção, programada ou não programada.

The events sequence during the scheduled maintenance activities (until 31 OCT) and in some moments on the troubleshooting phase (from 1 to 11 NOV) evidenced a team with lack of solid technical knowledge in the E190 product, as well as weaknesses in the maintenance planning and preparing for both scheduled or unscheduled work.

A não interpretação da posição física dos *ailerons* relativamente aos *spoilers*, considerada uma evidência aerodinâmica relevante, indicia uma falta de compreensão básica dos sistemas da aeronave e levanta questões precisamente sobre a formação base aeronáutica dos técnicos envolvidos nos inúmeros ensaios realizados com movimentação física das superfícies de comando de voo.

The non-interpretation of the ailerons physical position relative to the spoilers, considered relevant aerodynamic evidence, indicates a lack of basic aircraft systems understanding and raises questions indeed about the basic aeronautical training of the involved technicians in the numerous tests performed with aircraft flight control surfaces physical movement.

Foram, contudo, reconhecidas pela investigação um conjunto de ações e tentativas, para colmatar deficiências identificadas nos aspetos de formação e treino do pessoal que serve de base para a sua certificação enquanto prestador de serviços de manutenção EASA Parte 145. Não foram observados resultados mensuráveis pela investigação das referidas ações durante a fase de recolha de evidências.

However, a set of actions and attempts were recognized by the investigation, to address the identified deficiencies regarding personal training and experience that basis its EASA Part 145 maintenance services certification. No measurable results were observed by the investigation over these actions during the evidence gathering phase.

2.1.2. Processo de supervisão interna || Internal oversight process

As organizações de manutenção, como boa prática reconhecida internacionalmente, devem formalmente rever regularmente a adequação das suas defesas, como sejam a realização de testes finais à aeronave com motores em funcionamento, ou verificações específicas, pensadas para detetar eventuais erros de manutenção. De acordo com as metodologias de análise e controlo de riscos, essa revisão pode começar com uma lista de riscos com a correspondente lista de defesas existentes projetadas para lidar com esses mesmos riscos. O objetivo dessa revisão é identificar as defesas ausentes ou consideradas inadequadas.

It is an internationally recognized good practice that maintenance organisations should formally and recurrently review the adequacy of defences, such as full aircraft operational checks with engine runs or specific inspections, designed to detect maintenance errors.

According to the risk analysis and control methodologies, such review can begin with a list of risks/hazards followed by the listing of existing defences designed to address these same hazards.
The aim of such a review is to identify absent or considered inadequate defences.

De acordo com a regulamentação EASA Parte 145, as organizações de manutenção devem reconhecer que as tarefas de supervisão e a gestão do nível de supervisão podem necessitar de incremento, principalmente nas tarefas complexas/sequência de tarefas ou em ambientes sob pressão operacional, situações em que os erros se tornam mais prováveis.

According to EASA Part 145 regulations, maintenance organisations should recognise that supervision and management oversight may need to be increased, particularly in complex tasks/task sequences or in operational stressed environments, situations such where errors become more likely.

Uma forma reconhecidamente útil de desenvolver esse processo de supervisão pelas organizações e autoridades de certificação é usar o conceito de supervisão baseada no risco ou RBO - *Risk-based Oversight* tendo a EASA publicado material guia em NOV 2016 (*Practices for risk-based oversight*).

A execução da RBO altera significativamente a relação entre a autoridade e as entidades reguladas, mostrando também que a interação direta entre regulador e regulado vai além da mera verificação do cumprimento de todos os requisitos regulatórios aplicáveis. A comunicação ocorre em diferentes níveis, não apenas no técnico. Em particular, quando um sistema de gestão de segurança operacional é estabelecido, os gestores seniores da organização têm de estar envolvidos na avaliação e discussão do desempenho de segurança operacional.

Tudo isso requer capacidade da organização em se afastar das tradicionais listas de verificação, por forma a entender como a organização está a gerir os seus próprios riscos e se o sistema de gestão (de segurança operacional) é eficaz e se fornece os resultados esperados.

O erro ou desvio no cumprimento de um procedimento é um acontecimento expectável num ambiente exigente de execução de trabalhos de manutenção em equipamentos de complexidade tecnológica elevada; já a não deteção desse mesmo erro ou desvio pelas defesas da organização não é aceitável. Por esse motivo, todas estas situações devem estar previstas nas análises de risco da organização, com as correspondentes medidas de controlo.

Ao longo do processo produtivo de manutenção da aeronave acidentada, foram desperdiçadas numerosas oportunidades de deteção do erro/desvio.

A sequência de eventos identificada pela investigação demonstra, entre outros problemas, a ausência de implementação de barreiras eficazes no processo produtivo, todas elas perfeitamente definidas na regulamentação, e nos procedimentos específicos de manutenção. O sistema implementado e em vigor no terreno com as demonstradas fragilidades de cultura aeronáutica, permitiu que uma ação de manutenção, não identificada como um desvio

A recognized useful way to develop this supervisory process by organizations and certification authorities is to use the risk-based supervision concept or RBO- Risk-based Oversight, having EASA published relevant guidance material in NOV 2016 (Practices for risk-based oversight).

The execution of RBO significantly change the relationship between the authority and their regulated entities and shows that the direct interaction between regulator and regulated goes beyond the simple compliance verification with all applicable regulatory requirements. The communication takes place at different levels, not only at the technical one. In particular, when a safety management system is established, the organisation's senior management needs to be involved when assessing and discussing the safety performance.

All this requires an ability to move away from the traditional checklist, to understand how an organisation is managing its own risks and whether the (safety) management system is effective and delivering the expected results.

The error or deviation in the performance of a procedure is an expected event in a demanding environment for carrying out maintenance work on high technological complex equipment; the non-detection of the same error or deviation by the organization's defences is not acceptable. For this reason, all these situations must be provided for in the organization's risk analyses, with the corresponding control measures.

Throughout the productive maintenance process of the accident aircraft, numerous opportunities for error/deviation detection were wasted.

The events sequence identified by investigation reveals, among other problems, the lack of effective safety barriers implementation in the production process, all of them perfectly defined in the regulations and on the specific maintenance procedures. The implemented system with the demonstrated aeronautical culture weaknesses allowed a maintenance action, not identified as a deviation by the error capture system, to be hidden covered with a

pelo sistema de captura de erro, se revestisse de uma suposta falha técnica de um componente ou equipamento.

supposed technical failure of a component or equipment.

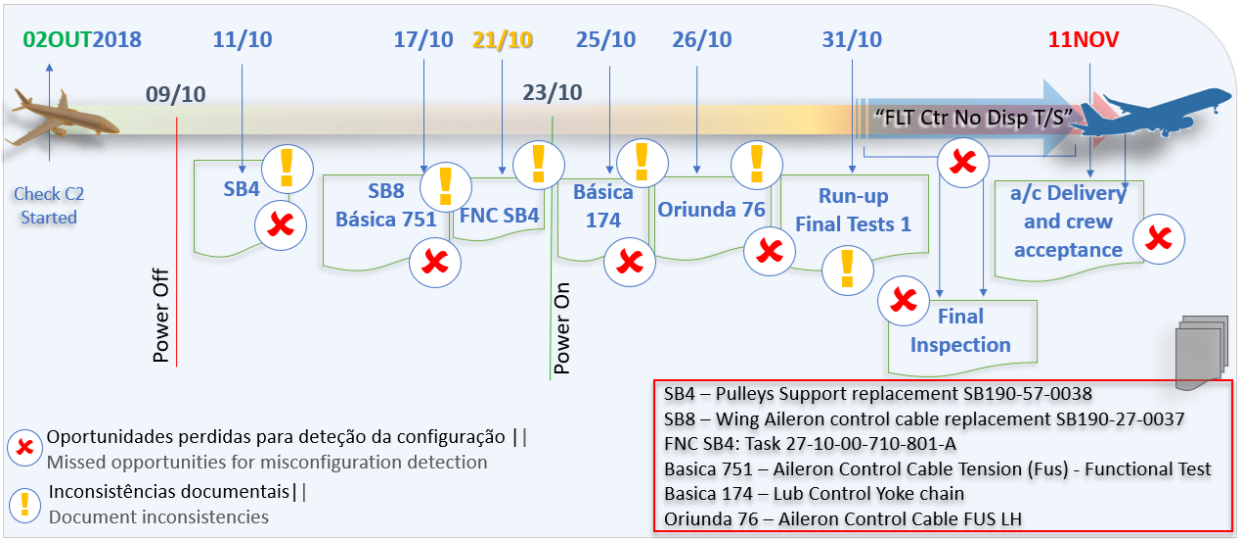

Figura 23 || Figure 23

Sequência de oportunidades perdidas de deteção do erro de configuração || Sequence of lost opportunities for detecting the misconfiguration

O referido desvio de configuração de projeto da aeronave (a inversão dos cabos) não foi detetado nas diversas modificações, tarefas e sub-tarefas realizadas no sistema da aeronave por diferentes técnicos e com verificação (DC), incluindo a equipa dedicada, que durante 11 dias trabalhou em detalhe no sistema afetado na tentativa de resolver a mensagem de não despacho da aeronave.

The referred aircraft design configuration deviation (cable inversion) was not detected in the numerous modifications, tasks and sub-tasks performed on the aircraft system by different technicians with double-check (DC), including the dedicated team, who worked in detail on the affected system for 11 days, in an attempt to solve the aircraft non-dispatch message.

É então provável que a aeronave não apresentasse qualquer problema para justificar a condição de FLT CTR NO DISPATCH; simplesmente não era possível eliminar esta mensagem por impossibilidade de execução da rotina de validação dos CBIT e limpeza das NVM dos FCM durante o procedimento de RTS, conforme detalhado em 2.2.2.

It is then probable, that the aircraft did not present any issues that justifies the FLT CTR NO DISPATCH condition; it was simply not possible to eliminate this message due to the CBIT not completed validation routine and clear the FCM NVM during the RTS procedure, as detailed in 2.2.2.

2.1.3. Cultura de segurança operacional || Safety culture

As falhas identificadas pela investigação nos registos constantes das cartas de trabalho foram sobretudo ao nível da sequência de execução (datas incongruentes), confusão entre inspeções de verificação (DC) e inspeções independentes, revelando uma falta de entendimento dos técnicos e respetivo sistema de qualidade no conceito de inspeção independente e, não menos

The work documents records discrepancies identified by the investigation were mainly regarding the performed sequence (inconsistent dates), misunderstanding between double-check (DC) and independent inspections, revealing a lack of understanding of the technicians and their quality system in the independent inspection concept and, not least, the regular closing

importante, o fecho (*release)* sistemático das tarefas de manutenção pelos chefes de equipa (TL).

procedure or so-called tasks maintenance release by the team leaders (TL).

A literatura da especialidade designa por "normalização social dos desvios" quando as pessoas dentro de uma organização se acostumam a um comportamento frequente enviesado que já não o consideram como um desvio, apesar de eventualmente esse desvio exceder em muito as suas próprias regras de segurança elementar.

The specialty literature designates "social normalization of deviance" when people within the organization become so much accustomed to a deviant behaviour that they don't consider it as deviant, despite the fact that eventually they far exceed their own rules for the elementary safety.

A banalização de assinatura de cartas em momentos diferentes da sua execução e/ou, eventualmente, realizadas por técnicos diferentes, entre outros que a investigação encontrou, é um exemplo demonstrativo do ambiente da cultura organizacional e do controlo dos riscos nas atividades.

The trivialization of working documents signing at different times of their completing and/or, eventually, performed and signed-off by different technicians is a demonstrative example, among others found by the investigation, of the organizational culture environment and respective activities risk control.

Para a avaliação do estado de implementação de uma cultura de segurança na organização, a investigação seguiu o modelo de análise por comparação a um padrão[12] internacionalmente reconhecido como sendo de referência nas cinco dimensões consideradas.

To assess the organization safety culture implementation status, the investigation followed the analysis model[12] using the comparison to the international recognized reference in the five considered dimensions.

É expectável que uma AMO com a dimensão, complexidade e âmbito alargado dos serviços oferecidos, identifique frequentemente áreas de melhoria em procedimentos técnicos ou organizacionais, retirando úteis ensinamentos para a melhoria da segurança operacional.

It is expected that an AMO with the size, complexity and broad scope of the offered services, may frequently identify areas for improvement in technical or organizational procedures, drawing useful lessons for safety improvements.

Associando o baixo número de reportes a uma ausência de implementação efetiva de um sistema de análise e gestão do risco das atividades desenvolvidas pela AMO, a organização demonstrou fragilidades na avaliação e controlo do risco das atividades para as quais estava certificada.

Associating the low reports number to a lack of effective implementation of a risk assessment and management system for the developed activities by the AMO, the organization demonstrated weaknesses in the risk assessment and control for the activities for which it was certified.

[12] Reason [1997] The Components of Safety Culture: Definitions of Informed, Reporting, Just, Flexible and Learning Cultures

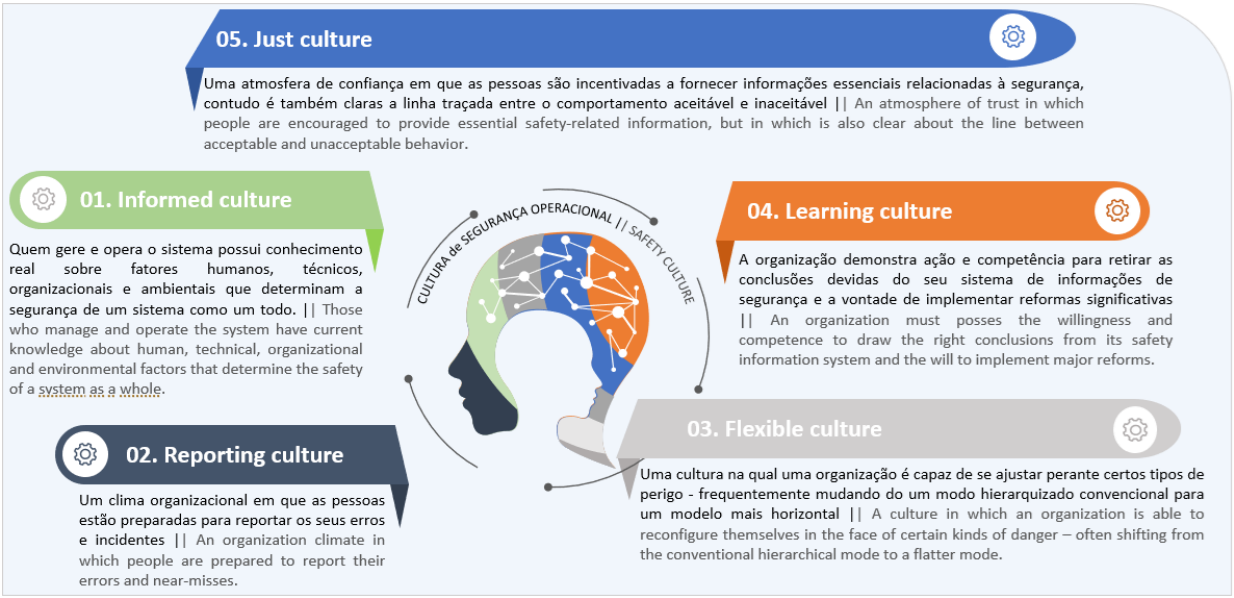

Figura 24 || **Figure 24**

Fatores base (padrão) de uma cultura de segurança operacional || Safety culture main factors (standard)

Em concreto e analisando os facilitadores e ferramentas para a supervisão baseadas no risco, foi observada uma ausência efetiva de práticas em vigor na organização referente a:

- Gestão efetiva da segurança operacional;
- Gestão de informação de dados de segurança;
- Partilha de informações;
- Tomada de decisão sustentada em dados;
- Treino e qualificação.

Na literatura da especialidade e estudos de consultadoria na matéria, é habitual categorizar o grau de maturidade da cultura de segurança operacional das organizações através de uma taxonomia baseada nas constatações feitas sobre as práticas efetivas em relação às cinco dimensões acima consideradas.
A taxonomia do Prof. Patrick Hudson[13] é das mais frequentemente utilizada neste contexto, com base na qual a organização se c como "reativa", o que mostra que existem ainda naquela AMO múltiplas oportunidades para desenvolvimento da cultura de segurança.

In detail and when analysing the enablers and tools for the risk-based oversight, was observed an effective absence of practices in force in the organization regarding:

- Mature safety management;
- Management of safety information;
- Information sharing;
- Data driven decision making;
- Training and qualification.

In the literature and consultancy studies on the subject, it is common to categorize the safety culture maturity level of organizations through a taxonomy based on the findings made regarding the real practices regarding the above considered five dimensions.

Prof. Patrick Hudson[13] taxonomy is one of the most frequently used in this context, based on which the organization is categorized as "reactive", evidencing that there are still multiple opportunities for the development of safety culture in that AMO.

[13] Safety Management and Safety Culture paper, The Long, Hard and Winding Road - Prof. Patrick Hudson Centre for Safety Research Leiden University

Figura 25 || **Figure 25**

Tipos de cultura de segurança || Types of safety culture
Fonte – Professor Patrick Hudson: Cultura de segurança e liderança | Source – Professor Patrick Hudson: Safety Culture and Leadership

Deve ficar claro que este tipo de taxonomia não se destina à classificação hierárquica da qualidade das organizações, mas sim para aferir o seu posicionamento quanto à maturidade da sua cultura de segurança, a fim de caracterizar de forma objetiva o seu ambiente interno nesta matéria e auxiliar na definição estratégias de desenvolvimento nesse domínio.

It should be clear that the purpose of this type of taxonomy is not to classify organizational quality level, but to assess their positioning regarding the maturity of their safety culture, so as to categorize in an objective manner their internal environment and support in defining development strategies in this field.

2.1.4. Supervisão pelas autoridades de certificação || Certification authorities oversight

A organização de manutenção é certificada pela autoridade de Aruba, certificação essa com base na qual realizou os trabalhos e emitiu o certificado de retorno da aeronave ao serviço.

Por outro lado, e como base de certificação sob os padrões EASA e em representação desta, a AMO é certificada pela Autoridade Nacional de Aviação Civil – ANAC pelos padrões da EASA Parte 145 e em cumprimento com os requisitos do regulamento (UE) 1321/2014.

The maintenance organization is certified by the Aruba authority, with which it carried out the work and issued the aircraft's return to service certificate.

On the other hand, and as a basis for certification under EASA standards and in his representation, the AMO is certified by the National Civil Aviation Authority - ANAC by EASA Part 145 standards in compliance with regulation (EU) 1321/2014 requirements.

2.1.4.1. Pela CAA Aruba || By CAA Aruba

A autoridade de Aruba, dentro dos seus deveres de supervisão, realizou no pré-evento auditorias de certificação inicial e continuada à AMO. Durante o ano de 2019, no pós-evento, foi reavaliada a prestação de serviços, sendo que nenhuma das referidas auditorias evidenciou

The Aruba authority, within its supervisory duties, carried out initial and continued certification audits to AMO in the pre-event time period. During 2019, in the post-event, the service provider was reassessed, with none of

problemas ou achados significativos na organização.

referred audits evidenced problems or significant findings in the organization.

Esta realidade poderá ter como origem o processo documental da AMO (ONS), que apesar de algumas falhas, é considerado robusto relativamente a procedimentos e ao encadeamento regulamentar. No entanto, apenas um acompanhamento próximo e continuado das atividades de manutenção permitiria uma avaliação efetiva entre o declarado nos procedimentos e o praticado nas atividades diárias.

This scenario may have its origin in the documentary process of AMO (ONS), which despite some flaws, is considered robust in terms of procedures and follows a proper regulatory framework. However, only a close and continuous monitoring of maintenance activities would allow an effective assessment between what was declared in the procedures and that practiced in daily activities.

A ausência de deteção das incongruências detetadas pela investigação pode demonstrar ainda falta de seguimento das contratações do operador aéreo aos seus prestadores de serviços de manutenção EASA Parte 145, para além da mera observação dos requisitos legais definidos pela Autoridade de Aruba.

The lack of inconsistencies detection found by the investigation may also demonstrate a lack of follow-up of the operator's contracting of its EASA Part 145 maintenance service providers, in addition to purely observing the legal requirements established by Aruba Authority.

O operador tinha previsto o controlo de tarefas críticas no seu manual de procedimentos de engenharia (EPM-KC/EPM de 01 JUN2018). Não há evidências que o operador tenha verificado o requisito na Parte 145 ou que a autoridade de certificação do operador tenha verificado ou auditado o mesmo.

The operator had foreseen the control of critical tasks in its engineering procedures manual (EPM-KC/EPM from 01 JUN2018). There is no evidence that the operator has verified the requirement on the Part145 or that the operator's certification authority has verified or audited it.

2.1.4.2. Pelo padrão Europeu EASA e autoridade nacional - ANAC || By European standard EASA and national authority - ANAC

A EASA, seguindo o regulamento de base, adotou várias iniciativas e ações com o objetivo da implementação efetiva de supervisão da segurança operacional. O EPAS pretende garantir que os princípios de gestão de segurança operacional sejam aplicados na comunidade da aviação europeia, com a finalidade de melhorar continuamente o desempenho da segurança operacional e fornecer orientações aos Estados para o desenvolvimento do respetivo Programa de Segurança do Estado (SSP).

EASA following the basic regulation, adopted several programs initiatives and actions with the objective of the effective implementation of safety oversight. EPAS intend to ensure that the principles of safety management are applied within the European aviation community so as to continually improve safety performance and provide guidance to the States for the adequate State Safety Program (SSP) development.

O EPAS procura antecipar os riscos emergentes de segurança operacional da indústria e fazer o melhor uso dos recursos técnicos através de uma estrutura comum para priorizar, planear e implementar ações de melhoria de segurança operacional.

The EPAS seeks to anticipate emerging industry safety risks and make the best use of technical resources through a common framework for prioritising, planning and implementing safety improvement actions.

A EASA exige que cada organização da aviação seja responsável pela segurança operacional das suas operações.

EASA requires each aviation organisation to be responsible for the safety of its operations.

A gestão do risco de segurança operacional usando um sistema de gestão (SMS) é algo que as organizações devem cumprir como parte integrante das suas operações diárias. Para garantir uma eficácia mensurável, o processo deve ser desenhado para gerir de uma forma eficaz os riscos da atividade da organização, de uma forma funcional, focada na proteção dos elementos-chave dos processos, e não apenas no esforço de conformidade legal com o simples "marcar a caixa" de listas de verificação e eventualmente composto somente por processos e matrizes de risco.

Managing aviation safety risk within an safety management system (SMS) is something that organisations should do as an integral Part of their day-to-day operations.

To ensure measurable effectiveness, the process must be designed to effectively manage the organization's activity risks, in a functional way, focused on protecting the key elements of the processes, and not just on the effort of legal compliance with a simple checklist "tick on the box" and eventually simply made up of processes and risk matrices.

Ainda no âmbito da regulamentação básica, a EASA realizou em MAR de 2019 uma avaliação de padronização (auditoria) de certificação à ANAC usando como amostra a AMO envolvida no acidente, tendo especificamente encontrado desvios no âmbito do processo daquela autoridade relativo à aprovação do MOM, incluindo questões de informação do pessoal de certificação da organização.

Within the basic regulations scope, EASA performed on MAR 2019 a standardization (audit) assessment certification to ANAC using as sample the accident-involved AMO, having specifically found deviations in the scope of that authority's process regarding the approval of organization's MOM, including lack of information over the certification staff.

A investigação no decurso da análise documental aos procedimentos da AMO encontrou algumas inconsistências, de onde se salientam o processo de inspeção independente e o de reporte de ocorrências.

The investigation, on documental and procedures analysis phase to the AMO found some inconsistencies, such as the independent inspection process and on the occurrence reporting process as well.

O procedimento de inspeção independente (*independent inspection)* debatido em 1.17.2.3 e detalhado na ONS-000028 foi aprovado ou validado pela autoridade nacional de aviação (ANAC) com falhas de conceito e considerado quanto ao seu intento confuso pelos próprios técnicos de manutenção. Este procedimento não terá sido questionado por qualquer das autoridades de certificação durante as auditorias programadas.

The independent inspection procedure discussed on 1.17.2.3 and detailed in ONS-000028 was approved or validated by the national aviation authority (ANAC) with flaws in the concept and considered confusing regarding its intent by the maintenance technicians. This procedure wasn't questioned by any certification authority during the scheduled audits.

Quanto ao procedimento de reporte voluntário e obrigatório de ocorrências previsto no Regulamento (UE) n.º 376/2014, os dados com número de eventos (amostra) e conteúdo técnico pouco maduro, sugerem uma cultura de reporte deficiente e também falhas na supervisão do AMO pela Autoridade.

Regarding the voluntary and mandatory occurrence reporting procedure provided in (EU) Regulation n.º 376/2014, the collected data few number of events (sample) and undeveloped technical content, suggest a cultural reporting deficiency and also failures in the supervision of the AMO by the Authority.

2.1.5. Influências organizacionais || Organizational influences

"*As organizações precisam de entender e reconhecer que as **pessoas que estão na sua linha da frente não costumam ser os instigadores de incidentes** (desvios) e estão **mais propensas a herdar situações prejudiciais** que se vão desenvolvendo ao longo do tempo*"[14]

*"Organizations need to understand and acknowledge that **people at sharp end are not usually the instigators of incidents** (misharps) and are **more likely to inherit bad situations** that have been developing over a long period"*[14]

São vários os exemplos de acidentes/incidentes relacionados com comandos de voo de aeronaves como os enunciados em 1.18.3 e aos quais podemos complementar com outros exemplos de eventos catastróficos com origem em ações de manutenção como o AAL 191 (1979), Japan Airlines 123 (1985), UAL 232 (1989), TWA 800 (1996), Aero Peru 603 (1996), Swiss Air 111 (1998), Alaska 261 (2000), e o Airfrance 447 (2005), estes no seu conjunto, totalizaram 1749 fatalidades.

There are several accidents/incidents examples related to aircraft flight controls such as those listed in 1.18.3 and which may be complemented with other examples of catastrophic events originating in maintenance actions such as AAL 191 (1979), Japan Airlines 123 (1985), UAL 232 (1989), TWA 800 (1996), Aero Peru 603 (1996), Swiss Air 111 (1998), Alaska 261 (2000), and Airfrance 447 (2005), these together, totalized 1749 fatalities.

A Associação Internacional de Transporte Aéreo (IATA) revelou que "eventos" de manutenção contribuíram para 10% dos 432 acidentes investigados entre 2009 e 2013, enquanto 29% envolveram algum tipo de mau funcionamento da aeronave. Em outros casos, os procedimentos de manutenção deficitária foram identificados como um fator "latente" que contribuiu para o desfecho do acidente. Os dados mostram que erros de manutenção têm um impacto financeiro significativo no setor, para além do imensurável custo humano.

The International Air Transport Association (IATA) stated that maintenance "events" contributed to 10% of the 432 accidents investigated between 2009 and 2013, while 29% involved some kind of aircraft malfunction. In other cases, shoddy maintenance procedures were identified as a "latent" factor contributing to the outcome. Data shows that maintenance errors impose also a significant financial burden in the sector, beyond the immeasurable human cost.

Na origem de muitos destes eventos estão motivações consideradas sistémicas e com origens muito anteriores às causas ou contributos diretos encontrados nos referidos eventos.

At the origin of many of these events are aspects considered systemic and with its origins far behind the causes or direct contributions founded from these events.

O negócio de uma organização Parte 145 não é uma exceção no atual mercado global, onde está demonstrado que ameaças importantes estão presentes, pressionando no sentido de uma migração sistémica do comportamento organizacional em direção a situações que podem resultar num acidente, sob a influência da relação custo-benefício num ambiente competitivo agressivo.

A Part 145 business is not an exception of the current global market, where it is demonstrated that important threats are present, pressing for a systemic migration of organizational behaviour toward situations that may lead to the accident under the influence of pressure toward cost-effectiveness in an aggressive competing environment.

O modelo de migração de Rasmussen[15] demonstra que pequenas otimizações e adaptações nas práticas e processos

Rasmussen's migration model[15] illustrates that small optimizations and adaptations over the organizational practices and processes can

[14] *Reason*, [1997]
[15] "drift to danger" [Rasmussen 1997]

organizacionais se podem acumular ao longo do tempo, afastando o sistema dos seus parâmetros de projeto inicial. Se não forem implementadas contramedidas a esse "desvio real" pela organização, que deverá estar alerta para a possibilidade e para os perigos da normalização do desvio na função de segurança ou numa regulamentação eficaz, é provável que os sistemas se desviem para um resultado danoso.

Assim, organizações de manutenção devem garantir a implementação de sistemas adequados para disseminar informações importantes em todo o pessoal de manutenção, principalmente onde os procedimentos foram alterados ou onde ocorreu repetidamente um erro ou desvio numa tarefa.

accumulate over time, taking the system far from its initial design parameters. If there is no counterweight to this “practical drift” from the organization, who should be on alert to the possibility and the dangers of the normalization of deviance from the safety function or from an effective regulation, systems are likely to drift towards a harmful result.

Thus, maintenance organisations should ensure that adequate systems are in place to disseminate important information to all maintenance personnel, particularly where procedures have changed or where an error has occurred repeatedly on a task.

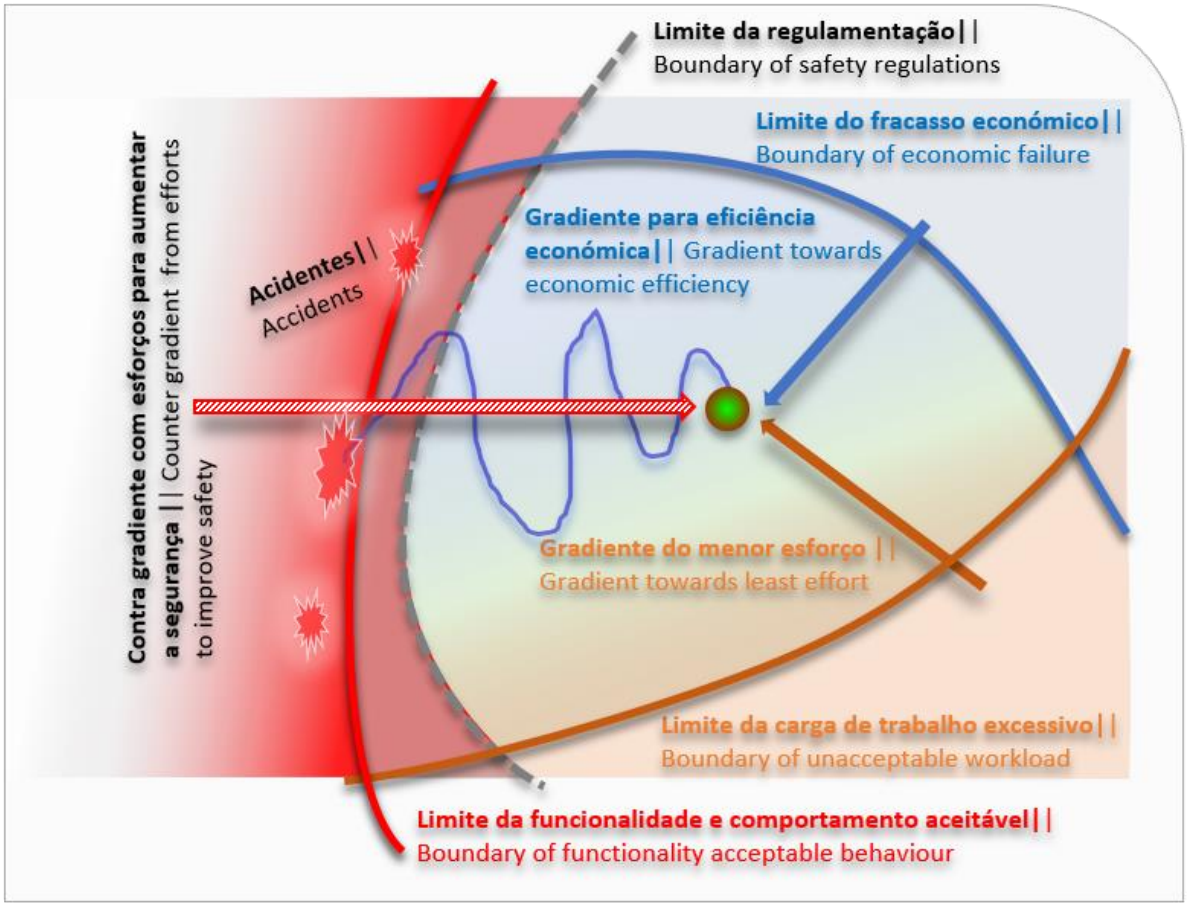

Figura 26 || **Figure 26**

Modelo de Rasmussen migração para o perigo || Drift to danger Rasmussen migration model

Fonte – https://risk-engineering.org/concept/Rasmussen-practical-drift

Source – https://risk-engineering.org/concept/Rasmussen-practical-drift

O modelo de eventos da Boeing MEDA (*Maintenance Error Decision Aid*) estima que 80% a 90% dos fatores que contribuem para o erro/violação de manutenção estão sob controlo da gestão, enquanto que os 10% a 20% restantes

Boeing’s event model MEDA (Maintenance Error Decision Aid) estimates that 80% to 90% of the contributing factors to maintenance error/violation are under management control, while the remaining 10% to 20% are under the

estão sob o controlo dos técnicos ou inspetores de manutenção. Portanto, a gestão tem uma larga intervenção nas ações de mudança para reduzir ou eliminar a maioria dos fatores que contribuem para um erro ou violação e, assim, reduzir a probabilidade de eventos semelhantes futuros.

control of the maintenance technician or inspector. Therefore, management can make changes to reduce or eliminate most contributing factors to an error or violation and thereby reduce the probability of future, similar events.

A liderança é essencial quando mais de uma pessoa está envolvida na realização de uma determinada tarefa.

Leadership is essential when more than one person is involved in carrying out a given task.

As evidências recolhidas pela investigação e abordadas em 1.17.2.4, indicam que a organização não desenvolveu um sistema eficaz para detetar problemas ou "desvios de manutenção", sobretudo devido à falta de comunicação e não usando um processo efetivo de reporte de ocorrências obrigatórios ou voluntários.

The evidence collected by the investigation and addressed in 1.17.2.4, shows that the organization did not develop an effective system to detect problems or "maintenance mishaps" by lack of communication, through a mandatory or voluntary occurrence reports effective process.

Sem esses dados mínimos, contudo valiosos, não se pode analisar ou tomar ações para validar o desempenho dos técnicos/inspetores de manutenção e que eventualmente podem levar a problemas, danos nos equipamentos ou aeronave, acidentes pessoais ou simples retrabalho.

Without these minimum but valuable data, no analysis and actions could be determined for the maintenance technician/inspector performance that could leads to problems on an aircraft, equipment damage, personal injury, or rework.

2.2. A aeronave || The aircraft

2.2.1. Projeto e especificações de certificação || Design and certification specifications

O projeto e respetivos requisitos de certificação das aeronaves, são em última instância o garante de que a missão para a qual a aeronave foi concebida será cumprida em segurança, mesmo na eventualidade de ocorrência de falhas expectáveis, sejam estas falhas de material ou procedimental pelos diferentes intervenientes da operação ou manutenção da aeronave.

The aircraft design and respective certification requirements are ultimately the guarantee that the mission for which the aircraft was designed will be carried out safely, even in the event of expected failures, whether these are material or procedural failures by the different stakeholders in the aircraft operation or maintenance.

Entre outros, os fabricantes devem também considerar as questões de facilidade e ergonomia de manutenção ao projetar sistemas e procurar ativamente informações sobre erros ou desvios que ocorrem aquando da manutenção dos equipamentos.

Among others, manufacturers should give higher consideration to maintenance access and ergonomic issues when designing systems and should actively seek information on the errors which occur when systems are being maintained.

Será unânime defender que não se pode esperar que um projeto possa lidar com todo e qualquer abuso de manutenção; no entanto e conforme as normas de certificação (ex. CS25), este deve

It cannot be expected that a design can cope with any maintenance abuse; however as per certification specifications (ex. CS25), it shall minimise the risk associated with the normal

minimizar o risco associado às normais práticas de manutenção num contexto de transporte aéreo.

Em complemento aos úteis dados da Boeing MEDA divulgados sobre eventos de manutenção de 1998 a 2006, a Autoridade de Aviação Civil do Reino Unido (CAA) publicou em 2016 a CAP1367 - Análise de Incidentes de Manutenção de Aeronaves, que procura fornecer informação sobre as causas comuns envolvendo erros de manutenção detetados e enquanto fator contributivo nos incidentes e ocorrências relatados à CAA. Esses importantes estudos tiveram como objetivo fornecer à indústria um conjunto de dados que podem rever e avaliar e, quando apropriado, usar para complementar as suas próprias análises como parte dos seus programas de treino e formação contínua nos sistemas de gestão de segurança e fatores humanos.

maintenance practices in the air transport environment.

In complement to the useful Boeing MEDA disclosed maintenance related events data, from 1998 to 2006, the UK Civil Aviation Authority (CAA) published on 2016 the CAP1367 - Aircraft Maintenance Incident Analysis, that seeks to provide information on the common causes where maintenance error has been a contributory factor in incidents and occurrences reported to the CAA.

These important studies aimed to provide industry with a set of data which they can review and, where appropriate, use to complement their own analyses as part of their Safety Management Systems and Human Factors continuation training programmes.

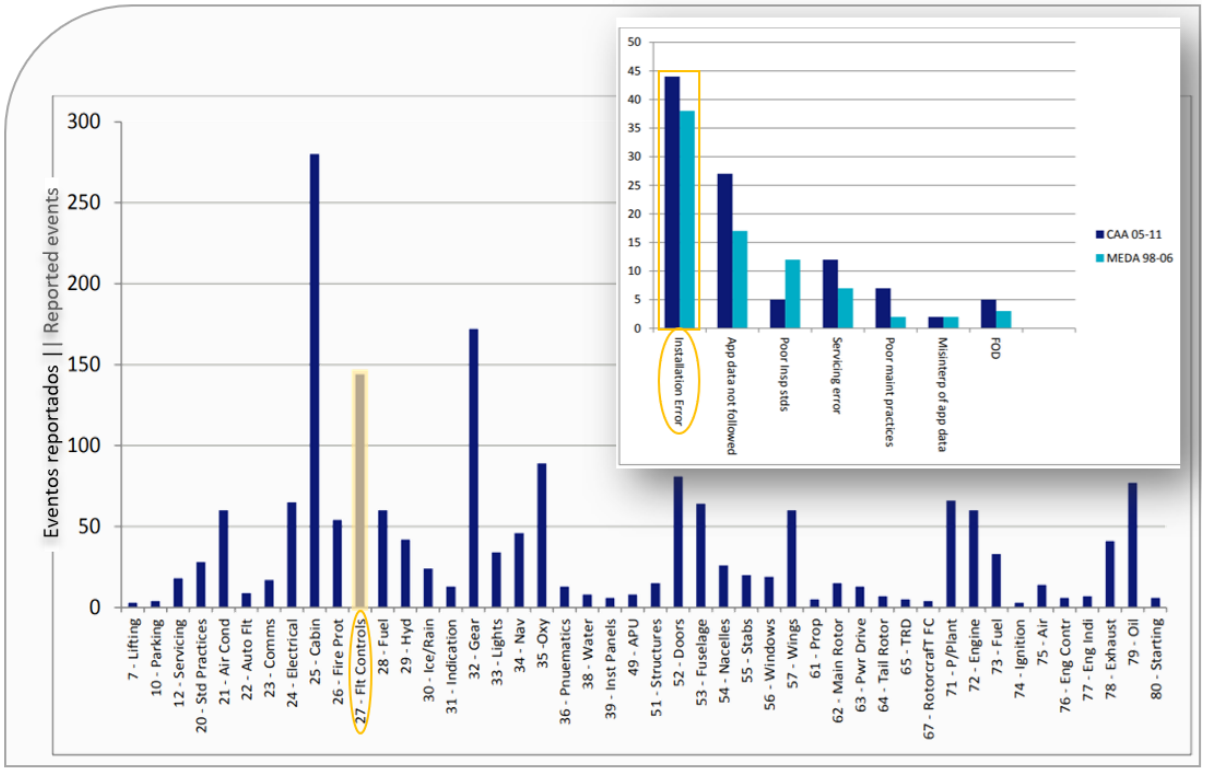

Figura 27 || **Figure 27**

Eventos de manutenção da análise CAA por capítulo ATA e dados MEDA || CAA event analysis by ATA chapter and MEDA maintenance

Fonte: publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=7185

Source: publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=7185

Conforme pode ser constatado nos gráficos de ambos os estudos, problemas com instalações e, quando detalhado em sistemas específicos, os comandos de voo (ATA 27), estão entre os mais recorrentes.

As can be seen in the graphs of both studies, problems with installations and when detailed in specific systems, flight controls (ATA 27) are among the most recurring.

Conforme os exemplos evidenciados em 1.18.3, os sistemas de comandos de voo são pouco tolerantes a desvios à configuração de projeto, devendo esta ATA 27 merecer especial atenção nas matrizes de risco das organizações Parte 145.

According to the shown examples in 1.18.3, flight control systems are not tolerant design configuration deviations, and this ATA 27 should deserve special attention in Part 145 organizations risk matrix.

2.2.2. Conspicuidade de instalação do sistema de comando dos *ailerons* || Conspicuity of aileron control system misrigging

A CS 25.671 estabelece que cada elemento de cada sistema de comando de voo deve ser projetado, ou marcado de forma distinta e permanente, para minimizar a probabilidade de montagem incorreta que possa resultar no mau funcionamento do sistema.

The CS 25.671 establishes that each element of each flight control system must be designed, or distinctively and permanently marked, to minimise the probability of incorrect assembly that could result in the malfunctioning of the system.

Conforme demonstram os factos, é possível inverter o sentido de operação dos comandos dos *ailerons* na aeronave tipo Embraer 170/190, com a inversão dos cabos de comando na sua última secção e sem que tal seja automaticamente detetado e anunciado, como evidenciado em 1.18.1 e respetiva figura e secção 1.16.3.

As demonstrated by facts, it is possible to invert the Embraer 170/190 aileron controls operation, by the control cables swap in their last section and without an automatic detection or message, as shown in 1.18.1 and respective figure and over section 1.16.3.

No entanto, deve ser notado que a inversão é percetível através da correta execução do teste operacional, da observação do sentido do deslocamento das figuras da página Sinóptica e confirmada a posição física das superfícies por comparação da posição do volante de controlo (*control yoke*).

However, it should be noted that the control cables swap was perceptible by the correct execution of the aileron system operational test, by the surface deflection observation on the Synoptic page and cross check the surface physical deflection versus the control yoke displacement.

A investigação seguiu uma análise de engenharia extensa e abrangente sobre a cadeia de eventos iniciada pela dificuldade de limpar a mensagem de FLT CTRL NO DISPATCH após os cabos de comando dos *ailerons* terem sido invertidos e que terminou com essa mensagem de alerta à tripulação (CAS) não presente nas horas antecedentes ao voo do acidente, embora com indicação a vermelho no eixo de rolamento relativo aos FCM (1A, 1B, 3A, 3B, 4A e 4B) durante o procedimento de retorno ao serviço do sistema de comandos de voo evidenciando que o procedimento não terá sido executado com sucesso, conforme figuras 17 e 28. Entretanto, os testes pós-evento realizados, confirmaram que a mensagem FLT CTRL NO DISPATCH não resultaria apenas da inversão do cabo de comando do aileron.

The investigation followed an extensive and comprehensive engineering analysis on the chain of events that started with the difficulty to clear the FLT CTRL NO DISPATCH after the aileron control cables were misconfigured and ended with the same CAS message not present in the hours before the accident's flight, although with red indication on the roll axis on the FCM (1A, 1B, 3A, 3B, 4A and 4B) status in red, during the flight control return to service procedure, providing evidence that probably was not successfully completed, as per figures 17 and 28. However, the post-event performed tests, confirmed that the FLT CTRL NO DISPATCH message would not result only from an aileron control cable reversal.

A análise focou-se em perceber a arquitetura dos sistemas e quais os sinais e indicações presentes

The analysis focused on understanding the systems design and architecture and which signs and indications were present during

durante os trabalhos de manutenção, pesquisa de anomalia e durante o voo.

Ficou claro que a ausência de indicação de falha nos dois canais do FCM2 e, por oposição a falha em todos os outros FCM, estava relacionada com a arquitetura do sistema, onde o FCM2 não recebe sinal da posição dos LVDTs da coluna de comando ou dos atuadores dos *spoilers*.

Não recebendo condição válida da posição comandada em relação à posição real recebida dos *ailerons* nas MAU 1 e 3 através das placas AFCS /AIOP 1A e 2B respetivamente, os CBIT não eram exercitados e por consequência, não permitia limpar as NVM dos FCM 1, 3 e 4.

maintenance tasks, troubleshooting and during the flight.

It was clear that the absence of a fault indication on both FCM2 channels and, as opposed to the failure on all other FCM, was related to the system architecture, where the FCM2 does not receive inputs from control column position LVDTs or from spoiler actuators.

Not receiving a valid condition relating the commanded position to the received ailerons actual position in MAU 1 and 3 through the AFCS/AIOP 1A and 2B plates respectively, the CBIT were not exercised and, consequently, it did not allow to clean the FCM NVM 1, 3 and 4.

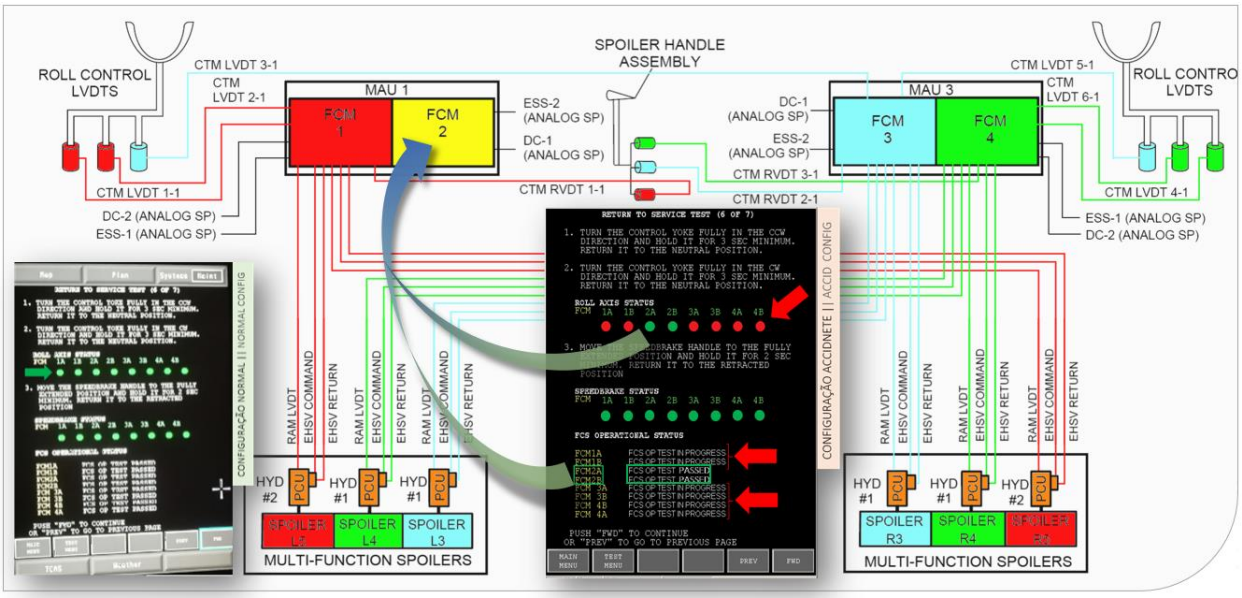

Figura 28 || Figure 28

Arquitetura do sistema de comando em malha fechada dos FCM || FCM closed loop command system design

A arquitetura do sistema terá funcionado conforme requisito de projeto, embora a informação disponibilizada nas diferentes páginas de manutenção (pontos verdes/vermelhos de condição dos módulos dos FCM) não tivesse sido usada. Devido à configuração física dos cabos, não estava prevista a interpretação desta informação pela Parte 145 ou pelo fabricante nos seus manuais técnicos. Os factos comprovam o desconhecimento técnico sobre tal combinação de fatores de ambas as entidades, evidenciado sobretudo durante o procedimento de pesquisa da anomalia.

As lições retiradas deste evento permitiram ao fabricante adicionar e prever a condição de cabos invertidos no novo procedimento de manutenção

The system architecture worked according to the project requirements, although the information provided on the different maintenance pages (FCM modules condition green/red dots) had not been used.

Due to the aileron cables physical configuration, it was not foreseen in the technical publications the interpretation of this information by Part 145 or by the manufacturer. The facts prove the technical unawareness on these combined factors by both entities, evidenced mainly during the troubleshooting procedure.

The lessons learned from this event allowed the manufacturer to add and predict the inverted cables condition in the new maintenance

descrito em 1.18.2.3 e exemplificado na respetiva figura com a nova página de CMC de verificação operacional da condição dos *ailerons*.

procedure described in 1.18.2.3 and exemplified in the respective figure with the new CMC page for ailerons condition operational check.

2.2.3. Publicações técnicas do produto E170/190 || E170/190 technical publications

A falta de pontos de controlo ou contacto físico em número suficiente no encaminhamento dos cabos ao longo da extensão da longarina traseira das semi-asas, torna a descrição das tarefas de manutenção complexa, recorrendo inevitavelmente ao método descritivo em detrimento do ilustrativo. Se a este facto se adicionar a necessidade de perceção visual nas trocas de posição relativa de vertical – horizontal – vertical entre os cabos fica aberta a janela de oportunidade para o erro.

The lack of check points or physical contact in number along the cables routing on both semi-wing rear spar extensions, makes the maintenance tasks wording complex, inevitably using the descriptive method instead of illustrative.
Adding to this fact the need for visual perception to the cables relative position change from vertical to horizontal and vertical again, the window for mistake is wide open.

Com a aplicação da modificação preconizada no Boletim de Serviço 190-57-0038, contemplando a desconexão total de ambos os cabos, deixou de haver encaminhamento e separação física dos mesmos em mais alguns pontos, nomeadamente na rib21, zona de inversão, requerendo maior atenção na compreensão das instruções do manual de manutenção e dificultando interpretação das ações de execução.

By introducing the modification in accordance with Service Bulletin 190-57-0038, considering both cables simultaneous disconnection, there was no longer the cable routing and additional physical separation around rib21, inversion zone, requiring more attention to understand the maintenance instructions and making harder the maintenance actions interpretation.

A deteção da condição de configuração incorreta da aeronave e respetivas ações de manutenção que desencadearam o evento, bem como as possíveis barreiras adicionais a implementar devem ser colocadas em prática bem antes da entrega da aeronave à tripulação.

The aircraft misconfiguration condition detection and the related maintenance actions that triggered the event, as well possible additional barriers, must be put in place well before the aircraft delivery to the crew.

Nesse sentido foi dado pelo OEM especial atenção à revisão dos manuais de manutenção e ao fortalecimento dos procedimentos para deteção de possíveis falhas de configuração em relação ao projeto, com as ações enumeradas em 1.18.2.3. O fabricante optou por não proceder à alteração e certificação dos requisitos de projeto devido à relativa obsolescência do modelo tipo, já com produto substituto com *design* substancialmente diferente relativamente aos comandos de voo.

Following this, special attention was paid by the OEM to the maintenance manuals review and procedures strengthening to detect possible design configuration flaws, with the implemented actions listed in 1.18.2.3. The manufacturer did not follow the way of changing and recertify the design requirements due to the relative obsolescence of the type, already with a substitute product with a substantially different design regarding flight controls system.

Com o intuito de adicionar um recurso para deteção de eventuais desvios de manutenção, o fabricante informou ter procedido a um estudo para introdução de um monitor de software dedicado para deteção e anúncio de inversão de cabos comandos no *aileron*.

The OEM informed the is conducting studies to introduce a dedicated software monitor to detect and announce the inverted aileron cables installation as an additional feature against maintenance deviations.

O fabricante não estabeleceu um procedimento guia para operadores ou AMO com instruções ou boas práticas para realizar o retorno da aeronave ao serviço após intervenções de manutenção complexas.
É reconhecido que cada tarefa de manutenção eventualmente terá a devida informação para fecho da mesma (*job close-up*), no entanto não existe procedimento ou política definida para encerrar combinações complexas de tarefas, pacote de tarefas ou de pesquisa de anomalia.

The manufacturer did not produce guidance material to operators or AMO with instructions or best practices for aircraft return to service after complex maintenance events.

It is recognized that each maintenance task will eventually have the necessary information to close it (job close-up), however there is no defined procedure or policy to close complex task combinations, task packages or troubleshooting.

Será legítimo questionar se não devem existir limites para o nível de intervenção de manutenção, sem que se coloque em causa os requisitos de projeto da aeronave, como por exemplo é feito no processo de aceitação da aeronave para o primeiro voo após fabrico. Assim, atendendo ao nível de intervenção em ações de manutenção pesada com modificações e eventuais ações de pesquisa de anomalia de intervenção complexa, fará sentido incluir um processo de validação e controlo de configuração diferenciado da aeronave antes do retorno ao serviço da mesma, seguindo instruções e material guia sugerido pelo fabricante

It is questionable whether there were no limits to the maintenance intervention level without jeopardizing the aircraft's design requirements, as for example it is performed in the aircraft acceptance process for the first flight after manufacture. Thus, taking in to account the intervention level in heavy maintenance actions with modifications and possible complex troubleshooting actions, it will make sense to include a validation process and differentiated aircraft configuration control before the release to service, following instructions and guidance material suggested by the manufacturer.

2.2.4. A dinâmica do voo || Flight dynamics

Foi analisada a dinâmica da aeronave durante o voo desde o momento da descolagem, subida inicial, perdas de controlo, as três aproximações e aterragem final.

The aircraft dynamics during the flight from take-off moment, initial climb, loss of control, the three approaches and final landing were analysed.

Observadas as características aerodinâmicas, leis de voo, configuração e operação de *slats*/*flaps*, operação dos *spoilers* e regimes de potência da aeronave, foi constatado que a aeronave, na configuração de *ailerons* do voo do acidente teve um comportamento dinâmico mais responsivo aos comandos dados pela tripulação quando configurado com *slats*/*flaps* acima da posição 1.

Observing the aerodynamic characteristics, flight laws, slats/flaps configuration and operation, aircraft spoilers and power settings operation, it was found that the aircraft, in the accident flight ailerons configuration, had a positive dynamic behaviour response on the controls given by the crew when configured with slats/flaps above position 1.

A baixa resistência aerodinâmica da configuração limpa com *slats*/*flaps* a 0 ou mesmo na posição 1, requer uma amplitude de deflexão superior das superfícies de comando a baixas velocidades, que geram combinações de forças causando momentos sobre os eixos de controlo não expectáveis e de difícil antecipação pela tripulação.

The low aerodynamic drag in clean configuration with slats/flaps at 0 or even in position 1, requires a greater control surfaces amplitude deflection at low speeds, which generate combinations of forces causing moments on the unexpected control axes and difficult for crew anticipation.

As atitudes anormais experienciadas durante o voo do acidente foram, em alguns casos, de

The abnormal attitudes experienced during the accident flight were, in some cases, extreme and

extremos e completamente fora do normal envelope de voo da aeronave. Essas atitudes anormais foram o resultado da configuração incorreta dos *ailerons*, combinada com a seleção de *slats/flaps*, em velocidades relativamente baixas e a reação da tripulação ao rolamento da aeronave, agindo nos comandos de voo de forma consistente com a normal operação, a sua experiência e treino.

well outside the aircraft's normal flight envelope. These abnormal attitudes were the result of the aileron misconfiguration, combined with, the slats/flaps configuration, the relatively low speed and the crew's reaction to aircraft roll by using control wheel inputs consistent with normal operation and their experience and training.

O uso dos comandos de voo em modo direto, conforme detalhado em 1.6.5.1, facilitou o controlo da aeronave sobretudo pela limitação de deflexão dos *roll spoilers*, que embora estando a atuar no sentido correto, entravam em oposição aos *ailerons*. Esta particularidade dos *roll spoilers* em atuação correta, inviabilizou a aplicação de comando (manche da coluna de controlo) invertido pela tripulação, após ter detetado a anomalia da inversão da atuação dos *ailerons*.

The use of flight controls in direct mode, as detailed in 1.6.5.1, facilitated the aircraft control mainly by limiting the deflection of the roll spoilers, which, although acting in the correct direction, acted in opposition to the ailerons.

The roll spoilers acting correctly, made it impossible for the crew to apply the reversed controls (yoke), after detecting the discrepancy on the aileron inversion.

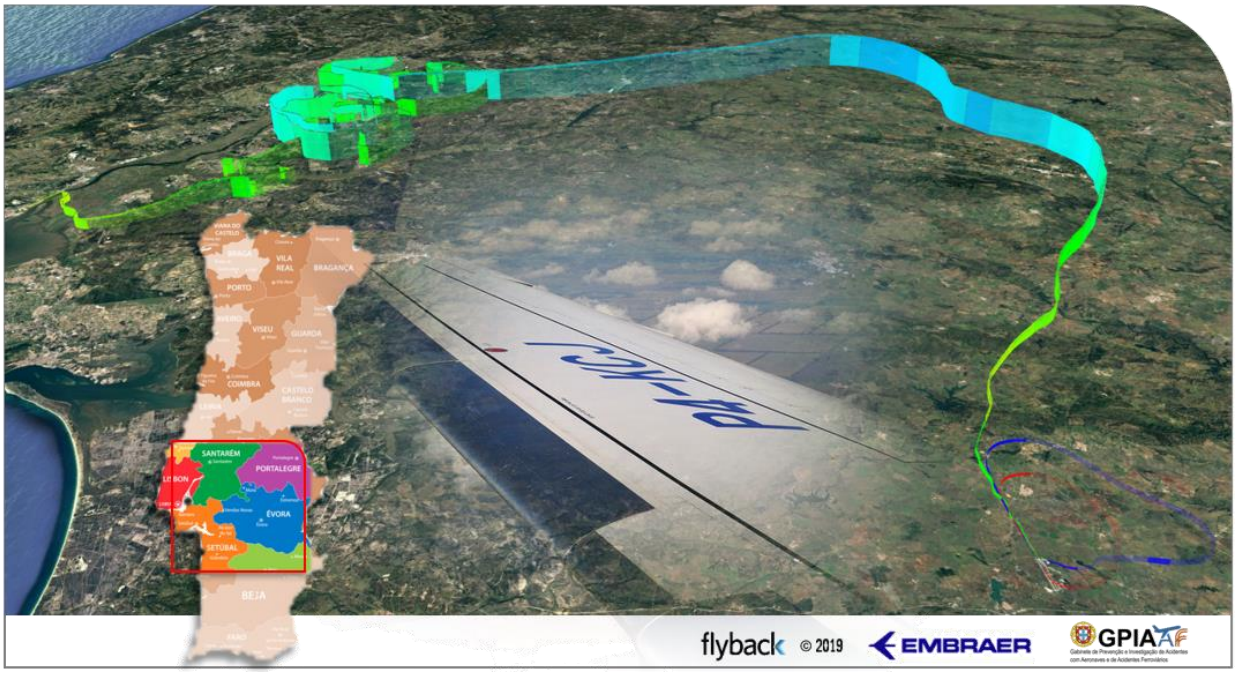

Figura 29 || **Figure 29**

Perspetiva geral do trajeto do voo do acidente || General accident flight path perspective

Por projeto, o volante de controlo (*yoke*) opera em "banda morta" de 5,5 graus, referente aos *roll spoilers* quando em modo DIRETO, proporcionando alguma previsibilidade de controlo à tripulação. A "banda morta" no modo NORMAL varia com a velocidade do ar e configuração de *flaps*.

As per design, the aircraft control yoke dead band regarding roll spoilers in DIRECT mode is 5.5 degrees, providing some predictability of controls to the crew. The dead band in NORMAL mode varies with air speed and flap setting.

Esta condição de projeto, associada à configuração de *slats/flaps* e ao voo com

This design condition, associated with the configuration of slats/flaps and flight with visual

condições visuais proporcionaram uma melhor perceção do comando-resposta, permitindo que a tripulação ganhasse controlo efetivo da aeronave, embora com limitações. Esta melhoria de cenário ocorreu pelas 14:50, 1:20 depois da descolagem de Alverca.

references provided a better perception of the command-response, allowing the crew to gain effective control of the aircraft, although with limitations. This scenario improvement occurred at 14:50, 1:20 after take-off from Alverca.

2.3. O operador || The operator

2.3.1. A contratação de serviços de manutenção a terceiros || Third party maintenance services contracting

A decisão de terceirizar serviços de manutenção especializada é uma prática comum, normalmente movida por questões de "custos de capacitação", ausência de especialização ou por simples decisão estratégica do operador. A contratação de serviços é, no entanto, distinta da contratação da gestão de determinados serviços.

The decision to outsource specialized maintenance services is a common practice in aviation, usually driven by "capability cost", lack of expertise, or simply by operator strategic decision. Contracting services is, however, distinct from contracting the management of that services.

O operador, enquanto detentor de um AOC é, de acordo com as diferentes legislações aplicáveis, responsável por garantir que os serviços que contrata cumprem com os desígnios da sua própria missão.

The operator, as AOC holder, is according to the different applicable regulations, responsible for ensuring that the services it contracts comply with the purposes of its own mission.

Dentro das suas responsabilidades, o operador deve garantir um programa de observação de manutenção, especialmente em contratos de longa duração, para monitorizar as práticas de manutenção do prestador de serviços, nomeadamente através da observação das ações de manutenção e agir em conformidade.

Within its responsibilities, the operator should assure a maintenance observation program, especially on long-term contracts, to monitor the service provider maintenance practices through observation of maintenance actions and act accordingly.

Para esse fim, a regulamentação[16] estabelece que observadores independentes treinados pelo operador devem coletar dados durante as atividades de manutenção, usando uma abordagem positiva e não punitiva. Complementarmente, devem ser realizadas auditorias, em ciclos predefinidos, às atividades de supervisão do fornecedor de serviços de manutenção com objetivo de obter uma visão sustentada dos fatores organizacionais, eficácia da formação e possíveis atalhos aos procedimentos.

For this purpose, regulation[16] establishes that the operator trained independent observers need to collect data during the maintenance activities, always using a positive and non-punitive approach. Complementary audits on pre-defined cycles to the maintenance provider supervisory activities to have a sustained insight into organizational factors, training effectiveness and possible short cuts on procedures.

Como boa prática, a certificação do prestador de serviços no produto e sob o normativo aplicável (Aruba, EASA, FAA ou outros), deve ser entendido

As a good practice, the service provider certification on the product and under the applicable certification standards (Aruba, EASA,

[16] Ex.: Regulation (EU) No 965/2012 on Air Operations, Annex III (Part-ORO.GEN.200).

apenas como um requisito inicial e não dispensando nunca o controlo próximo dos serviços prestados.

FAA or others) should only be understood as an initial requirement and never relieving close control of the contracted services.

2.3.2. O processo de aceitação da aeronave || The aircraft acceptance procedure

A transferência de responsabilidades entre o operador e a Parte 145 no momento de entrega da aeronave para manutenção e inversamente da manutenção para o operador no fim dos trabalhos, obriga a algumas formalidades e cumprimento de requisitos legais, como a entrega à tripulação do certificado de retorno ao serviço, contendo uma lista sumária dos trabalhos realizados.

The transfer of responsibilities between the operator and Part 145 at aircraft delivery for maintenance and, equally from maintenance to the operator at the end of the work, requires some formalities and legal requirements compliance, such as delivering the return service certificate to the crew, containing a summary list of the carried out work.

Para além desses requisitos legais, previstos na regulamentação da Parte 145 e Parte M, é essencial que a tripulação que recebe a aeronave e que irá realizar o primeiro voo após um serviço de manutenção significativo, tenha um conhecimento detalhado dos sistemas intervencionados e do grau de perturbação dos mesmos.

In addition to these legal requirements, established in Part 145 and Part M regulations, it is essential that the crew that receives the aircraft and that will conduct the first flight after a significant maintenance service, has a detailed knowledge of the systems involved and the degree of disturbance on those systems.

Os modelos de análise de fiabilidade revelam que a taxa de falha de um sistema, componente ou aeronave tem uma probabilidade significativa nos primeiros voos após as intervenções de manutenção, dependendo a sua magnitude do tipo ou extensão da intervenção e, também importante, da qualidade dos serviços prestados.

The reliability analysis models reveal that the failure rate of a system, component or aircraft has a significant higher probability on the first flights after maintenance interventions, depending on the magnitude, type and extent of the intervention and, also relevant, the quality of provided services.

É então relevante um adequado planeamento do processo de aceitação, minimizando as normais pressões da operação e todos os riscos associados às tarefas de manutenção realizadas.

An adequate planning of the acceptance process is therefore relevant, minimizing the normal operational pressures and all associated risks with the maintenance tasks performed.

Os procedimentos operacionais padrão do operador (SOP), em especial os relativos à verificação de comandos de voo e já discutidos em 1.17.1 devem ser cuidadosamente verificados.

The operator standard operating procedures (SOP), in particular those relating to flight controls check and discussed on 1.17.1 must be carefully confirmed.

O planeamento da aceitação e realização do primeiro voo após manutenção, deve ter em atenção um conjunto de restrições ou condições desejáveis, como sendo a composição e treino da tripulação, carregamento e limitações da aeronave e as condições meteorológicas.

The acceptance planning and the first flight after maintenance must take into account a set of restrictions or desirable conditions such as the crew composition and training, aircraft loading and limitations and relevant weather conditions.

O voo de posição para a base do operador sem passageiros (voo não comercial), como é prática na indústria, serve como uma validação da condição da aeronave após manutenção e deve, por aplicação dessas mesmas boas práticas, ser

The position flight to the operator base without passengers (non-revenue flight), common in the industry, serves as a validation of the aircraft's condition after maintenance and should, as best practice, be performed in daytime visual

realizado em condições visuais diurnas e com condições meteorológicas favoráveis na origem e no destino, prevendo a eventual necessidade de regresso ao aeroporto de origem (ATB).

Conforme descrito nos fatores meteorológicos, a aeronave descolou com um teto baixo, obrigando a tripulação a recorrer de imediato ao voo por instrumentos em IMC e à perda de referências visuais. Não sendo um requisito obrigatório, a realização deste tipo de voos em condições mínimas VFR seriam uma boa prática.

conditions and with favourable weather conditions at the origin and destination, preventing a possible air turn back (ATB).

As described in the meteorological factors, the aircraft took off with a low ceiling, forcing the crew to immediately change to instrument flight rules in IMC and the loss of visual references. Not being a mandatory requirement, carrying out this type of flight with minimum VFR conditions would be good practice.

Figura 30 || **Figure 30**

Simulação das condições meteorológicas à descolagem para o primeiro voo após manutenção || Meteorological conditions simulation for the first flight after maintenance

Relativamente aos fatores envolvidos na realização das verificações pré-voo e a não deteção da condição de configuração incorreta das superfícies dos *ailerons* pela tripulação e, independentemente das fragilidades identificadas na documentação de suporte à tripulação (SOP), a realização frequente do procedimento obrigatório antes de cada voo associado à habitual ausência e falhas, a interpretação do sentido de operação das superfícies dos *ailerons* é facilmente confundida pela tripulação.

Não estando a tripulação alertada e focada para esta interpretação e atendendo a que a possibilidade de inversão física dos comandos

Regarding the factors involved in carrying out the pre-flight checks and the crew failure to detect the incorrect ailerons configuration condition, in addition to the weaknesses already identified in the crew support documentation (SOP), the frequent performance of the mandatory procedure before each flight associated with unlikely system failures or misconfiguration detection, the crew interpretation on the aileron surfaces operating direction is easily missed.

As the crew was not alerted and focused on this interpretation and given that the possibility of physical controls inversion will only occur in

ocorrerá apenas em ações de manutenção relevantes, normalmente em ações de manutenção pesada com periodicidade típica de operação em torno das 5000 horas de voo, a tripulação fica exposta à possibilidade de erro de atenção (*slips*).

Pela taxonomia de fatores humanos, um erro de ação é uma ação não intencional. Este tipo de erro ocorre durante a execução da tarefa e inclui ações executadas com um comportamento em "modo automático", saltando ou reorganizando um determinado passo de um procedimento, executando a ação correta no objeto errado ou executando a ação errada no objeto certo. É um tipo de erro de aptidão que habitualmente ocorre durante atividades altamente rotineiras, quando a atenção é desviada de uma tarefa, seja por pensamentos ou por fatores externos.

relevant maintenance actions, normally in heavy maintenance actions with typical operation periodicity of about 5000 flight hours, the crew is exposed to the possibility of attention error (slips).

As per human factors taxonomy, a slip of action is an unintentional action. This type of error occurs at the point of task execution, and includes actions performed on “automatic mode” behaviour, skipping or reordering a step in a procedure, performing the right action on the wrong object, or performing the wrong action on the right object. It is a skill-based error type that tend to occur during highly routine activities, when attention is diverted from a task, either by thoughts or external factors.

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3. CONCLUSÕES || CONCLUSIONS

3.1. Constatações da investigação || Findings

3.1.1. A aeronave || The aircraft

A aeronave acidentada foi devidamente certificada e estava equipada de acordo com os regulamentos aplicáveis. Com exceção do sistema de comando dos *ailerons*, não foram encontradas evidências de anomalias na aeronave. Das verificações pós-evento aos componentes da aeronave, estes não evidenciaram falhas preexistentes adicionais na estrutura, motores ou nos sistemas.

The accident aircraft was properly certified and equipped in accordance with applicable regulations. Except for the aileron control system, no discrepancies evidence was found on the aircraft. The post event examinations to the aircraft components showed no evidence of any additional pre-existing structural, engine, or systems failures.

O sistema de comando dos *ailerons* da aeronave acidentada foi incorretamente instalado durante a execução dos trabalhos de manutenção pesada. Essa incorreta instalação afetou a controlabilidade da aeronave.

The accident aircraft aileron control system was incorrectly installed during the heavy maintenance check, and the incorrect installation impaired the aircraft controllability.

O projeto da aeronave, no que diz respeito à configuração do sistema de comando dos *ailerons*, evidenciou fragilidades que permitiram a instalação invertida dos cabos de comando nos quadrantes de ambas as PCU.

The aircraft design regarding the ailerons control system configuration showed weaknesses that allowed the inverted installation of the control cables in both PCU quadrants.

O fabricante da aeronave não forneceu instruções de manutenção claras e adequadas para a instalação do sistema de comando dos *ailerons* e respetivas verificações operacionais. As mesmas faltas de instruções de manutenção inequívocas na documentação foram evidenciadas em relação à deteção da incorreta configuração dos cabos dos *ailerons* da aeronave durante os procedimentos de verificação física dos cabos ou através de indicação digital aquando do retorno ao serviço dos comandos de voo (RTS).

The aircraft manufacturer did not provide proper and clear maintenance instructions for the aileron control system installation and operational checks. The same lack of unambiguous maintenance instructions on documentation was evident regarding the aircraft misconfiguration detection during the flight controls physical verification or by digital means during the return to service procedure (RTS).

3.1.2. Os serviços de manutenção || The maintenance services

O sistema de garantia de qualidade da AMO não teve a robustez necessária para a deteção de desvios de manutenção, por ausência de um sistema efetivo de recolha e processamento de dados de reporte de manutenção (SMS).

The AMO quality assurance system failure to detect maintenance deviations/escapes due to an absence of an effective system in place for collecting and processing maintenance deviation data (SMS).

Adicionalmente, a falta de equipas de manutenção devidamente organizadas por competências e especialidades, com formação e

Additionally, the lack of maintenance teams properly organized by competence and specialties, with proper training and experience

experiência e com uma gestão adequada, criou ou potenciou uma condição latente para a não deteção atempada da configuração da aeronave. A falta de experiência observada é transversal à organização, incluindo o pessoal de suporte, o pessoal de certificação, líderes de equipa e gestores.

and with an adequate management, created or enhanced a latent condition for the timely non-detection of the aircraft misconfiguration. The observed lack of experience is across the organization, including support staff, certification staff, team leaders and managers.

O processo deficitário de supervisão e controlo das atividades promoveu que a natureza independente das inspeções de verificação (*independente inspection*) quanto à "função e sentido", conforme definido na regulamentação aplicável, não foi seguida pelo prestador de serviços de manutenção e era genericamente desconhecida pelos técnicos de manutenção.

The ineffective supervision and control process of activities promoted the independent nature of the "function and sense" as defined in the applicable regulation, was not followed by the maintenance service provider and was generally unknown to the maintenance technicians.

3.1.3. O operador || The operator

O operador estava devidamente certificado para a operação da aeronave de acordo com os regulamentos aplicáveis.

The operator was properly certificated for the aircraft operation under the applicable regulations.

O operador não supervisionou adequadamente o trabalho executado pelo prestador de serviços de manutenção durante as atividades de manutenção pesada, incluindo os procedimentos de inspeção independente, e o pessoal técnico do operador não garantiu que a aeronave retornasse ao serviço em condições de aeronavegabilidade.

The operator did not adequately oversee the work performed by the maintenance service provider during the heavy maintenance activities, including the independent inspection procedures and technical personnel and did not ensure that the accident aircraft was returned to service in an airworthy condition.

O operador não tinha estabelecido um procedimento para a aceitação da aeronave após um evento de manutenção pesada.

The operator did not establish an aircraft acceptance procedure after a heavy maintenance event.

O operador não estabeleceu ou providenciou linhas de orientação à tripulação sobre as condições de realização do voo de posição, após intervenção de manutenção significativa, incluindo, entre outras boas práticas, a definição de condições meteorológicas mínimas.

The operator did not establish or provide guidelines to the crew on the conditions for carrying out the position flight, after significant maintenance intervention, including, among other good practices, the definition of minimum meteorological conditions.

3.1.4. A tripulação || The Crew

O comandante e os dois copilotos estavam devidamente certificados e qualificados de acordo com os regulamentos aplicáveis. Não foram evidenciadas quaisquer condições médicas ou comportamentais pré-existentes que possam ter negativamente afetado o seu desempenho durante o voo do acidente.

The captain and both first officers (co-pilots) were properly certificated and qualified under applicable regulations. No evidence indicated any pre-existing medical or behavioural conditions that might have adversely affected their performance during the accident flight.

A tripulação durante a fase de inspeção pré-voo e preparação do mesmo não detetou a inversão de configuração do sistema de comando dos

The crew, during the pre-flight inspection and preparation phase, did not detect the aileron control system configuration reversal resulting

ailerons resultante da sua incorreta instalação durante os trabalhos de manutenção.

from its incorrect installation during maintenance activities.

A tripulação não era conhecedora, ainda que de forma genérica, do escopo de trabalhos de manutenção ou sistemas intervencionados na aeronave.

The crew was not generally aware of the aircraft heavy maintenance work scope or disturbed aircraft systems.

A tripulação ao adotar uma estratégia de trabalho em equipa, discutindo opções com o terceiro ocupante do *cockpit* e com os técnicos a bordo, foram-se complementando nas ações necessárias para fazer face às dificuldades encontradas e colaborando para um desfecho com consequências mínimas para os ocupantes da aeronave.

The crew, by adopting a teamwork strategy, discussing options with the third cockpit occupant and with the technicians on board, complemented each other in the necessary actions to face the encountered difficulties and collaborated for an outcome with minimal consequences for all on board.

3.1.5. O meio ambiente || The environment

As condições meteorológicas na descolagem e ao longo da primeira hora do voo, nomeadamente o voo em condições IMC, dadas as condições de controlabilidade da aeronave, constituíram um obstáculo para as ações da tripulação.

The weather conditions at take-off and during the first hour of the flight, namely, the flight under IMC conditions and, given the aircraft controllability conditions, constituted an obstacle for the crew actions.

O apoio aéreo prestado pelos pilotos de caça, em conjunto com os controladores de tráfego aéreo que geriram o voo do acidente, estavam devidamente treinados e prestaram serviços adequados no controlo de tráfego aéreo. A resposta de emergência ao acidente foi oportuna e eficaz.

The air support provided by the fighter pilots along with the air traffic controllers that handled the accident flight were properly trained and provided appropriate air traffic control services. The emergency response for this accident was timely and effective.

3.2. Causas e fatores contributivos || Causes and contributing factors

3.2.1. Causas prováveis || Probable causes

A investigação determinou como causa mais provável para o acidente a instalação incorreta dos cabos dos *ailerons* de ambas as semi-asas durante as atividades de manutenção e subsequente inadequada inspeção independente aos sistemas de comando de voo da aeronave, que resultou numa reversão da operação do sistema dos *ailerons* da aeronave e levou à perda de controlo durante o voo.

The investigation determined as most probable cause for the accident the improper aileron cable installation on both semi-wings during maintenance activities and subsequent inadequate independent inspection to the aircraft flight control systems, which resulted in a reversal operation of the aircraft aileron system and led to loss of control in-flight.

3.2.2. Fatores contributivos || Contributing factos

Para o acidente, contribuíram os seguintes fatores:

- Deficiente funcionamento do sistema de garantia da qualidade da AMO e falha na implementação de uma supervisão eficaz da produção, incluindo, entre outros, os procedimentos de inspeção independente por forma a detetar falhas ou desvios de manutenção;
- Falta de gestão adequada do risco da AMO, com base num programa SMS eficaz suportado num sistema de reportes de falhas ou desvios;
- Falta de equipas de manutenção devidamente geridas e organizadas por competências e especialidades, com o treino e experiência necessários;
- Fragilidades na componente do projeto da aeronave referente à configuração do sistema de comando dos *ailerons*, que permitiram a instalação invertida dos cabos nos quadrantes de ambas as PCU;
- Descrição complexa e imprecisa no formato de apresentação das publicações de manutenção do fabricante da aeronave no encaminhamento dos cabos dos *ailerons*;
- Falta de instruções de manutenção claras pelo fabricante da aeronave para possibilitar a deteção de configuração incorreta da aeronave durante os procedimentos de retorno dos comandos de voo ao serviço (RTS);
- Falta de documentação guia ou definição de melhores práticas do OEM para orientação do operador e AMO relativamente ao processo de aceitação e retorno ao serviço da aeronave, após um evento de manutenção pesado ou complexo;
- A deficiente supervisão da organização de manutenção pelo operador;
- Supervisão deficiente da organização de manutenção pelas autoridades de supervisão, nomeadamente nos procedimentos internos de supervisão de manutenção e comunicação de ocorrências;

For the accident, the following factors contributed:

- Insufficient functioning of the AMO quality assurance and failure to implement an effective production oversight, including but not limited to the independent inspection procedures to detect maintenance escapes;
- The AMO lack of proper risk management, based on an effective SMS program with maintenance escapes reporting system;
- The lack of maintenance teams properly managed and organized by skills and specialties, with the necessary training and experience;
- Weaknesses in the aircraft design, referring to the ailerons control system configuration, allowing the inverted cables installation in both PCU quadrants;
- The aircraft manufacturer's inaccurate depiction, complex and limitations on presentation of the aileron cables routing maintenance publications;
- The aircraft manufacturer's lack of proper maintenance instructions to detect the aircraft misconfiguration during the flight controls return to service procedure;
- The lack of proper guidance or best practices from the OEM to the operator and AMO regarding aircraft acceptance and return to service, after a heavy or complex maintenance event;
- The poor supervision of the maintenance organisation by the operator;
- Deficient maintenance organisation oversight by the supervising authorities, namely on the internal maintenance supervision procedures and occurrence reporting;

— Falta de orientações adequadas do operador à tripulação sobre o processo de aceitação da aeronave após um evento de manutenção pesada;

— Não deteção pela tripulação da configuração incorreta dos *ailerons* durante os procedimentos de verificação operacional ao seguirem SOP com limitações nas verificações altamente rotineiras antes do voo.

— The lack of proper guidance from the operator to the crew regarding aircraft acceptance after a heavy maintenance event;

— The crew failure to detect the ailerons misconfiguration during the operational check procedures following limited SOP's on the highly routine pre-flight checks,

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4. RECOMENDAÇÕES || RECOMMENDATIONS

De acordo com o artigo 17.3 do Regulamento Europeu (UE) n.º 996/2010 do Parlamento Europeu e Conselho, de 20 de outubro de 2010, sobre investigação e prevenção de acidentes e incidentes na aviação civil, **a formulação de uma recomendação de segurança não constitui, em caso algum, presunção de culpa ou de responsabilidade** relativamente a um acidente, a um incidente grave ou a um incidente.

In accordance with Article 17.3 of European Regulation (EU) No. 996/2010 of the European Parliament and Council of 20 October 2010, on the investigation and prevention of accidents and incidents in civil aviation, **a safety recommendation shall in no case create a presumption of blame or liability** for an accident, a serious incident or an incident.

O destinatário de uma recomendação de segurança deve, no prazo de 90 dias, informar à autoridade responsável pelas investigações de segurança que formulou a recomendação, das ações tomadas ou em consideração, nas condições descritas no artigo 18 do referido Regulamento.

The addressee of a safety recommendation shall, within 90 days, inform the safety investigation authority which issued the recommendation, of the actions taken or under consideration, under the conditions described in Article 18 of the aforementioned Regulation.

Nesta seção são descritas as ações de segurança entretanto tomadas pelas partes relevantes assim como as recomendações que o GPIAAF entende emitir para mitigar as questões de segurança operacional identificadas na investigação que subsistam.

This section describes the safety actions taken by the relevant parties after the event, as well as the recommendations that GPIAAF still considers necessary to issue in order as to address the remaining safety issues identified in the investigation.

4.1. Ações de segurança tomadas desde o evento || Safety actions taken after the event

4.1.1. Operador Air Astana|| Air Astana operator

O operador, seguindo os seus procedimentos de investigação interna e processo de melhoria contínua, informou a investigação sobre as ações de segurança entretanto implementadas:

The operator, following the internal investigation procedures and its continuous improvement process, informed the investigation about the already implemented safety actions:

- O manual de gestão de segurança (SMM) foi revisto em março de 2019, na Parte IV, por forma a incluir uma nova análise de risco e implementadas respetivas medidas de controlo em relação à prestação de serviços inadequados por organizações de manutenção pesada contratadas. Uma das ações visou fortalecer as listas de verificação de conformidade das Parte 145 contratadas usadas nos processos de avaliação inicial;
- The safety management manual (SMM) was revised on March 2019 on its Part IV to include a new hazard analysis and related control measures put in place regarding inappropriate services by contracted heavy maintenance organizations. One of the implemented actions aimed to strengthening the compliance checklists used in the initial assessment processes to the Part 145 contracted parties.
- Foram incluídos novos procedimentos operacionais (CED-06) para garantir um
- New operational procedures were added (CED-06) to cover crew briefing procedures

briefing da tripulação após a realização de manutenção, agora incluído no Manual de Procedimentos de Operações de Voo - Apêndice A, assegurando um *briefing* para voos não comerciais;

after maintenance checks, now included on Flight Operations Procedures Handbook – Appendix A cover the Non-revenue Flight Briefing;

- A secção de verificações antes de voo do manual de procedimento padrão (SOP) foi revisto no sentido de reforçar a visualização e interpretação da posição das superfícies de comando de voo em relação ao comandado.

- The pre-flight checks section on the standard operating procedures manual (SOP) has been revised to reinforce the visualization and interpretation of the flight control surfaces position relative to the given command.

4.1.2. OEM EMBRAER || OEM EMBRAER

O fabricante desenvolveu esforços em duas áreas distintas no sentido de reforçar as barreiras de segurança e mitigar as debilidades identificadas (detalhes em 1.18.2.3):

The manufacturer has made efforts in two different areas to mitigate the identified weaknesses (details in 1.18.2.3):

- Revisão dos manuais de manutenção aplicáveis,

• Revision of applicable maintenance manuals,

- Revisão e inclusão de um novo procedimento de validação da posição física dos *ailerons* relativamente à posição da coluna de controlo.

• Review and inclusion of a new procedure for validating the aileron physical position vs control column position.

- O fabricante declarou ainda que está em processo de avaliação para a introdução de um monitor dedicado capaz de alertar a tripulação em caso de inversão de cabos de aileron.

• OEM declared that, is studying the introduction of a dedicated monitor to alert the crew in case of inverted installation of the aileron cables.

4.1.3. A organização de manutenção OGMA, S.A. || The Maintenance organization OGMA, S.A.

A AMO iniciou um processo de restruturação continuada das áreas produtivas na busca de soluções para um incremento das barreiras de deteção da falha (denominados de *quality gates*), seguindo uma estratégia de aplicação de uma equipa de inspetores dedicada e independente dos técnicos executantes. Foi ainda observado o início de um processo de revisão do sistema de cartas de trabalho.

The AMO started a process of continuous restructuring of productive areas aiming solutions for an error capture and barriers increase (named quality gates), following an strategy to allocate a dedicated and independent inspectors team (out of production team). It was also observed the beginning of a working document system revising process.

Procedeu à contratação de serviços de consultoria externa para avaliação do sistema de gestão de segurança operacional (SMS), com o objetivo de mapear e definir um plano de implementação transversal na organização.

External consultancy services contracting to evaluate the safety management system (SMS), aiming the organization mapping and to establish a transversal implementation plan.

Foram dados alguns passos no processo de definição do padrão ou referencial para a avaliação de competências do pessoal técnico.

Nota: Estas e outras medidas que venham a ser definidas, requerem invariavelmente uma validação, aprovação e um acompanhamento próximo das diversas autoridades de certificação para a qual a AMO está atualmente certificada.

Some steps have been taken in the process of establish the standards for competency and skills assessment for technical personnel.

Note: These measures and others that may be outlined, invariably require validation, approval and a close follow-up by the several certification authorities that the AMO is currently certified.

4.2. Recomendações de segurança | | Safety recommendations

Após uma análise criteriosa de todos os dados e factos do evento, assim como das ações de segurança entretanto tomadas pelas partes, a autoridade de investigação de segurança determinou como útil e necessária a emissão das seguintes recomendações de segurança com o objetivo de mitigar os aspetos de segurança identificados no processo de investigação:

After a thorough analysis of all event data and facts, as well as of the safety action meanwhile taken by the involved parties, the safety investigation authority determined that the following safety recommendations would be deemed useful and necessary in order to mitigate the safety aspects identified during the investigation:

À OGMA, S.A.,

Recomendação de Segurança PT.SIA 2020-09:

Recomenda-se que a OGMA, S.A. proceda, no prazo de seis meses, à revisão do seu sistema de gestão (Garantia da Qualidade) por forma a garantir que os processos implementados estão em conformidade com os requisitos da Parte 145 aplicáveis e um sistema de auditoria interna efetivo para verificar a sua correta implementação.

Adicionalmente e tendo a OGMA, S.A. em implementação um SMS desde 2013, é recomendado que este seja revisto garantindo uma efetiva gestão dos riscos inerentes às atividades desempenhadas, nomeadamente baseado nas devidas análises de risco suportadas em dados reais das operações de manutenção e num sistema em que o reporte de ocorrências seja incentivado, assente no princípio de cultura justa.

To OGMA, S.A.,

Safety Recommendation PT.SIA 2020-09:

It is recommended that OGMA, S.A. review, within six months, its Management System (Quality Assurance) in order to ensure that the processes in place are compliant with the applicable Part-145 requirements and an effective internal auditing system to verify their correct implementation.

Furthermore, having OGMA, S.A. implemented an SMS since 2013, it is recommended to review it in order to ensure that an effective risks management inherent to the performed activities, namely based on the appropriate risk analyses supported by real data from the maintenance operations and a system in which occurrence reporting is encouraged, based on the just culture principle.

À OGMA, S.A.,	**To OGMA, S.A.,**
Recomendação de Segurança PT.SIA 2020-10:	**Safety Recommendation PT.SIA 2020-10:**
Recomenda-se que a OGMA, S.A., no prazo de três meses, proceda a um levantamento transversal e exaustivo de competências na organização, avaliando e discernindo sobre cada um dos seus elementos, e tome as medidas consideradas apropriadas para a correta alocação de técnicos às tarefas, eventualmente limitando o âmbito das autorizações de execução e/ou certificação de supervisão nas especialidades para as quais os seus colaboradores não demonstrem ainda as competências necessárias.	It is recommended that OGMA, SA, within three months, carries out an organization-wide exhaustive competencies survey, evaluating and discerning about each one of its elements, and take the considered appropriate measures for the correct technicians assigning to the tasks, possibly limiting the authorizations and/or supervisory certification in the scope specialties for which its employees do not yet demonstrate the necessary skills.

À OGMA, S.A.,	**To OGMA, S.A.,**
Recomendação de Segurança PT.SIA 2020-11:	**Safety Recommendation PT.SIA 2020-11:**
Recomenda-se que a OGMA, S.A., no prazo de três meses, proceda à revisão da sua política de supervisão das atividades, revendo e alterando conforme aplicável o seu MOM, ONS-000028 e os demais procedimentos aplicáveis, nomeadamente, mas não limitado, ao conceito de inspeção independente, cumprindo o previsto na Parte 145.A.48 do Regulamento (UE) n.º 1321/2014.	It is recommended that OGMA, SA, within three months, reviews its policy for activities supervision, reviewing and changing as applicable its MOM, ONS-000028 and other applicable procedures, namely, but not limited to, the independent inspection concept, fulfilling with Part 145.A.48 of Regulation (EU) No. 1321/2014.

À EMBRAER, S.A.,

Recomendação de Segurança PT.SIA 2020-12:

Recomenda-se que a Embraer, no prazo de seis meses, defina material de orientação adequado para apoiar os operadores e organizações de manutenção durante a fase de retorno ao serviço das aeronaves após um evento de manutenção significativo ou pesado, garantindo que os padrões de certificação da aeronave sejam mantidos e não afetados por complexas tarefas de manutenção e/ou combinações de tarefas.

To EMBRAER, S.A.,

Safety Recommendation PT.SIA 2020-12:

It is recommended that Embraer, within six months, establishes proper guidance material to support operators and maintenance organizations during the aircraft return to service phase, after a significant or heavy maintenance event, in other to ensure the aircraft certification standards were kept and not affected by complex maintenance tasks and/or task combinations.

Atendendo ao processo de padronização atualmente em execução e seguimento pela Agência da União Europeia para a Segurança da Aviação (EASA) à Autoridade Nacional de Aviação Civil (ANAC) conforme regulamento (UE) 628/2013, a autoridade de investigação de segurança determinou como não sendo eficaz a emissão de recomendações de segurança à ANAC sobre as questões de segurança operacional identificadas na investigação relacionadas com o processo de supervisão desta autoridade à AMO.

Contudo, perante as evidências e conclusões patentes neste relatório, a Autoridade, no exercício das suas competências e responsabilidades, necessariamente que deverá dedicar uma especial atenção à monitorização e supervisão da organização de manutenção OGMA, S.A., nomeadamente e entre outros aspetos, quanto ao seu Sistema de Garantia da Qualidade interno e de gestão do risco sobre as atividades de manutenção de aeronaves cujas lacunas foram identificadas na investigação, em detalhe:

- Sistema da Qualidade,
- Realização das inspeções independentes,
- Seguimento das tarefas executadas pelos técnicos de manutenção por forma avaliar a execução da tarefa de acordo com os manuais do fabricante e o correto preenchimento das cartas de trabalho,

Considering the European Union Aviation Safety Agency (EASA) standardization process currently in implementation and follow-up to the National Civil Aviation Authority (ANAC) as per Regulation (EU) 628/2013, the safety investigation authority determined that it was not necessary nor effective to issue safety recommendations to ANAC regarding the identified safety issues related to the AMO oversight process by this authority.

However, having present the findings and conclusions from this report, the Authority, in the exercise of its competences and responsibilities, must necessarily monitor and oversight with a special focus the AMO OGMA, S.A., namely and among other aspects, the gaps in the internal Quality Assurance System and risk management over the aircraft maintenance activities identified in the investigation, in detail:

- Quality system,
- Independent inspections follow-up,
- Close follow-up of the performed tasks by the maintenance technicians in order to evaluate the task accomplishment according to the manufacturer's manuals and the correct completion of the working documents,

- Avaliação de competências dos técnicos que executam a manutenção e o pessoal de suporte e de certificação,
- Verificação do conhecimento dos técnicos relativo aos procedimentos internos da organização,
- Procedimento e eficácia do sistema de reporte de ocorrências,
- Processo de supervisão e gestão do pessoal da manutenção,
- Reavaliação das competências do pessoal de gestão e nomeado (*Post holders*),
- Controlo da gestão da mudança (nomeadamente rotatividade do pessoal técnico e de gestão),
- Controlo de equipas de manutenção externas à AMO.

De igual forma, a Autoridade de Aruba (DCA), dentro das suas responsabilidades e respetivo referencial de certificação, deverá supervisionar o prestador de serviços sobre as lacunas identificadas nesse domínio.

- Competency assessment to the maintenance support and certifying staff,
- Technicians' knowledge assessment regarding the organization's internal procedures,
- Occurrence reporting procedures and effectiveness,
- Maintenance staff oversight and management process,
- Management and post holders competency assessment,
- Management strategies for organizational change (namely the technical and management personnel turnover),
- AMO external maintenance teams' management.

Likewise, the Aruba Authority (DCA), within its responsibilities and respective certification framework, should properly oversight the maintenance service provider on the gaps identified in that domain.

Este relatório final foi homologado pelo diretor do GPIAAF, nos termos do n.º 3 do art.º 26.º, do Decreto-Lei n.º 318/99.

This final report was approved by the director of the Portuguese SIA, as per article 26, no. 3, of Decree-Law no. 318/99.

A equipa de investigação

The investigation team

Anexos com os comentários não adotados ou parcialmente adotados | |

Appendixes with not adopted or partial adopted comments

Nota preliminar do GPIAAF:

Os anexos seguintes apresentam os comentários ao projeto de relatório final, que não tenham sido aceites ou parcialmente aceites pela investigação e integrados no relatório, formulados pelas seguintes entidades:
Representantes acreditados:

- CENIPA/Embraer,
- MIID/Air Astana,
- Aruba DCA,

Conselheiros técnicos:

- EASA,
- ANAC (Portugal),
- OGMA, S.A.

Os comentários são apresentados sem quaisquer alterações, exceto no que concerne à remoção de eventuais nomes de pessoas mencionadas.

Os comentários são aqui apresentados apenas em língua inglesa. Excetua-se o comentário da ANAC, fornecido apenas em português e que o GPIAAF optou por não traduzir para inglês a fim de não ser responsável por alguma eventual e inadvertida alteração do conteúdo pretendido.

Quando relevante ou necessário, é também apresentada a justificação da investigação quanto à não aceitação ou adoção dos comentários.

Preliminary GPIAAF Note:

The following Appendices present the comments to the draft report that were not adopted or partially adopted by the investigation and integrated in the report, submitted by the involved parties:

Accredited representatives:

- CENIPA/Embraer,
- MIID/Air Astana,
- Aruba DCA,

Technical advisors:

- EASA,
- ANAC (CAA PT),
- OGMA, S.A.

The comments are transcribed without editorial alterations, except for the removal of any names of mentioned persons.

The comments are here presented solely in English. Exception is made to the comments from ANAC, supplied only in Portuguese and that GPIAAF decided not to translate so as not to be responsible for any undue and involuntary change of the desired intent.

Whenever relevant, it is presented the GPIAAF comments justifying the reasons for not accepting or adopting the comments.

Anexo I: Comentários do CENIPA/Embraer ao projeto de relatório final

Appendix I – CENIPA/Embraer comments to the draft final report

#	Draft Final Report Text	Proposed Text by CENIPA	CENIPA Comments	GPIAAF Comments
8	Pag. 37: [Figure 9]	[Removal of the "airspeed vs gain" graph]	Embraer requires the removal of the graph (airspeed vs gain) as it is a design specification and thus is part of the company intellectual property. Besides that, Embraer considers that the removal of this graph will not affect the understanding of the report.	**Partially adopted** The investigation considers essential to keep the graph to allow the reader to understand important information regarding the FLT CTR sys different behaviour; however the content was simplified to protect the intellectual property.
18	Pag. 62: Maintenance services performed on the accident aircraft were performed with the manufacturer's technical support and using the appropriate and applicable technical publications to the aircraft.	Maintenance services performed on the accident aircraft were performed **using the appropriate and applicable technical publications to the aircraft.**	The phrase as it is in the report's DRAFT leads the reader to erroneously understand that there was an on-site technical support from Embraer for all the activities of the P4-KCJ aircraft throughout the period in which it was at OGMA. It is important to note that remote support (by email or by phone) was provided to address specific issues on demand. The Embraer Technical Representative was present at OGMA only from 08 to 09.NOV, after the 'C' closing. Additionally, the aspects associated with the on-site support of the Embraer Technical Representative is already contemplated in item 1.18.2.2 "Technical Support Service Provided". In this sense, the CENIPA proposes the removal of the text "[...]with the manufacturer's technical support and[...]".	**Partially adopted** The investigation decided not limiting the scope of the sentence to technical publications, as it intends to clarify the reader that the manufacturer was involved in supporting AMO, as an Embraer approved service centre and specifically for the work developed together in the troubleshooting process during the maintenance event.

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Appendix I – CENIPA/Embraer comments to the draft final report

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19	Pag. 62: Inconsistencies were found in some of the technical instructions used, namely in tasks related to aileron control cables. The inconsistencies in the aileron cables removal and installation tasks exhibited complex understanding on description and sub-tasks sequencing and with a high potential for misunderstanding.	**The CENIPA proposes to suppress the phrase "Inconsistencies[...]cables"** The technical instructions included in the aileron cables removal and installation tasks exhibited complex description and sub-tasks sequencing.	The aileron cable removal and installation tasks contained the information necessary for the correct installation of the cables, including barriers, with operational checks of the correct physical deflection of the surfaces and through the synoptic page to ensure the correct installation and operation of the aileron system.	**Not adopted** The investigation does not agree to limit the text to the task description complexity, because, as timely transmitted and discussed with the manufacturer, including sending the findings data to Embraer in each of the maintenance tasks, the inconsistencies were not restricted to the aileron system nor to E190 product. These complexity and inconsistencies have impact on human factors, facilitating incorrect interpretation or misunderstanding. Such inconsistencies were already addressed by the manufacturer has mentioned in the report's appropriate section.
21	Pag. 63: Regarding the working document for the cables pulley support replacement, service bulletin SB190-57-0038R2, mentioned the need for a complete disconnection of both control cables in the rear wing spar area on both semi-wings aiming the new frame installation (figure 1). This procedure jeopardises the aircraft project configuration due to the facility of incorrect reinstallation, not complying with the certification specifications listed in 1.6.2.	"Regarding the working document for the cables pulley support replacement, service bulletin SB190-57-0038R2, mentioned the need for a complete disconnection of both control cables in the rear wing spar area on both semi-wings aiming the new frame installation (figure 1). This procedure, combined with the no execution of the Aileron operational test, jeopardises the aircraft project configuration due to the facility of incorrect reinstallation, not complying with the certification specifications listed in 1.6.2.	The CENIPA emphasizes that, if a wrong installation occurs, this condition will only remain if the maintenance tasks, which includes the aileron system operational test, are not correctly followed.	**Not adopted** The operational test was performed without positive results regarding the misconfiguration detection; If properly performed, it provides the possibility of detecting erroneous configuration, however the complete disconnection of both cables at the same time, jeopardizes the aircraft design configuration, regardless of any subsequent barriers developed by the OEM or the AMO. The cable end configuration design is the questionable project configuration certification by CS 25.671.
22	Pag. 64: In all this troubleshooting process, at no time was questioned, either **by the manufacturer or** the Part 145, whether the aircraft still maintained the initial certification conditions, given the extend of the maintenance intervention with massive flight control system primary components replacement.	In all this troubleshooting process, at no time was questioned by the Part 145 whether the aircraft still maintained the initial certification conditions, given the extend of the maintenance intervention with massive flight control system primary components replacement.	The CENIPA suggests removing the mention to manufacturer, as it is the Part 145 responsibility to ascertain and to maintain the aircraft airworthiness during maintenance interventions. It is not up to Embraer to audit the sequence and/or the completeness of the activities conducted by a Part 145 certified provider.Therefore, the CENIPA proposes to suppress the text "[...] the manufacturer or [...]".	**Not adopted** The investigation considers that the manufacturer had detailed, continuous and exhaustive access to the aircraft's maintenance data, especially during the phase in which it was represented at AMO, the period referred in the text.

Anexo I: Comentários do CENIPA/Embraer ao projeto de relatório final

Appendix I – CENIPA/Embraer comments to the draft final report

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25	Pag. 66: The solution uses low-level software (software used in maintenance only), and therefore, without the certification process requirements, that through a code 0 – Failure; 1 – Pass; 2 – Waiting for command, informs the technician of the ailerons position in relation to the control column command.	The solution uses a maintenance software that, **trough the code 0 for "Failure"; code 1 for "Pass" and code 2 for "Waiting for Command",** informs the technician of the ailerons position in relation to the control wheel.	The Embraer suggests removing the considerations related to the software certification requirements and removing the expression "low-level" software, which may induce the reader to mistakenly associate it with the software quality.	**Partially adopted** The investigation agrees to rephrase the concept of "low-level" and change the codes phraseology; however the reference to the software certification is relevant information, as, accordingly to the OEM, it sustained the simplified solution framework with rapid and simple implementation.
26	Pag. 89: The aircraft design and respective certification requirements are ultimately the guarantee that the mission for which the aircraft was designed will be carried out safely, even in the event of expected failures, **whether these are material or procedural failures by the different stakeholders in the aircraft operation or maintenance.**	The aircraft design and respective certification requirements are ultimately the guarantee that the mission for which the aircraft was designed will be carried out safely, even in the event of expected failures.	The CENIPA clarifies that the aircraft design requirements are not procedural failures proof, such as negligence and violations. Therefore, it is suggested to limit the escope of this excerpt by suppressing the text "[...] *whether these are material or procedural failures by the different stakeholders in the aircraft operation or maintenance.*"	**Not adopted** It is the investigation understanding that eventual failures on procedures do not fit in the CENIPA attributed categorization. The phrase suggested to be removed is generally accepted as one of the main design objectives for any equipment subject to human interface (maintenance or operational).
30	Pag. 92: The system architecture worked according to the project requirements, although the information provided on the different maintenance pages (FCM modules condition green/red dots) had not been used. Due to the aileron cables physical configuration, it was not foreseen in the technical publications the interpretation of this information by Part 145 or by the manufacturer. The facts prove the technical unawareness on these combined factors by both entities, evidenced mainly during the troubleshooting procedure.	The system architecture worked […] by Part 145 or by the manufacturer. **It is important to note that the flight control system RTS procedure is specifically designed to correctly clear an eventual failure message of the fly by wire portion of the flight control system, and does not include the verification of the correct installation of the aileron control cables, which should be done following the operational test during the cables installation task.**	To provide context and additional details on the objective and scope of the return to service procedures for the flight control system	**Not adopted** The investigation acknowledges the intent of the comment to underline the scope of the procedure, however the suggested phrase is already included in the comprehensive approach to the RTS procedure contained in the report. It is important to keep the reference to the fact that both parties lack technical knowledge about the FCM condition.

Anexo I: Comentários do CENIPA/Embraer ao projeto de relatório final

Appendix I – CENIPA/Embraer comments to the draft final report

#	Draft Final Report Text	Proposed Text by CENIPA	CENIPA Comments	GPIAAF Comments
32	Pag. 93: The manufacturer did not follow the way of changing and recertify the design requirements due to the relative obsolescence of the end-of-life E190 type, already with a substitute product with a substantially different design regarding flight controls system.	**The manufacturer minimized the possibility of aileron cables inversion through the use of different cables lengths with different cable threaded terminal (right hand thread and left hand thread) for attachment at the turnbuckle, in combination with the installation instructions and operational test required per aircraft maintenance manual. Also, the manufacturer is conducting studies to introduce a dedicated software monitor to detect and announce the inverted aileron cables installation as an additional feature against maintenance deviations.**	The Embraer has reviewed the requirements compliance status and considers that aileron control system complies with the applicable requirements. Despite that, the Embrear is currently studying the instroduction of a dedicated software monitor, as described in the propposed text. Also, the Embraer adds that that the E-Jets familiy is not at the end of its product cycle. Its fleet logs 1561 delivered aircaft and 185 orders, according to last Standard Financial Statements by the company on December 31st, 2019.	**Partially adopted** The investigation evidenced that the differentiated cable lengths design solution is only effective for the intermediate control cable sections. This solution does not address the possibility of inversion by its ends, as was the case with the maintenance event on the damaged aircraft. The sentence “end-of-life” has been removed and the suggested text for the additional resource has been added.

Anexo I: Comentários do CENIPA/Embraer ao projeto de relatório final

Appendix I – CENIPA/Embraer comments to the draft final report

#	Draft Final Report Text	Proposed Text by CENIPA	CENIPA Comments	GPIAAF Comments
33	Pag. 93/94: The manufacturer did not produce guidance material to operators or MROs with instructions or best practices for aircraft return to service after complex maintenance events. It is recognized that each maintenance task will eventually have the necessary information to close it (job close-up), however there is no defined procedure or policy to close complex tasks combinations, task packages or troubleshooting. **[...]** Thus, taking in to account the intervention level in heavy maintenance actions with modifications and possible complex troubleshooting actions, it will make sense to include a validation process and differentiated aircraft configuration control before the release to service, following instructions and guidance material suggested by the manufacturer.	**There was not, nor it was required from the manufacturer, a guidance material to operators or MROs with instructions or best practices for aircraft return to service after complex maintenance interventions.** **However, for each task of the aircraft maintenance manual, there were instructions for the job close-up, which assure that the correct functioning of the refered component/system.** **In this specific event, the aileron control cable operational test was among the job close-up instructions for the aileron cables installations task.**	The CENIPA notes that the E-Jets maintenance manuals meet all the requirements set by the aviation authorities and include all the necessary information for the safe job close-up of each task, including the correct installation of the aileron control cables and correct operation of the system. Therefore, the CENIPA suggests adding that the Guidance Material refered by the GPIAAF is not required by the aviation authorities. Besides that, the CENIPA understands that by suggesting that the manufacturer should have provided such guidance material, the GPIAAF is transfering the MRO rightfully responsibility as a Part 145 certificate holder over its quality and safety assurance processes to the manufacturer.	**Not adopted** It is the investigation understanding that the final report text is sufficiently clear regarding the scope of the instructions or guidance material required from the OEM. It is known that each maintenance task, when well designed and explained in the respective manual, has its own sequence, tests, necessary warnings or attentions and the task closing instructions. The scope of the safety recommendation to the OEM refers to possible task combinations, which, due to their combined complexity, can put the operator/AMO without the necessary skills to foresee possible unsafe conditions. With the sole purpose of trying to clarify, a possible combination is given, and it should be understood as one example only, occurred at the event, however not supported in the necessary studies to be developed by the OEM: - During the maintenance event, for the structural SB accomplishment, it was necessary to remove all the equipment (up to the level of the flight control modules boards) in the fwd avionics compartment. This work was performed simultaneously with other SBs, such ailerons control cables replacement, flight controls disassembly, including some actuators and functional tests performed. Such combination and disruption levels to the entire flight control system will easily be comparable to a significant fraction of the manufacturer's aircraft assembly. Thus, if the aircraft's manufacturing validation process at the production line follows a stablished rigorous test program, including acceptance flights, in some extent, complex tasks and possible combinations, to be determined by the manufacturer and included in the referred guidance material , must be taken into account

Anexo I: Comentários do CENIPA/Embraer ao projeto de relatório final

Appendix I – CENIPA/Embraer comments to the draft final report

#	Draft Final Report Text	Proposed Text by CENIPA	CENIPA Comments	GPIAAF Comments
				for aircraft validation before the return to service. The maintenance activities by performing complex tasks combinations, task packages or complex troubleshooting may require, for its close-up and aircraft return to service, specific validation procedures, which must be subject to evaluation by the AMO. In these situations, support from the manufacturer should be obtained. It is also important to clarify that, in the understanding of the investigation, which CENIPA will surely share as a preventive and safety investigation body, the actions within the scope of the regulated entities do not end in strict regulatory requirements compliance, which establishes the minimum standards, but in no way harm anything else that is necessary or appropriate to reduce as low as reasonable any associated risk with the products or services. In addition, the investigation does not understand that the report section in question is suggesting any type of responsibility transfer, but rather to warn of the need for all parties to proactively assume their responsibilities in the risk management.
35	Pag. 101: The aircraft design regarding the ailerons control system configuration showed weaknesses that allowed the inverted installation of the control cables in both PCUs quadrants.	The aircraft design regarding the control system configuration **showed the possibility of inverted aileron cables installation in both PCUs quadrants before the detection of such condition during the aileron operational test.**	The CENIPA suggests removing the term “weaknesses”, as although the inverted installation of the aileron cables was shown to be possible, the aileron system operational test, if performed, would effectively detect this condition. Still, the Embraer is studying the introduction of a dedicated monitor will make the design more robust. **It is important to note that the maintenance tasks specified by the OEM are part of the aircraft design.**	**Not adopted** The investigation considers that if the design allows inverted cable installation, this is a weakness. On the other hand, the maintenance tasks designed to detect failures were not effective or sufficient.

Anexo I: Comentários do CENIPA/Embraer ao projeto de relatório final

Appendix I – CENIPA/Embraer comments to the draft final report

#	Draft Final Report Text	Proposed Text by CENIPA	CENIPA Comments	GPIAAF Comments
36	Pag. 101: The aircraft manufacturer did not provide proper and clear maintenance instructions for the aileron control system installation and operational checks. The same lack of unambiguous maintenance instructions on documentation was evident regarding the aircraft misconfiguration detection during the flight controls return to service procedure (RTS).	**The CENIPA proposes to suppress the phrase "The same lack […] return to service procedure (RTS)"**	The verification of the correct installation of the flight control cables is done through the operational test at the end of the aileron cable installation task and is outside the scope of the return to flight control service (RTS) procedures.	**Not adopted.** The text aims to underline that the procedures described by the manufacturer do not allow a physical or digital visualization of the inversion through the procedure, including the RTS. The text was detailed with physical and digital verification.
37	Pag. 104: — Weaknesses in the aircraft design, referring to the ailerons control system configuration, allowing the inverted cables installation in both PCUs quadrants;	**— Possibility of the inverted cable installation in both PCUs quadrants;** **— The lack of accomplishment of the operational test task of the aileron, which would identify the reversal of the cables;**	The CENIPA notes that the maintenance tasks specified by the OEM are part of the aircraft design. Therefore, the evaluation of robustness of an aircraft system cannot be restricted only to the physical aspect. In addition, in the penultimate paragraph on page 58 (item 1.18.1), the report mentions that "the tests to verify the ailerons correct operation were not carried out."	**Not adopted.** Both alternative texts are already included in the contributory factors sentences (technical publications and AMO procedures). The text in 1.18.1, was clarified with a temporal reference to the non-execution of the test.
38	Pag. 104: — The aircraft manufacturer's inaccurate depiction of the aileron cables routing in maintenance publications;	— **Complexity and limitations in the presentation** of aileron cable routing on maintenance publications;	The text proposed aims to clarify that the information contained in the maintenance publications were not imprecise, but rather complex. The aileron cables installation tasks contained all the necessary information and barriers for the correct installation and operation of the aileron system. The figure mentioned on the item 1.18.2.1., page 62/63, extracted from AMM TASK 27-11-03-720-803-A, aims to illustrate and emphasize the installation of the rigging pin rather than providing information on the cables installation. Nonetheless, even if the cable adjustment tasks Figure was incorrectly used for that purpose, the cables would be installed in the correct sense if the inboard/outboard position depicted in this figure was respected.	**Partially adopted.** It is a fact that the instructions effectively contained inaccuracies as per the investigation review and duly shared with the OEM. Text partly revised, maintaining however the reference to tech pubs inaccuracy.

Anexo I: Comentários do CENIPA/Embraer ao projeto de relatório final

Appendix I – CENIPA/Embraer comments to the draft final report

#	Draft Final Report Text	Proposed Text by CENIPA	CENIPA Comments	GPIAAF Comments
39	Pag. 104: — The aircraft manufacturer's lack of proper maintenance instructions to detect the aircraft misconfiguration during the flight controls return to service procedure;	**The CENIPA proposes to suppress the part "during the flight controls return to service procedure (RTS)"**	The Flight Control System RTS procedures did not detect the inverted installation of the aileron cables, the report induces the reader to the incorrect understanding those procedures were expected to do so. The verification of the correct installation of the aileron cables is done through the operational test, performed at the end of aileron cables installation task and is out of the scope of the RTS procedure.	**Not adopted.** The specific mention to the absence of a procedure in the RTS, which could eventually lead to the misconfiguration detection, refers to the lack of meaning of the bits (red dots) in the referred procedure (figure 28 of the report)
40	Pag. 104: — The lack of proper guidance or best practices from the OEM to the operator and MRO regarding aircraft acceptance and return to service, after a heavy or complex maintenance event;	**(The CENIPA proposes removing this topic)**	As previously explained, the E-Jets maintenance manuals meet all the requirements set by the aviation authorities and include all the necessary information for the safe job close-up of each task, including the correct installation of the aileron control cables and correct operation of the system. Besides that, the CENIPA understands that by suggesting that the manufacturer should have provided such guidance material, the GPIAAF is transferring the MRO rightfully responsibility as a Part 145 certificate holder over its quality and safety processes to the manufacturer. Therefore, the CENIPA does not agree that the lack of a Guidance Material by the OEM to the MRO is a contributing factor for this event and proposes the removal of this topic.	**Not adopted.** As explained and justified on comment ref.#33, the investigation underlines that the implementation of this procedure is an important step to assisting operators and AMOs, providing relevant technical information for the safety barriers implementation in the aircraft release to service after complex maintenance events.
42	Pag. 110: It is recommended that Embraer, within six months, establishes proper guidance material to support operators and MROs during the aircraft return no service phase, after a significant or heavy maintenance event, in other to ensure the aircraft certification standards were kept and not affected by complex maintenance tasks and/or task combinations.	**(The CENIPA proposes removing the paragraph)**	The CENIPA does not agree that the lack of Guidance Material by the OEM to the MRO is a contributing factor for this occurrence, as each task of the maintenance manual has its appropriate (job close-up information), which if duly followed guarantee the safe termination and return to service, even considering complex combination of tasks, tasks packages or troubleshooting. Also, by considering it a contributing factor and addressing the Safety Recommendation to Embraer, the GPIAAF is transferring the MRO rightfully responsibility as a Part 145 certificate holder over its quality and safety processes to the manufacturer. Therefore, the CENIPA proposes removing this Safety Recommendation. If the GPIAAF decides to maintain the Recommendation, we kindly request to forward it to CENIPA, in order to allow this Center to attend the Annex 13, Paragraph 6.12 provision.	**Not adopted.** Please see comments ref.#33 and #40

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
4	**1.1 History of the Flight, Page 18, 1st Paragraph** starting with "Other maintenance work…" The paragraph on the aileron cable control system mentions inconsistencies in the maintenance records including errors on working card sign-offs and dates and independent inspections". A footnote describing "independent inspections" is provided, but there is no information provided on the inconsistencies or errors, no regulatory or OEM or OGMA reference, no explanation of the occurrences and no defining of the consequences and no comment from OGMA. The lack of detail makes understanding the validity, the context and the prevention very difficult.		It is suggested that further detail be included in this, or supplementary paragraphs, regarding the maintenance inconsistencies	**Not adopted.** On the same paragraph is mentioned: "including errors among the working cards sign-off namely inconsistencies on dates and independent inspections procedures not performed." The investigation considers this as sufficient.
5	**1.1 History of the Flight, Page 19, 2nd Complete Paragraph** starting with "The aircraft final delivery date…"	It is suggested that the paragraph be amended as follows: "The aircraft final delivery date was initially scheduled for OCT 24th, later renegotiated with the operator for OCT 31st. At this point, the maintenance organization started to suffer internal pressure for the delivery and return to service of the aircraft. The operator, during several attempts to obtain answers regarding the problem resolution, made its technical services available. The operator gave suggestions of possible problems induced during the aircraft's scheduled maintenance, including, asking if OGMA had checked the flight control rigging during the troubleshooting."	This paragraph refers to internal and external pressures that the MRO was facing. The MRO created their own pressures by the way they operated. For example, on the night of the 10th November, an FCM2 was coming from Amsterdam, to be fitted to the aircraft as they stated this was the last part required to fix the aircraft. The part was going to be delivered to the security hut during the night. It was then going to be picked up from the security hut by a technician during the night and he was to fit it to the aircraft. This never happened. Instead, an OGMA maintenance team started fitting the FCM2 in the morning of the 11th. When asked why, OGMA said that the Night Shift person did not show up for work. This gave them far less time to fit and test the FCM2 and the flying controls system. They created their own pressure.	**Not adopted.** It is the investigation understanding that the text contains enough information to the reader comprehend the experienced pressure scenario (internal or external induced).

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
9	**1.1 History of the Flight, Page 20, 3rd paragraph -** The report requires more detail regarding the flight control difficulties and the first attempt to engage the autopilot just after take-off.	It is suggested that the 3rd paragraph be amended as follows: "The take-off from runway 04 occurred at 13:31:35. While climbing through about 1000 ft, at time 13:32:48, the PF tried to engage the autopilot (AP), but the AP did not engage and the system provided an aural "autopilot" warning. The flight data recorder (FDR) "Autopilot Fail Caution Message" discrete parameter was triggered, along with the "Master Caution" Discrete Lamp" parameter. At the time of the autopilot engagement attempt, the aircraft was in a steep bank angle and large control forces were being used. The crew noted that the aircraft had constant tendency to roll left. At this point, while still in contact with Alverca tower and on initial climb heading, the crew declared an emergency. Meanwhile, the crew tried to diagnose the cause of the aircraft's abnormal roll attitudes, receiving only autopilot system (AP FAIL) fault information, without any other associated messages."		**Not adopted.** After extensive discussion with the OEM regarding the AP engagement parameters recorded on DVDR and FHDB, the text expresses the factual information with additional information on DVDR, section 1.11
10	**1.1 History of the Flight, Page 23, Last Paragraph -** The text refers to one of the passengers falling as he was out of his seat, whilst communicating with the cockpit.	It is suggested that the paragraph be amended as follows: "The technical-personnel passengers were asked questions by, and made suggestions to, the pilots when they were trying to regain aircraft control. It was not possible for the passengers to communicate effectively with the flight deck without getting out of their seats as the flight deck door kept opening and closing and had to be held open. Also, the flight loads forced a passenger to the aircraft floor, and he had to lie on the floor panel just aft of the flight deck to lessen the effect the forces on him. During one of the sudden movements of the aircraft, while he was out of his seat, the passenger sprained his ankle. He was transported to the nearest hospital and discharged later that day."	More details are needed regarding the unavoidable difficulties the technical- personnel passengers faced when required to communicate with the pilots during the flight.	**Not adopted.** Air Astana is referring to 1.2, not 1.1. The unavoidable difficulties experienced by everyone in the event flight were clear. The report already extensively covers out of maintenance event details, aiming to take as many lessons as possible. The flight was for sure one important phase and how the crew and passengers handled it.

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
16	**1.5.3 Maintenance Team Page 28 –** The section describing the maintenance personnel is missing important information.		Specific information such as licenses, experience etc. is not given. Maintenance personnel information, particularly for those that rigged the semi-wings, is essential.	**Not adopted.** On the report is stated "*…the technicians directly involved in the event are duly certified and authorized, the investigation identified several gaps within the team members in the training, technical and procedural knowledge*". All AMO team members were checked for certification, qualification and experience. During the T/S phase, there were persons involved that were not certified, as mentioned on 1.18.1. There is no useful purpose to the reader to fully list each member. The number of technical personnel involved in the several maintenance event tasks related with ailerons, make it irrelevant to focus on the person but rather the process and the organization.
18	**1.6.5 ADMS – Aircraft Diagnostic and Maintenance System, Page 38 –**		There is a critical need for detailed information as to what triggers or does not trigger the "FLT CTRL NO DISPATCH" EICAS message. Information as to what Fault Isolation Manual (FIM) sections and pages were used during the troubleshooting is needed in the report.	**Not adopted.** As explained on the report, the msg FLT CTR NO DISPATCH is a "global" message triggered by sub systems condition. The T/S procedure followed several directions, including non-related systems. As referred in 1.18, the AMO and the OEM were following multiple paths, none of them detected the real fault in the aircraft.
20	**1.11.1 Flight Recorders, Page 43, 1st paragraph –**	The following text is suggested: - "Both the flight data recorder (FDR) and the cockpit voice recorder (CVR) were…"	The term "CVFDR" is not consistent with the description of the flight recorders in the E190 Manuals.	**Partially adopted** Text amended to DVDR as OEM technical pubs.
25	**1.11.1 Flight Recorders, Last paragraph, Page 44**	"Based on FDR data and crosschecked with FHDB information, at about 14:22, there were three more unsuccessful attempts to engage the autopilot. This was about 51 minutes after the crew's first attempt to engage the autopilot just after take-off."	As discussed previously, the FDR recorded discrete parameters, just after take-off, that indicated that the pilot attempted to engage the autopilot.	**Not adopted.** As discussed in item #9 above.

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
26	**1.16.3 OEM Performed tests, pages 47 and 48 –**	It is suggested that this deficiency be included as a Contributing Factor in the accident and merits safety action (Recommendation). This suggestion, including some proposed text, will be repeated during the review of the Causes and contributing Factors	This is a very important section and is difficult to follow because of the translation and the use of so many abbreviations. The message of the section is that the FLT CTRL NO DISPATCH EICAS warning will not be displayed even with the aileron cable inversion if an FCM with cleared NVM is installed in the system. This indicates that the FLT CTRL NO DISPATCH warning is not effective, and a redesign of the system warning is needed.	**Not adopted.** The investigation acknowledges that it is a complex chapter because of the need to cover in a sufficiently abbreviated manner highly detailed technical aspects, and tried to draft the text as clearly as it was possible due to the difficult topic. As discussed over the report, the msg FLT CTRL NO DISP is a global msg and does not intend to cover any specific item. The flight control system needs to identify that the NVM were not cleared and thus, not allowing the next task step. The already available software ("low level" or non-approved software for flight, only for maintenance) included on the task to be performed after the aileron disturbance, already detects this possible misconfiguration. Additionally, Embraer informed that a study to implement a dedicated software monitor (high level) to detect and announce the inverted installation of the aileron cables as an additional feature to detect maintenance deviations is currently underway.
27	**1.17.1 Operator – Air Astana, page 49, 3rd paragraph –**	**It is suggested that this paragraph be removed or amended as follows:** – "Air Astana carried out two types of quality audits of the base maintenance provider, OGMA: "Supplier (Organisational)" audit and production audit "Aircraft on C-check". During the selection process the operator relied upon the validity of audits carried out by ANAC Portugal, as verified by Aruba."	There is no regulatory requirement for Air Astana to perform an audit of Part 145 OGMA, however the airline carried our both organisational and product audits.	**Not adopted.** The operator, through its contracted airworthiness control organization, needs to demonstrate to the certifying authority that the contracted services, including maintenance, follow the approved procedures and standards that assured the AOC. This is accomplished in two steps, first agree the standards and procedures with the service provider and then verify their proper accomplishment and difficulties. Relying only on the service provider certification standards (EASA, FAA, DCA,…) does not assure the operator standards. Please see Regulation (EU) No 965/2012 on Air Operations, Annex III (Part-ORO.GEN.200) also detailed on the report 2.3.1.

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
30	**1.17.1.1 Post-accident actions from the operator, Page 50, 1st Paragraph, 2nd bullet** – The following text is suggested: "The operator's SOP, used by the crew, followed the exact wording as the manufacturer's SOP. Following the accident, the operator improved the wording of its SOP 2-25 regarding the After Start – Control Check. The manufacturer's SOP remains unchanged."	"The operator's SOP, used by the crew, followed the exact wording as the manufacturer's SOP. Following the accident, the operator improved the wording of its SOP 2-25 regarding the After Start – Control Check. The manufacturer's SOP remains unchanged."		**Not adopted.** The following bullets on the paragraph already mentions the OEM SOP, that is supplied to the operators as a reference only. The OEM clarified that the SOP is not a certified publication and needs to be adjusted by the operator and approved by the Authority.
31	**1.17.1.1 Post-accident actions from the operator, Page 50, 1st Paragraph, 2nd bullet –**	"For instance , if the flight control column is turned to the left, then the left aileron rises up (together with the left multifunction spoilers) and if the flight control column is turned to the right, then the right aileron rises up (together with the right multifunction spoilers). LSP calls out full travel of deflection elevators, ailerons (together with multifunction spoilers) and rudder."	The inserted text from SOP 2-25 is not correct.	**Not adopted.** The SOP text in the report is the correct sentence as per SOP 30.11.2018 REV.FCI 013-18; it is not the intent of the report to include all the procedure. Only the directional control was highlighted, the (…) states for the omitted part as per editorial normal practice.
33	**1.7.2 Maintenance services provider, Page 51 -**	Suggestion: It is essential that the relevant ANAC audit information regarding OGMA be included in the report.	The section introduces the safety issues at OGMA found during the investigation, but nowhere in the report is it mentioned whether the ANAC audits detected the problems or if any corrective action was taken.	**Not adopted.** The AMO productive process, internal quality system and safety management were detailed over the applicable chapters. It is recognised that the main certifying authorities (ANAC) with EASA oversight, need to be continuously followed as expressed on chapter 4.
34	**1.17.2.1, Starting on Page 51 -**	The paragraphs describe, in general terms, various latent safety issues within OGMA. The text states: "…high staff turnover…frequent organizational changes…not possible to identify a solid standard on the technical competence and skills assessment and development process with the consequential training plan …".	It is suggested that specific examples of these latent safety issues be included in the report, leading to findings, contributing factors, and more safety action (Recommendations) needed to address the safety issues.	**Not adopted.** The AMO weaknesses, safety issues and improvement opportunities were extensively discussed along the report and a significant number of specific gaps were disclosed.

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
40	**1.18.1 Maintenance event sequence for the aileron cable transposal, 2nd Paragraph, Page 58 –**		It is stated that "Documentary inconsistencies were also found here" More detail regarding the inconsistencies would be helpful and would lead to a better understanding the Part 145 practices and problems. Also, more importantly, there is no specific information in the report as to what misled the "technicians" resulting in the crossed aileron control cables on both semi-wings. This information is needed for the reader to understand the safety issues that may be present because of possibly unclear Aircraft Maintenance Manual (AMM) instructions or the ability of the users to understand the English-only instructions.	**Not adopted.** The AMM and SB's instructions are detailed in 1.18.2.1 and figure 14 intends to explain the technicians' difficulties in detecting the control cable crossing.
43	**1.18.1 Maintenance event sequence for the aileron cable transposal, Page 60, 1st Paragraph**	— On NOV 2nd, OGMA indicated that the aircraft had a "GROUND SPOILER FAIL EICAS message with associated faults that resulted in FLT CTRL NO DISPATCH EICAS message and as part of the troubleshooting, checked the rigging of all flight control system surfaces several times. — On NOV 5th, OGMA, in questions to the OEM, noted that, following tests, there were fault bits on FCM1 and FCM4, but none on FMC2 and asked if this observation was relevant. (suggest that a footnote should be inserted for this bulleted text as follows "FCM2 does not receive inputs from control column position LVDTs or from spoiler actuators") — On NOV 8th, OGMA indicated that, following troubleshooting suggested by the OEM for the return-to-service (RTS), the indication following the roll test did not turn green after 3 attempts.	The paragraph commencing with "Below, in summary…" could be enhanced by the insertion of additional relevant items/actions. Based our review of the history of the troubleshooting, more items are relevant.	**Not adopted.** It is investigation opinion that sufficient and relevant data was listed to explain the sequence of events. The red/green dots are explained on figure 17 and the FCM2 architecture is also detailed on figure 28.

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
44	**1.18.1 Maintenance event sequence for the aileron cable transposal**	The MAINTENANCE ACTION for the MESSAGE/FAULT for FLT CTRL NO DISPATCH includes the instruction "Do the return-to-service test of the flight control system (AMM TASK 27-00-00-070-801-A/200.)" Was this used? It is suggested that the information above be inserted in the report in 1.18.1 and be considered as the basis for a Recommendation to Embraer.	It would be helpful for the reader to have a better understanding of the manuals used during the troubleshooting process. Also, during our review of AMM TASK 27-00-00-070-801-A/200, we noted that, although some tests required full travel of the primary flight controls (ailerons, elevator and rudder), that the AMM TASK did not specify the control surface position corresponding to the control input. Perhaps this is because the FAULT CONDITION is limited to "After Landing" and does consider the situation of "After Maintenance". This appears to be a deficiency in the AMM and indicates the need for Safety Action (Recommendation).	**Not adopted.** It is investigation opinion that adequate and relevant data was included on the report to explain the system and tasks requirements and limitations. None of FIM tasks are designed for out-of-project configuration. The task to return the aircraft to service after a FLT CTR NO DISP requires a full surface deflection in other to erase the NVM memory. We encourage the operator to discuss in detail these topics with the OEM, using the internal investigation process prerogatives.
45	**1.18.1 Maintenance event sequence for the aileron cable transposal, Page 60, Last 2 bullets – .**	It is suggested that the text in the existing last bullet on page 60 be amended as follows: "On NOV 11th, on the morning of the accident flight, another FCM2 was installed, replacing FCM2 that been installed on NOV 9th, which had to be returned back to a donor aircraft after the troubleshooting."	It is not clear from the report text if the FCM2 installed on 11 November replaced the FCM2 installed on 9 November. Our review indicates that another FCM2 was installed on 11 November, allowing the FCM2 installed on 9 November to be returned after the 9 November tests	**Not adopted.** The FCM2 module and other FCM, PSEM, P-ACE, among others, were replaced several times during the T/S. As explained on the text: "Below, in summary format, are listed the considered items/actions by the investigation as most relevant and related with the discrepancy presented in the aircraft by the FLT CTR NO DISPATCH message. Some of the replaced components were items with origin in other positions of the same aircraft or from another aircraft due to lack of stock in the AMO for troubleshooting purposes."
46	**1.18.1 Maintenance event sequence for the aileron cable transposal, Page 61, 1st Paragraph –**	Suggestion: The paragraph information needs to include release to service limitations with 6 "red" and 2 "green" indications.	The report text, in describing the lights that indicate the status of the FCMs, states "The FCMs maintenance status page presented the configuration shown in the above figure, where only the FCM2 presented the green status after the test (RTS). The others FCMs memory modules (NVM) did not successful pass the test and the respective NVMs did not accept the reset during last step (7 of 7) of the RTS procedure, however the aircraft system assumed as completed." There is, however, no indication in the report text whether this 6 "red" and 2 "green" situation allows the aircraft to be released for service.	**Not adopted.** According to the OEM, the red and green dots on the test pages, that represent the CBITS explained on 1.6.5 is not part of aircraft certification documentation and do not need to be interpreted by none of the maintenance or crew personal. Additional information on the system limitations, AMO and OEM knowledge about the system can be found on 2.2.2.

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
48	**1.18.1 Maintenance event sequence for the aileron cable transposal, Page 60, Last Paragraph –**		The paragraph beginning with "None of the involved technicians…" requires more detail. For example, did any of the maintenance personnel refer to the Aircraft Maintenance Manual which describes the correct aileron movement with pilot control yoke action? Did the maintenance personnel understand "CW" as a right-turn movement of the control yoke and "CCW" as a left-turn movement of the control yoke? We note that the Maintenance Manuals of some other aircraft manufacturers avoid these abbreviations and state "clockwise" instead of "CW" and "counterclockwise" instead of "CCW".	**Not adopted.** As detailed on OEM actions 1.18.2.3 figure 20, one of the reviewed tasks was the aileron OPC, with new figures including the spoilers now represented and the CCW and CW question. As explained and can be seen on figure 16, none of the teams (initial check, T/S team and the crew later) realized the control-to-surface function and sense.
50	**1.18.3.4 Airbus A320 roll control serious incident, Pages 69 and 70 –**	Suggestions: The BFU information related to control checks should be included in the report and text, as given in the paragraph above, is suggested for your use. In addition, as in the example of the BFU report whereby they recommended a change in the Airbus A320 "FLIGHT CONTROL CHECK", the GPIAAF could recommend that Embraer include descriptions of control-surface movements corresponding to control inputs in the OEM SOP.	This was a very good occurrence example for the GPIAAF to choose. One of the BFU Findings from the incident investigation was a shortcoming in the "AFTER START CHECK LIST" for the execution of the "FLIGHT CONTROL CHECK" A safety Recommendation from the investigation indicates the need to modify to the A320's "FLIGHT CONTROL CHECK". The report noted that the FLIGHT CONTROL CHECK included deflection but did not include a description of correct control surface movement for sidestick travel.	**Not adopted.** This example and others were extensively discussed with Embraer, having already a formal position, as described on item #30 above. Embraer do not recognise the SOP as an official product certification publication. It is considered a guide and the operator, as Air Astana and many other operators, already improved their own SOPs.
51	**2.1.1 Competence assessment and task suitability, Page 79 –**	It is suggested that a new paragraph be inserted page 79 after the existing 1st complete paragraph as follows: "During the troubleshooting, OGMA seemed very focused on the avionics (FCMs and SPBAs) that it had disturbed during the modifications to the forward Electronic Centre. This is where they found broken pins on circuit boards etc. As a result, they may not have suspected that the aileron misrigging was the reason for the FLT CTRL NO DISPATCH EICAS message."	During the maintenance a structural modification was carried out which required the removal of all the FCM and SPBAs as well as other avionics from the forward Electronics Centre. During the troubleshooting, OGMA seemed to mainly focus its attention to the avionics that it had disturbed. This is where they found broken pins on circuit boards etc. As a result, they did not detect the mis-rigged ailerons.	**Not adopted.** The suggestion was not found on the report topic context, or possibly not understood the operator intention.

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
52	**2.1.1 Competence assessment and task suitability, 2nd Last Paragraph, Page 79 –**		Paragraph commencing with "The non-interpretation…" is very important. Some added detail in the paragraph would help the reader to understand the errors and omissions that allowed the incorrect aileron movement to go undetected after the maintenance work in replacing the cables. For example, did anyone refer to the Aircraft Maintenance Manual SUBTASK which describes the movement of the ailerons based on the movement of the pilot control yoke? Or, were the instructions in the Maintenance Manual not clear or not understood by the maintenance team? We don't believe that basic aeronautical training, which we interpret as instinctively knowing the correct control surface movement corresponding to a flight control input, is as important as being able to correctly follow the task instructions in the AMM.	**Not adopted.** The AMM and SB instructions was already discussed and found to be a contributory factor 3.2.2. Regarding the RTS task, this requires physical surface movement with control column and yoke command. This task was performed countless by several teams. It was ascertained that FLT CTR Synoptic page was coherent with the surfaces physical condition, meaning that during the RTS, the technician is looking to an aileron moving surface in opposition to the spoiler surface (if spoilers not in maintenance mode). The report does not intend to explain basic aerodynamics. This topic was called on AMO competency assessment, precisely to highlight for possible gaps up to the basic training.
53	**2.1.4.1 By CAA Aruba, Last Paragraph, Page 85, 3rd Paragraph -** "… demonstrate a lack of follow-up of the operator's hiring its Part 145 maintenance service providers."		An audit carried out by the operator is limited and cannot be considered close and continuous monitoring. This is also the case for Aruba as the certifying authority. The report makes a finding but does not otherwise comment on the 145 requirement concerning the MRO Quality System and in particular the independent audit of procedures and processes. Considering the concerns about the lack of competency and deviation from procedures, we would have thought that there would be a discussion on this failure of the internal quality system. After all, the MRO internal quality system does have day to day responsibility for "close and continuous monitoring of maintenance activities" and should have identified these deficiencies. The report includes comments on SMS which has not yet been fully implemented by EASA. It would have been more productive to fully analyse the shortcoming in their quality system.	**Not adopted.** The AMO quality system and SMS implemented process are linked and, as detailed on the report, reflect the organization culture. This culture was not questioned or challenged by DCA Aruba. The referred paragraph expressed the raised questions over the operator regarding the pre-event inexistent findings or inconsistencies on the contracted AMO quality system.

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
54	**2.1.4.1 By CAA Aruba, Last Paragraph, Page 85**	It is suggested that the last paragraph of "2.1.4.1 By CAA Aruba", on Page 85, be deleted.	Air Astana's EPM LMP-10 procedures describe only how Air Astana's maintenance department carries out critical tasks. The Air Astana Safety Compliance M&CA department carries out internal audits to check how the Air Astana maintenance department is in compliance with the provisions of these procedures and Air Astana MOE Ch. 2.23. OGMA as an EASA Part 145 organisation must carry out own its internal audits to check compliance with the provision of its own MOE and Procedures manual related to Critical maintenance tasks and error-capturing methods. Only one regulation is applicable for Air Astana as operator. It is the order of MIIR KZ "Certification requirements for operators". This regulation does not contain the provisions that an operator must carry out the audit of contracted organisation. Air Astana as the operator cannot carry out a review the activity of the DCA of Aruba. Vice Versa - DCA Aruba carries out annual audit of Air Astana various departments. For Air Astana one of mandatory conditions for the selection of base maintenance contractors is that the MRO must have a DCA Aruba acceptance certificate. For this purpose, DCA Aruba carries out the audit. By the result of the audit, DCA Aruba issued an acceptance certificate to allow OGMA to maintain aircraft registered on the Aruba Registry. Only by having evidence that a DCA Aruba acceptance certificate has been issued, is Air Astana able to sign the contract with MRO for base maintenance. In summary, Air Astana's Engineering Procedures Manual (EMP) LMP-10 is only applicable to maintenance carried by Air Astana. There is no regulatory requirement for the operator to conduct its own audit of the Part 145 MRO or to review the activity of the CAA of Aruba.	**Not adopted.** The operator trained and accepted the AMO quality system to provide services under EPM LMP-10. The AMO was required to sign operator task cards to be accepted by the operator airworthiness control. This also means that the operator accepted the AMO quality system based on Aruba DCA, that is supported in EASA Part 145. Within AMO's quality system is the critical task control, named independent inspection by EASA, requirement that was assessed as not fully understood by the organization. The paragraph will be kept on the final report: "The operator had foreseen the control of critical tasks in its engineering procedures manual (EPM-KC/EPM from 01 JUN2018). There is no evidence that the operator has verified the requirement on the Part145 or that the operator's certification authority has verified or audited it."

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
55	**2.2.2 Conspicuity of aileron control system misrigging, Page 91, 2nd Last Paragraph –**		The paragraph beginning with "It was clear that…" needs clarification. The text explains that the absence of faults with FCM2 was because it did not receive control column LVDT or spoiler actuator information. It would be helpful in this section of the report to provide the reader with more information and make a link to the fact that FCM2 did not sense the incorrect aileron rigging. Also, there is no explanation regarding the acceptability of dispatching an aircraft with 6 red fault lights and 2 green lights. This important information needs to be added to the report.	**Not adopted.** The FCM integration on the FCS architecture is detailed on figure 28: FCM closed loop command system design. Regarding the CBIT logic, please see comment to item #46.
57	**2.3.1 Third party maintenance services contracting, Page 96, 2nd Paragraph –**	It is suggested that this paragraph be deleted	The paragraph states that "The operator, as AOC holder, is according to the applicable regulations, responsible for ensuring that the services it contracts comply with the purposes of its own mission." The paragraph is not correct and should be deleted. Our responsibilities related to contracted services are as follows. For Air Astana as operator only one regulation is applicable. It is the order of MIIR of RK "Certification requirements for Air operators". We confirm there is no such requirement in this order. EASA Part M is not applicable because Air Astana does not have and can not have in principle EASA Part M approval.	**Not adopted.** The paragraph does not refer any specific regulation. The investigation did not cover the MIIR RK requirements. As stated on Air Astana comment #54: "*For Air Astana one of mandatory conditions for the selection of base maintenance contractors is that the MRO must have a DCA Aruba acceptance certificate*"; This confirmation is clear enough to keep the mentioned paragraph on the final report.
58	**2.3.1 Third party maintenance services contracting, Page 96, 3rd Paragraph –**	It is suggested that this paragraph be deleted.	The paragraph beginning with "Within its responsibilities…" indicates a need for detailed oversight of contracted Part145 MROs by the operator, but there is no regulatory requirement and it is not consistent with usual practice.	**Not adopted.** The RBO - Risk-based Oversight concept discussed on 2.1.2, as possible solution for mature AMO EASA organizations, requires a close follow-up from all parties for a healthy quality system. It was established that Air Astana acceptance of the contracted AMO was based on EASA certification through Aruba DCA. Even certain requirements are not applicable to local regulatory, the aircraft maintenance release was over Aruba DCA. The contracted EASA AMO requires operator follow-up.

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
61	**2.3.2 The aircraft acceptance procedure, 2nd Paragraph, Pages 96 and 97**	It is proposed the that the text be amended as follows: "In addition to the legal requirements established in Part M regulations,…"	– Regarding the paragraph beginning with "In addition to…", Air Astana agrees in principle with the paragraph, but we believe that Part145 would not apply to Operators. This paragraph indicates the need for additional provisions in Part M regulations regarding the crew's knowledge of maintenance action carried out during aircraft acceptance. This indicates the need for a Recommendation.	**Not adopted.** The mention to Part 145 was to underline that the aircraft handling is both ways in different moments. The Part 145 is not applicable to the operator. The EASA GM2 ORO.GEN.200(a)(6) Management system refers: (b) Operators should monitor compliance with the operational procedures they have designed to ensure safe operations, airworthy aircraft and the serviceability of both operational and safety equipment. In doing so, they should, where appropriate, additionally monitor the following: (11) aircraft maintenance/operations interface;
62	**3.1.1 The Aircraft, 4th Paragraph Finding, Page 101**		– Regarding the Finding beginning with "The aircraft manufacturer…", Air Astana does not disagree with the finding, but there is not enough factual detail in the report about what things in the maintenance and return-to-service instructions that confused or misled the maintenance team. This type of information is required to identify the need for safety action.	**Not adopted.** The report covers the technical publication shortcomings, but mainly reports the already introduced improvements over those findings. The investigation detailed line by line, with the help of maintenance engineers, the improvement opportunities identified on the maintenance tasks and SBs related to the event. The result was a list of suggestions to the OEM that were already updated on the maintenance manual. The safety report is not the proper document to list the modifications introduced on those tech pubs by the OEM.

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
63	**3.1.3 The operator, 2nd Paragraph Finding, Page 102 –**	It is suggested that the finding beginning with "The operator did not adequately oversee…" be deleted.	Air Astana, as substantiated in Comments 53 and 54 of this document, does not agree with the finding paragraph that begins with "The operator did not adequately oversee…". There is no Regulatory requirement for Air Astana to conduct the stated oversight: Air Astana is not subject to EASA approval for the CAMO. Kazakhstan regulations are applicable, namely the order of Ministry of Infrastructure and Development "Certification requirement for an operator of civil aviation aircraft". This order does not contain any provision related to oversight/audit of contracted maintenance organization. It is not practical for an operator to insert its own supervision process into the layered combination of MRO internal and Regulatory certification and oversight (para 2.1.2, para 2.1.3, para 2.1.4 and para 2.1.4.1 of the Draft Report). Air Astana performed two audits of the OGMA organisation (in 2016 and 2018) based on IOSA standards. As well, three production audits "Aircraft on C-check/OGMA" were performed in 2016, 2017 and 2018.	**Not adopted** Noted, please refer to the same comments above.
66	**3.2.2 Contributing Factors, Final Factor, Page 105**	It is proposed that text of the final Contributing Factor be amended as follows: "Because of SOP limitations in describing the control surface positions during the "Control Check" of the After Start Check, the absence of colour change or EICAS warnings, and skill-based errors that occurred during the highly routine activity of checking the controls, the flight crew did not detect the misconfiguration of the ailerons.	– Air Astana agrees that an opportunity to detect the incorrect aileron performance was missed by the flight crew during the After Start Check. We believe that the safety message would be enhanced, and the justification for the safety action taken by the operator would be better served, by modifying the final Contributing Factor.	**Partially adopted** Not fully adopted regarding the colours or Eicas warnings. Revised wording for: "The crew failure to detect the ailerons misconfiguration during the operational check procedures following limited SOP's on the highly routine pre-flight checks,"
67	**Additional Safety Action – Recommendations**	There should be a Recommendation to Embraer to include an "After Maintenance" FAULT CONDITION for the MAINTENANCE ACTION addressing the MESSAGE/FAULT "FLT CTRL NO DISPATCH".	The MAINTENANCE ACTION for the MESSAGE/FAULT for FLT CTRL NO DISPATCH includes the instruction "Do the return-to-service test of the flight control system (AMM TASK 27-00-00-070-801-A/200.)". Some tests from AMM TASK 27-00-00-070-801-A/200 required full travel of the primary flight controls (ailerons, elevator and rudder), but the AMM TASK did not specify the control surface position corresponding to the control input. Perhaps this is because the FAULT CONDITION is limited to "After Landing" and does consider the situation of "After Maintenance". This appears to be a deficiency in the AMM.	GPIAAF does not comment the operator opinion, however decided to publish the supplied information as a comment to the draft report.

Anexo II: Comentários do MIID/Air Astana ao projeto de relatório final

Appendix II – MIID/Air Astana comments to the draft final report

#	Draft Final Report Text	Proposed Text by Air Astana	MIID/Air Astana Comments	GPIAAF Comments
68	**Additional Safety Action – Recommendations**	There should be a Recommendation to Embraer to have them modify the OEM SOP to include the verification of control surface direction of travel in its "After Start – Control Check"	The operator's SOP 2-25 regarding the After Start – Control Check used by the crew followed the exact wording of the manufacturer's SOP. Following the accident, the operator improved the wording of its SOP to include control surface direction of travel in the check, but the manufacturer's SOP remains unchanged." Other aircraft manufacturer SOPs do include verification of control surface direction of travel during their flight control checks	GPIAAF does not comment the operator opinion, however decided to publish the supplied information as a comment to the draft report.

Anexo III: Comentários da Aruba DCA ao projeto de relatório final

Appendix III – Aruba DCA comments to the draft final report

#	Draft Final Report Text	Proposed Text by Aruba DCA	Aruba DCA Comments	GPIAAF Comments
2	Paragraph 1.1	"After performing the final tests (except the flight control operational test) within the scheduled inspection scope"	Relating to the sentence-part: "*After performing the final tests within the scheduled inspection scope*" If we understand that correctly, the flight control operational tests were not accomplished or initiated at that stage due to the FCND EICAS message. If this is the case, we suggest changing the text as follows:	**Not adopted.** As detailed on 1.18.1., the Aileron OPC was performed several times at the end of the scheduled maintenance event, namely, pre-engine run, during engine runs and after. The test failed in all those attempts.
3	Paragraph 1.6.5		Maintenance team: This Chapter is missing the qualification, ratings and overall experience of the maintenance team assigned to P4-KCJ that did the critical tasks as referred in the report;	**Not adopted.** On the referenced paragraph is stated "*…the technicians directly involved in the event are duly certified and authorized, the investigation identified several gaps within the team members in the training, technical and procedural knowledge*". All AMO team members were checked for certification, qualification and experience. During the T/S phase, there were persons involved that were not certified, as mentioned on 1.18.1. There is no useful purpose to the reader to fully list each member.
4	Paragraph 1.6.5		We kindly request a little more in depth explanation as to what triggers a FLT CTRL NO DISPATCH EICAS message	**Not adopted.** As detailed on the report, the msg FLT CTR NO DISPATCH is a "global" message triggered by multiple sub systems condition. On 1.6 it is explained that it is likely that the NVM of FCM was triggered during the schedule maintenance event (it is an expected condition), then the aileron configuration did not allow the memory to erase and consequently to clear the message.

Anexo III: Comentários da Aruba DCA ao projeto de relatório final

Appendix III – Aruba DCA comments to the draft final report

#	Draft Final Report Text	Proposed Text by Aruba DCA	Aruba DCA Comments	GPIAAF Comments
5	Paragraph 1.18.1		Will the 6 red and 2 green light indication allow the aircraft to be released to service?	**Not adopted.** There are no indications or mentions on the maintenance manuals to that condition. According to the OEM, the red and green dots on the test pages, that represent the CBITS explained on 1.6.5, is not part of aircraft certification documentation and do not need to be interpreted by none of the maintenance or crew personal. Additional information on the system limitations, AMO and OEM knowledge about the system can be found on 2.2.2.
6	Paragraph 1.18.1		It would be recommendable to provide a more extensive analysis as to why the cable was installed incorrectly in the first place.	**Not adopted.** On the contributory factors 3.2.2 can be found in a short format the Why chain of events, supported on the report applicable chapters.
7	Paragraph 3.2.2		Contributory factors – 9th bullet: *Deficient maintenance organisation oversight by the supervising authorities, namely on the internal maintenance supervision procedures and occurrence reporting;* The evidence provided is the report does not support this as a contributing factor.	**Not adopted.** The identified gaps and opportunities found over the AMO should have been previously identified and properly addressed by the certification authorities. A not sufficiently effective AMO oversight certainly contributed to allow the identified gaps in the AMO management system. Please refer to figure 26 on 2.1.5 for support on the AMO - Authorities oversight environment.

Anexo IV: Comentários da EASA ao projeto de relatório final

Appendix IV – EASA comments to the draft final report

With reference to page 104 – *Par. 3.2.2 – Contributing factors*: "Deficient maintenance organisation oversight by the supervising authorities, namely on the internal maintenance supervision procedures and occurrence reporting;" (and to other parts of the report), it appears that some gaps in the due oversight of the competent authority were identified as one of the elements of the root cause. Therefore, we would suggest to add another Safety Recommendation, addressed to the National Aviation Authority, requesting to monitor/oversight the implementation the actions requested by the Safety Recommendation No. PT.SIA 2020-09.

Comentários da investigação:

Depois da devida análise, a autoridade de investigação considerou não ser eficaz a emissão da recomendação de segurança sugerida, uma vez que é uma obrigação própria da ANAC a monitorização/supervisão dos processos relacionados com as lacunas agora identificadas no relatório relativas ao prestador de serviços de manutenção, objeto das recomendações de segurança a ele formuladas.

No entanto, a secção 4.2 do relatório foi atualizada de forma a evidenciar e clarificar para o público e *stakeholders* a referida obrigação.

Investigation comments:

After due analysis, the safety investigation authority considered not effective to issue the suggested SR to the National Aviation Authority, as it is an obvious ANAC obligation to monitor/oversight the processes related to the gaps now identified in the report concerning the maintenance provider, focus of the SRs issued to this last mentioned organization.

Nevertheless, section 4.2 of the report was updated so as to evidence and clarify to the public and stakeholders this obligation.

Anexo V: Comentários da ANAC ao projeto de relatório final

Appendix V – ANAC comments to the Draft final Report

" (…)

na auditoria realizada pela EASA à ANAC, quatro meses volvidos desde a data do acidente, e que compreendeu, como já se referiu, uma visita à OGMA, S.A., as UNC[17] relativas à Parte 145 limitaram-se às instalações (norma 145.A.25(c) – pó visível numa prateleira) e a dados de manutenção (normas 145.A.45(a) e 145.A.65(b) – papel autocolante num cabo de alimentação).

Refira-se, aliás, que, por força da UNC a que o projeto de relatório se refere, a ANAC suscitou não-conformidades à OGMA, S.A., as quais foram si corrigidas e consideradas encerradas por esta Autoridade em junho de 2019 e aceites e encerradas pela EASA em novembro de 2019.

Saliente-se que a auditoria que a EASA realizou em março de 2019 à ANAC foi considerada encerrada pela Agência em 14 de abril de 2020. E no que especificamente diz respeito às ações corretivas apresentadas pela ANAC à EASA relacionadas com a OGMA, S.A. foram as mesmas encerradas pela EASA em novembro de 2019, como já se referiu.

A ANAC, por seu turno, no ano em que se verificou o acidente, 2018, realizou três ações de supervisão à OGMA, S.A. incluindo uma auditoria não anunciada. Tais auditorias receberam a numeração interna DSO/MNP – 59/2018, DSO/MNP – 543/2018 e DSO/MNP – 2018/1051, e realizaram-se, respetivamente em 31 de janeiro de 2018, 19 de julho de 2018 e 19 de novembro de 2018.

Nas acima identificadas auditorias foram levantadas 22 (vinte e duas) não-conformidades, tendo uma delas sido classificada de nível 1.

Saliente-se que a última ação de supervisão da ANAC à OGMA, S.A. em 2018 decorreu uma semana após o acidente.

Na auditoria realizada em 19 de julho de 2018 (DSO/MNP – 543/2018), a ANAC já havia detetado deficiências no sistema de reporte de ocorrências da OGMA, S.A., tendo sido suscitada a não-conformidade NC 9: - *Procedimento ONS-000056 "comunicação de ocorrências" não clarifica quanto à investigação interna das ocorrências e quanto ao processo interno de recolha, tratamento e comunicação externa das ocorrências*.

Ainda nessa auditoria, foram reportadas pela ANAC, duas não-conformidades relacionadas com fragilidades no sistema de qualidade NC 10 e 11.

O Regulamento (UE) n.º 1321/2014, da Comissão, de 26 de novembro de 2014, no que especificamente à Parte 145 diz respeito, certificação de que a OGMA, S.A. é detentora, determina que as Autoridades devem verificar os requisitos desta Parte em cada ciclo de supervisão (norma 145.B.30).

Concretamente no que se refere à OGMA, S.A. a ANAC entendeu por uma questão de maior rigor e eficiência realizar um conjunto de auditorias parcelares ao longo do ciclo de supervisão ao invés de realizar uma auditoria única durante todo o ciclo de supervisão. Esta opção permite manter um contacto mais próximo com a organização ao mesmo tempo que permite verificar na auditoria parcelar seguinte os progressos alcançados e a correção de eventuais deficiências detetadas na auditoria anterior.

Durante o ano de 2018 a ANAC realizou previamente ao acidente duas ações de supervisão, por recurso a amostragem, com vista a auditar os requisitos regulamentares aplicáveis.

[17] Esclarecimento GPIAAF: *Undertaking Non Compliances* (UNC)

Anexo V: Comentários da ANAC ao projeto de relatório final

Appendix V – ANAC comments to the Draft final Report

À data do acidente encontravam-se em curso por parte da OGMA, S.A. a resolução das não-conformidades detetada na ação de supervisão internamente identificada como DSO/MNP – 543/2018, realizada, recorde-se, em 19 de julho.

Na ação de supervisão realizada em julho haviam já sido detetadas pela ANAC, como já se referiu, nomeadamente deficiências no sistema de reporte de ocorrências e fragilidades no sistema de qualidade da OGMA, S.A. a que esse Gabinete alude no projeto de relatório.

Quanto à não-conformidade relacionada com deficiências no sistema de reporte de ocorrências, o respetivo procedimento havia sido aprovado em outubro de 2018 e estava em fase de implementação na OGMA, S.A. à data do acidente.

Relativamente à não-conformidade relacionada com as fragilidades no sistema de qualidade, a proposta de resolução da mesma por parte da OGMA, S.A. encontrava-se a ser avaliada pela ANAC em novembro de 2018.

Uma semana após o acidente, e tendo presente os contornos específicos do mesmo, a ANAC realizou à OGMA, S.A. uma ação de supervisão não planeada.

Constatou, assim, a ANAC nesta ação de supervisão que a ONS 000028 não era clara relativamente à definição e identificação das tarefas críticas, sobretudo nos seus parágrafos referentes à utilização de inspeção dupla ou inspeção independente, bem como, no que se referia à execução de tarefas similares/criticas.

Ainda relativamente a esta norma, foi também reportada pela ANAC, a 20 de novembro de 2019, uma não-conformidade respeitante à necessidade da MRO definir a sua lista de tarefas críticas para componentes.

Tendo como base o histórico e o risco operacional resultantes do desempenho da OGMA, S.A. em 2018, a ANAC reforçou a sua atividade de supervisão àquela MRO, tendo em 2019 realizado quatro auditorias parcelares e uma não anunciada, as quais receberam a numeração interna DSO/MNP – 69/2019, DSO/MNP – 350/2019, DSO/MNP – 432/2019 e DSO/MNP – 1107/19, respetivamente, em 23 de janeiro de 2019, 20 de março de 2019, 30 de abril de 2019 e 20 de novembro de 2019, durante as quais foram suscitadas 29 (vinte e nove) não-conformidades, quatro (4) delas classificadas de nível 1, que pela sua gravidade, conduziram à suspensão temporária, durante sete (7) dias, da atividade de manutenção da OGMA, S.A. relativamente às aeronaves com uma massa máxima à descolagem acima de 5700 Kg.

E por força da determinação de submeter a OGMA, S.A. a uma supervisão acrescida, foi realizada em 23 de janeiro de 2019 uma ação de supervisão na qual foram apontadas pela ANAC, através da análise por amostragem, diversas não-conformidades relacionadas com a formação e competência do pessoal da OGMA (norma 145.A.30 – requisitos de pessoal, do Regulamento (UE) n.º 1321/2014).

(…)

Na página 49 do projeto de relatório refere-se que «…*o operador contratava tais serviços a diferentes Parte 145, escolhendo o respetivo prestador após uma avaliação de capacidade técnica e de certificação pela autoridade de Aruba*.», sendo que tal aeronave se encontrava sob a supervisão da Autoridade de Aruba.

O artigo 2.º, n.º 1 do Regulamento (UE) n.º 2018/1139, do Parlamento Europeu e do Conselho, de 4 de julho de 2018, bem como o artigo 1.º do Regulamento (UE) n.º 1321/2014, referem que as regras constantes deste último regulamento está limitado às organizações sediadas na União Europeia e com

Anexo V: Comentários da ANAC ao projeto de relatório final

Appendix V – ANAC comments to the Draft final Report

aeronaves aí registadas. Por outro lado, a aeronave acidentada encontra-se registada num país terceiro e a sua supervisão, como já se referiu, não está delegada num Estado-Membro da União Europeia.

A aeronave acidentada, como se faz constar do projeto de relatório, tem registo na Autoridade de Aruba e, consequentemente, está sob a sua supervisão (cfr. página 49).

Logo, os requisitos constantes do identificado regulamento europeu não é aplicável às tarefas de manutenção realizadas pela OGMA, S.A. na aeronave acidentada.

Por outro lado, a certificação para a realização de tarefas de manutenção em aeronaves de registo não europeu e sob a supervisão de uma Autoridade de um país terceiro não é da competência da ANAC mas sim da Autoridade responsável pela supervisão das mesmas, neste caso a Autoridade de Aruba.

Logo, quaisquer eventuais deficiências verificadas durante as tarefas de manutenção na aeronave acidentada não podem ser imputadas à ANAC mas sim à Autoridade de registo da mesma.

Ainda assim, a ANAC auditou de forma sistemática, em cumprimento do Regulamento (UE) n.º 1321/2014, os requisitos regulamentares por que se deve pautar a atividade da OGMA, S.A., e exerceu os poderes de supervisão e de fiscalização que lhe estão estatutariamente atribuídos. Por outro lado, e como já se teve oportunidade de referir, em 2019 esta Autoridade submeteu a OGMA, S.A. a um ciclo de supervisão acrescida que culminou na realização de quatro auditorias parcelares e uma não anunciada.

De salientar que o ciclo de supervisão da ANAC à OGMA, S.A. quer em 2018 quer em 2019 em muito excedeu as exigências constantes do Regulamento (UE) n.º 1321/2014.

De todo o exposto, resulta que a Autoridade Nacional da Aviação Civil cumpriu com a missão que resulta dos seus Estatutos, aprovados e em anexo, ao Decreto-Lei n.º 40/2015, de 16 de março: *«...regular e fiscalizar o setor da aviação civil e supervisionar e regulamentar as atividades desenvolvidas neste setor*...».

Comentários da investigação à opinião da ANAC acima transcrita:

Os comentários da ANAC acima não propõem qualquer alteração ao texto do projeto de relatório e a investigação entende não comentar as informações neles facultadas. No entanto, o GPIAAF entende publicar a informação fornecida de modo a garantir a transparência do processo.

Investigation comments to ANAC (CAA PT) opinion expressed above:

The above Authority's comments do not propose any change to the text in the draft report and the investigation does not comment the information provided in the text. Nevertheless, GPIAAF decided to publish the supplied information in the final report to ensure transparency in the process.

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

"

A. OPERATOR

1. Operator verified all maintenance activities performed by the MRO and was fully aware of all maintenance actions taken on the aircraft.

1.1. Operator was actively involved in the troubleshooting activities performed before the aircraft Certificate of Release to Service (CRS) was issued by the MRO (cfr. page 19 of the Report).
1.1.1. In particular, Operator had a tech representative present on site during such actions and Operator was specifically warned on the 6 red flags being detected on the roll axis test (information directly provided by the MRO to Mr. xxxxxx).
1.2. Without any apparent reason, Operator failed to provide the flight crew with detailed information on said maintenance activities.
1.2.1. Does the Operator have a standard procedure in place defining the flow of information between the Operator's tech representative and flight crew during an aircraft acceptance following heavy maintenance?

1.2.2. Why was this relevant information not passed by the Operator to the flight crew?

1.2.3. Why did the flight crew also not request such information from the MRO?

1.2.4. Was there internal pressure on the Operator's tech representative to have the aircraft accepted?

Annex I to ED Decision 2015/029/R
AMC M.A.201(h) Responsibilities
(…)
(3) The requirement means that the operator is responsible for determining what maintenance is required, when it has to be performed and by whom and to what standard, in order to ensure the continued airworthiness of the aircraft being operated.
(4) (…)
(5) An operator should establish adequate co-ordination between flight operations and maintenance to ensure that both will receive all information on the condition of the aircraft necessary to enable both to perform their tasks.
(6) The requirement does not mean that an operator himself performs the maintenance (this is to be done by a maintenance organisation approved under Part-145) but that the operator carries the responsibility for the airworthy condition of aircraft it operates and thus should be satisfied before the intended flight that all required maintenance has been properly carried out.
EASA Part 145 CRS Policy (17 December 2015)
"In addition, it is important to stress that a release to service, whether it is single or multiple, does not necessarily mean that the aircraft is airworthy and ready for flight. A release to service is just a release after the performance of maintenance and its issuance is the responsibility of the maintenance organisation. However, the responsibility for defining the airworthiness status of the aircraft is the responsibility of the CAMO/operator"

CONCLUSION: The operator is the one **responsible** for ensuring that the aircraft is in an **airworthy condition** at all times and the MRO release to service is not a certificate for the aircraft airworthiness that can be used by the Operator to discharge itself from its legal obligations.

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

Relevant maintenance information (following a C-Check) was not passed by the Operator's technical staff to the Operator's flight crew who should have used such information during the aircraft acceptance and pre-flight checks.
None of these issues are reflected or at all addressed in the Report.

2. Flight crew failed to detect the flight controls misconfiguration when accepting the aircraft after a C-Check (heavy maintenance)

2.1. What is the Operator's standard procedure for the acceptance of aircraft after heavy maintenance?

2.1.1. Does the Operator have an established Safety Management System (SMS) (which is mandatory for the Operator)?

2.1.2. Is the said SMS adequately implemented?

2.1.3. What risks were identified and which mitigation actions were devised relating with aircraft acceptance after heavy maintenance?

2.2. What is the Operator's training plan for aircraft acceptance following heavy maintenance?

2.3. What is the process and requirements used by the Operator for the selection of the crew to perform such task?

2.3.1. How did this crew fit in the established selection procedure?

2.3.2. What was the flight crew previous experience in performing similar tasks?

2.4. Was the flight crew subject to internal pressure to accept the aircraft?

EASA Part 145 CRS Policy (17 December 2015)
"In addition, it is important to stress that a release to service, whether it is single or multiple, does not necessarily mean that the aircraft is airworthy and ready for flight. A release to service is just a release after the performance of maintenance and its issuance is the responsibility of the maintenance organisation. However, the responsibility for defining the airworthiness status of the aircraft is the responsibility of the CAMO/operator"

CONCLUSION: The operator is the one **responsible** for ensuring that the aircraft is in an **airworthy condition** at all times and the MRO release to service is not a certificate for the aircraft airworthiness that can be used by the Operator to discharge itself from its legal obligations.
Operator's safety barrier (post-maintenance) failed to detect the misconfiguration of the aileron cables after completion of the maintenance tasks.
Operator's SMS also does not seem to address and manage the relevant safety risks related to the lack of any clear Operator procedures to the crew regarding aircraft acceptance and performance of flights after a heavy maintenance event, including setting minimum weather conditions, crew training, selection and experience, etc.
This is not reflected or at all addressed in the Report. Should this critical issue remain unaddressed the safety investigation will clearly be deficient.

3. Flight crew failed to detect the flight controls misconfiguration during the pre-flight checks

3.1. Did the flight crew actually perform the pre-flight checks?

3.1.1. Was the procedure fully followed and completed by the crew?

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

3.1.2. Is such full completion duly confirmed by the CVR?

3.1.3. What was the pilots' explanation for failing to detect the flight controls misconfiguration during the mandatory pre-flight checks?

3.2. Did the pilots adequately interact and communicate with each other during the pre-flight checks?

3.2.1. Does the Operator have a Crew Resource Management (CRM) training program duly implemented?

3.2.2. Have the crew members received periodic CRM training?

3.3. What is the Operator's training plan for flight controls pre-flight operational checks?

3.4. How do other pilots from the same operator read the information displayed in the EICAS synoptic page for completion of the pre-flight checks?

3.5. Was the flight crew subject to internal pressure to perform the flight and thus avoid delaying the repositioning of the aircraft for at least one additional day (considering the weather conditions were getting worse by the minute)?

3.5.1. Are there any reports of previous incidents resulting from pressure on the pilots to meet deadlines (*i.e.* "jumping" of mandatory procedures by pilots under time pressure)?

3.5.2. What is the Operator's reporting culture and reporting score for pilot induced errors?

Regulation (EC) nr. 216/2008 (and the corresponding provisions in Regulation 2018/1139)
Article 5(1) – Aircraft referred to in Article 4(1)(a), (b) and (c) shall comply with the essential requirements for airworthiness laid down in Annex I (article 9(1) of Regulation 2018/1139).
Article 8(1) – The operation of aircraft referred to in Article 4(1)(b) and (c) shall comply with the essential requirements set out in Annex IV and, if applicable, Annex Vb Article 5(1) (article 29 of Regulation 2018/1139).
Annex 4, paragraph 1.c. – "Before every flight, the roles and duties of each crew member must be defined. The pilot in command must be responsible for the operation and safety of the aircraft and for the safety of all crew members, passengers and cargo on board" (Annex V, paragraph 1.3 of Regulation 2018/1139).
Annex 4, paragraph 2.a.3(i) –"The pilot in command must be satisfied that the aircraft is airworthy as specified in point 6" (Annex V, paragraph 2.c(i) of Regulation 2018/1139).
Annex 4, paragraph 6.a(i) – "The aircraft must not be operated unless the aircraft is in an airworthy condition" (Annex V, paragraph 6.a(i) of Regulation 2018/1139).
Annex 4, paragraph 6.b – "Before each flight or consistent series of consecutive flights, the aircraft must be inspected, through a pre-flight check, to determine whether it is fit for the intended flight " (Annex V, paragraph 6.2 of Regulation 2018/1139).

CONCLUSION: The flight crew is the **ultimate responsible** to make sure that the aircraft is in an airworthy condition before (i) they accept the aircraft released by the MRO and (ii) they perform any flight.

The aviation industry safety net is established in such way that the pilot-in-command is, by Law, the **ultimate responsible** for the safe operation of the aircraft. This is the **last safety barrier effectively** in place to prevent any incident/accident.

Non adopted or partial adopted suggestions and comments to draft report as defined on Annex 13, chapter 6.3.

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

In the case of the incident under review the flight crew **should have detected** the flight controls misconfiguration during the pre-flight checks as long as they had fully complied with the SOP and by using the information displayed in the EICAS synoptic page (pilots receive extensive training in flight control surfaces operation and also benefit of a specific warning in the SOP that a full "Green Box" may not lead to a successful check, this warning not being included in the AMM or in the Part 147 training syllabus available to the MRO's Technicians). This is further exacerbated by the fact that the flight in question was not a routine flight but rather the first flight after heavy maintenance (maintenance check flight). Hence, the crew should have been especially alert during the pre-flight checks for the detection of any potential problem.
It is mentioned in the Report that "improvements" were made by the Operator to the SOP pre-flight checks. However, such purported improvements consist only of a call-out acknowledging that the same procedure that was in place at the time of the incident is in fact performed by the pilot-in-command. We fail to see how this small change can consist on any actual material improvement with any real impact in preventing future incidents. Furthermore, the need to make such "improvement" seems to lead to the conclusion that the pre-flight checks were not actually performed by the flight crew, hence the need for the call-out confirming the check.

All things considered, in OGMA's view the crew's failure in detecting the ailerons misconfiguration during the operational check (pre-flight check) is clearly less excusable than the MRO's failure in detecting the same problem during the maintenance operational checks (see conclusion reached in the safety investigation for "Airbus A320 roll control serious incident" mentioned in section 1.18.3.4 of the report). However, such conclusion is not reached in the report being even suggested that the crew acted appropriately during the acceptance of the aircraft and when performing the pre-flight checks for this non-routine flight (maintenance check flight).

OGMA finds the different treatment and assessment of the MRO's operational checks *vs* Crew's (Operator) operational checks to be unreasonable and clearly unfair.

The flight crew inability to detect the aileron inversion must be **clearly identified** as a **crucial breach of safety by the Operator** otherwise the investigation will be deficient. The **reasons** for such breach must be **determined** and **robust safety recommendations** must be drawn to prevent similar incidents from happening again in the future.

4. Did the pilots select the flight controls direct mode later than required under the Aircraft Operations Manual?

4.1. What impact did this late action have in the aircraft recovery during the emergency?

4.2. What impact did this late action have in the structural stress and damage caused to said aircraft and engine(s)?

4.3. What is the Investigators' assessment on the adequacy of the Aircraft Operations Manual emergency procedures?

4.4. Is the crew properly trained in emergency procedures for the loss or impairment of flight controls?

Regulation (EC) nr. 216/2008 (and the corresponding provisions in Regulation 2018/1139)
Article 2 – Airworthiness aspects of product operation

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

2.a. The following must be shown to have been addressed to ensure a satisfactory level of safety for those onboard or on the ground during the operation of the product:
(,,,)
2.a.5. Procedures for normal operations, failure and emergency conditions must be established. (article 2(1)(e) of Regulation 2018/1139).

Annex 3, paragraph 1.d. – Practical Skill
1.d.1. A pilot must acquire and maintain the practical skills as appropriate to exercise his/her functions on the aircraft. Such skills must be proportionate to the risks associated to the type of activity and must cover, if appropriate to the functions exercised on the aircraft, the following:
(…)
(x) abnormal and emergency operations, including simulated aircraft equipment malfunctions; (Annex IV, sub-paragraph 1.4(j) of Regulation 2018/1139).

Annex 4, paragraph 1.b. – Essential requirements for air operations

1.b. A flight must be performed in such a way that the operating procedures specified in the Flight Manual or, where required the Operations Manual, for the preparation and execution of the flight are followed. To facilitate this, a checklist system must be available for use, as applicable, by crew members in all phases of operation of the aircraft under normal, abnormal and emergency conditions and situations. Procedures must be established for any reasonably foreseeable emergency situation. (Annex V, paragraph 8.11 of Regulation 2018/1139).

CONCLUSION: The draft report, whilst noting that the Aircraft Operations Manual did not provide a procedure for dealing with the flight control issue, does not provide any analysis or commentary as to whether the Manual should have addressed this issue or whether the Operator (noting the responsibilities above) should have identified and addressed any such lack of procedure. The draft report also does not provide details of what steps the crew took, by reference to any procedures in the Manual, or whether there was any non-compliance with such procedures. Such points should be addressed in the report (as they are in detail in relation to OGMA's compliance/non-compliance with maintenance procedures) and relevant recommendations made.

B. OEM

1. EASA and FAA requirements for flight controls design specify that each flight control system shall be designed, or distinctively and permanently marked, to minimise the probability of incorrect assembly

1.1. The safety investigators mention OEM statement of not being necessary to revise the E190 flight controls design (*i.e.* "obsolete" model being phased out of production).

1.1.1.1. Did the safety investigators assess the number of similar aircrafts available worldwide with the same design (more than 560 E190 aircrafts are deemed to have been produced)?

1.1.1.2. Is there any actual information on the potential risk of a similar incident with another E190 with the same design and configuration occurring in the future?

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

1.2. Was the possibility of the aircraft design allowing for the incorrect assembly of the aileron cables reported to the certification authorities (EASA, FAA, etc) and were they consulted on any related measures to be adopted?

1.3. What safety lessons can be drawn from analysing the certification process of this aileron flight control system?

CONTROL SYSTEMS
CS 25.671 General (See AMC 25.671)
(a) Each control and control system must operate with the ease, smoothness, and positiveness appropriate to its function. (See AMC 25.671 (a).)
(b) Each element of each flight control system must be designed, or distinctively and permanently marked, to minimise the probability of incorrect assembly that could result in the malfunctioning of the system. (See AMC 25.671 (b).)
US Code of Federal Regulations (CFR) 14 part 25
25.671(b) Each element of each flight control system must be designed, or distinctively and permanently marked, to minimise the probability of incorrect assembly that could result in the malfunctioning of the system.

CONCLUSION: Whilst the draft report comments on the aircraft flight controls design and the associated certification requirements, the report does not make any clear conclusions in that respect, or details the steps taken (if any) by the investigators in relation to the relevant certification authorities. The investigators' conclusions on these points should be **expressly and clearly stated** in the Report as it is the **initial contributory factor for the incident**.
This was the **first safety barrier** to be broken as aircraft certification requirements exist to minimize the probability of a serious incident or accident occurring. In the incident under review, had the cables been designed to prevent incorrect assembly, or distinctively and permanently marked the probability of them being incorrectly installed during a maintenance activity would be significantly reduced if not at all eliminated.
OGMA believes this conclusion to be fully applicable in the case under review as should this first safety barrier have not been breached the cables would not be cross-installed and the incident would not have happened at all.
Certification authorities should be consulted and a simple and easily implemented solution for the aileron cables design should be available (e.g. colour coding of the aileron cables).

2. AMM and SB technical instructions do not identify the need to use an unorthodox routing requiring the crossing of the aileron cables for correct installation

2.1. SB 190-57-0038 also instructs maintenance technicians to completely disconnect both aileron cables simultaneously leading them to lose visual reference with the cables original routing and without clear visual instructions being included in the available technical publications for correct reconnection of the cables

2.2. Part 147 type training course does not address the need to use an unorthodox routing requiring the crossing of the aileron cables for correct installation

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

Regulation (EC) nr. 216/2008 (and the corresponding provisions in Regulation 2018/1139)

Article 5(1) – Aircraft referred to in Article 4(1)(a), (b) and (c) shall comply with the essential requirements for airworthiness laid down in Annex I (article 9(1) of Regulation 2018/1139).

Annex 1, paragraph 1.d.3 – The instructions for continuing airworthiness must be in the form of a manual, or manuals, as appropriate for the quantity of data to be provided. The manuals must cover maintenance and repair instructions, servicing information, trouble-shooting and inspection procedures, in a format that provides for a practical arrangement (Annex II, paragraph 1.5.3 of Regulation 2018/1139).

CONCLUSION: the available **technical materials** and the **Part 147 training course** submitted to MRO's technicians, in not addressing the unusual nature of the installation procedure and/or directing technicians to undertake tasks in a non-standard manner, increased the risk of mistakes by technicians.

Only a seasoned technician who has previously dealt with an error resulting in the incorrect installation of the aileron cables could already be alerted to this hidden issue and thus being able to avoid making the same error. By simply following the available technical publications the error would not be apparent for any technician.
The revised technical materials already have incorporated improvements in the instructions for disconnection and reassembly of aileron cables. However, OGMA does not consider that the impact that issues with the technical publications and training had on the performance of maintenance tasks is sufficiently detailed throughout the report which leads to an unfair and unbalanced assessment of the technicians' performance.
Also see "Conclusion" section in paragraph 3. below.

3. EICAS synoptic page uses "green lights" to signal the flight controls surface movement during flight controls checks and a green light is shown even if the flight controls are incorrectly installed.

3.1. No further guidance or caution is provided in the AMM to the possibility of all "green boxes" being displayed in the Synoptic page not resulting in a successful test (contrary to the specific warning provided to the pilots in the SOP)

3.2. Part 147 type training course does not properly address the possibility of all "green boxes" being displayed in the Synoptic page not resulting in a successful test.

Regulation (EC) nr. 216/2008 (and the corresponding provisions in Regulation 2018/1139)

Annex 1, paragraph 1.C.4 - Information needed for the safe conduct of the flight and information concerning unsafe conditions must be provided to the crew, or maintenance personnel, as appropriate, in a clear, consistent and unambiguous manner. Systems, equipment and controls, including signs and announcements must be designed and located to minimise errors which could contribute to the creation of hazards (Annex II, paragraph 1.3.4 of Regulation 2018/1139).

CONCLUSION: the available **technical materials** and the **Part 147 training course** provided to MRO's technicians, in not highlighting the meaning of the "green boxes" in the synoptic page, increased the risk for errors by OGMA's technicians.

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

No reference is made in the report to the fact that the operational checks/independent inspections performed by the MRO were **impaired** by the wrong perception that the full "green boxes" in the synoptic page meant a successful test to the flight controls. This is clearly a relevant issue that led the OEM to introduce improvements on the maintenance operational checks to the flight controls as a post-incident action. However, this issue **is not properly addressed** in the Report and should be the subject of further detail and analysis.
Furthermore, it is also not mentioned that the pilots who should have done a similar operational test (last safety barrier) also failed to detect the aileron misconfiguration, despite the fact they receive additional training than Part 66 licensed engineers on flight controls surface movement and pilots also benefit of a clear warning on the SOP that a full "green box" may not lead to a successful test (such warning not being available to MRO technicians).

Also see section A.3 above.

4. The FIM does not address the FLT CTL NO DISPATCH error message resulting from the incorrect installation of the aileron cables and so it was impossible for OGMA, following the FIM, to resolve the error message without further technical support from the OEM. OGMA, in such circumstances, requested the assistance of the OEM, which was the only step available given the issue could not be resolved by reference to technical materials available to OGMA.

4.1. Troubleshooting was performed with the support of the OEM. Technical representatives from the OEM and Operator were present on site and actively involved in the troubleshooting. This does not come across in the draft report.

4.2. Six Red flags on the roll axis display were identified by the MRO even after the FLT CTL NO DISPATCH error message was successfully cleared and the issue was reported to the OEM and Operator. Aircraft was released to service as the OEM advised that no additional action was required.

Regulation (EC) nr. 216/2008 (and the corresponding provisions in Regulation 2018/1139)
Article 5(1) – Aircraft referred to in Article 4(1)(a), (b) and (c) shall comply with the essential requirements for airworthiness laid down in Annex I (article 9(1) of Regulation 2018/1139).

Annex 1, paragraph 1.d.3 – The instructions for continuing airworthiness must be in the form of a manual, or manuals, as appropriate for the quantity of data to be provided. The manuals must cover maintenance and repair instructions, servicing information, trouble-shooting and inspection procedures, in a format that provides for a practical arrangement (Annex II, paragraph 1.5.3 of Regulation 2018/1139).

CONCLUSION: troubleshooting procedures and FIM must be revised by the OEM (not a MRO responsibility contrary to what seems to be suggested in the Report) as the incident proves that an aircraft could be released to service while in a non-airworthy condition, without any other error or alert message being displayed.

The Report should include a **clear and express statement on the existence of such possibility of release to service** and the need for steps to be taken to prevent it happening again. Even if the OEM has already taken corrective measures, it should not prevent the need of the issue being **clearly identified and dealt with** in the Report as it was clearly a relevant contributory factor for the incident.

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

C. MRO

1. OGMA feels that the investigation major focus was on the maintenance tasks being performed while other relevant and significant contributory factors were not as thoroughly investigated

1.1. Analysis of the design of the E190 flight controls is not addressed in detail and the investigations findings in relation to the design are unclear.

1.2. Relevant impact of the technical publications in the chain of events is not duly addressed (the technical instructions increase the likelihood for errors by the maintenance technicians and the presence of Green boxes in the EICAS synoptic page is not addressed at all)

1.3. Impact of the absence of any training on the complexities of the aileron cable installation in the approved Part 147 maintenance training syllabus is not addressed at all.

1.4. Only MRO´s SMS is subject to a very detailed analysis when it is not even a mandatory requirement for a part 145 organization

1.5. Insufficient investigation on the Pre-flight checks made by the crew (which is the last safety barrier effectively in place, being the Pilots the ultimate responsible for the safe operation of the aircraft)

1.5.1. Was the flight controls pre-flight check actually done by the crew?

1.5.2. Investigation does not address what was missed by the crew during the flight controls operational check, the reasons for such failure (when pilots are known to receive extensive training on flight controls surface movement and also benefit of additional warnings in the SOP) and no recommendations are given to the Operator to prevent future incidents

1.6. Pilot training is not assessed

1.7. Previous experience in the acceptance of aircraft after heavy maintenance is not assessed

1.8. Internal pressure on the flight crew is not assessed

1.9. Performance of the flight under foreseeable IMC and its negative impact on the recovery of the aircraft under emergency is not duly assessed

1.10. Operator's SMS is also not evaluated

1.11. Operator's reporting culture is not assessed at all

1.12. Operator's organizational aspects are not assessed

CONCLUSION: This leads to an **unfair balance and treatment of the different undertakings** involved and also weakens the safety investigation performed and conclusions reached in the Report. As a consequence, **not all contributory factors are duly assessed** and **safety recommendations are lacking** to address all relevant safety issues which are essential to prevent future similar incidents.
While we do recognize that it was OGMA's technicians who have not properly installed the aileron cables, there are relevant design issues in the aircraft and technical publications and gaps

in the Part 147 training program that were conducive to this unfortunate result. Also, the post-maintenance operational checks and inspections conducted by the Operator, which are legally established as the last safety barrier for any flight related incident, failed to detect the incorrect configuration of the flight controls.
However, the message conveyed by the Report to any average reader is that only OGMA was at fault and that no other parties had any real contribution for the incident. That is inaccurate and incorrect and creates an unfair balance in the report.
If OGMA's training, SMS, reporting culture, internal pressure on the technicians and organizational structure were questioned (rightfully so, as any safety report should focus on those issues) why was the same approach not used in respect of the Operator? More crucially, why were the pre-flight operational checks to the flight controls not meticulously addressed in the Report (contrary to what was done in respect to the maintenance operational checks)?
OGMA already highlighted above the main issues that must be revisited in respect to the OEM and Operator and additional suggestions are made in OGMA's observations to the full Report (in attachment).

2. All MRO technicians were duly certified by the relevant aviation authorities and properly trained for the tasks
CONCLUSION: Thorough evidence was provided to the safety investigators on the certification of each technician involved and also on the training provided to said technicians on the tasks to be performed.

Training is provided by an approved Part-147 training organization following the technical manuals and instructions provided by the OEM. Any **shortfalls** on said **training** cannot be attributed to the MRO.

This must be **duly reflected in the Report** and **relevant conclusions** should be drawn in respect of the need to **revise the training materials** provided by the **OEM** (if and when applicable) and the **training courses** organized by the **Part-147 training organization**.

3. Technicians' qualification for the task *vs.* lack of prior experience on said task

CONCLUSION: All technicians were duly qualified and received the required training for the tasks to be performed.
Technicians are required to rely on their training and also follow the SBs and AMM. Even a seasoned technician could make the same error if he/she would to simply follow the said technical instructions and materials from the OEM. This is further confirmed by the fact that the more experienced technicians that performed SB190-27-0037R1 also did not detect the error.
The technicians that performed the tasks fully complied with the SBs and AMM as per the Part-147 training they have received. We find it **unfair and unreasonable** to demand for the technicians to **perform above and beyond** the technical instructions provided by the OEM and the official training they have received. This is clearly unfair not only to each of the technicians involved but also to the MRO.

The lack of experience on the task **was not a contributory factor** for the incident and this must be **properly reflected** in the Report.

4. The allocation of human and material resources to the production line cannot be fully planned in advanced

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

CONCLUSION: Heavy maintenance operation involves a significant number of different tasks, parts and human resources. Some of them can be planned in advance but the need for other tasks, parts and human resources only originates once the maintenance operation starts, as the aircraft parts start to be disassembled and inspected and new items to be addressed are detected, demanding a constant and organic flow of allocation of parts and human resources.
The MRO **organizational** aspects had no demonstrable impact on the incorrect assembly of the aileron cables. This was **not a contributory cause** for the incident and it must be **clearly stated** in the Report.

5. Approved error capturing methods vs. purported inadequacy of the independent inspection procedure used by the MRO

5.1. As required by EASA Part 145 requirements, OGMA developed several error capturing methods and embedded them within its own system.

5.2. The Double Check is part of the developed methods for error capturing. The Double Check is included in OGMA normative system ONS-000028 procedure and is mandatory for all critical tasks or tasks in critical systems.

5.3. The procedure is part of OGMA's Maintenance Organization Exposition and it is approved by our National Airworthiness Authority (ANAC).

5.4. The disturbance of the aileron flight control system was necessary to implement two Service Bulletins, as required by the Operator. Namely the replacement of the aileron cable supports and the replacement of the aileron cables. Both service bulletins require, for their completion, several steps to be performed and some of them are common to both Service Bulletins.

5.5. The SB is divided into several steps on the work cards. The steps to prepare or verify the compliance of the performed task are separated, namely it separates the operational checks from the implementation (support or aileron cable replacement).

5.6. The support replacement task requires an independent inspection, identified by a "stamp" of duplicate inspection as per the Operator's requirements.

5.7. The independent inspection was performed by using a 100% follow up double check inspection, meaning that throughout the entire task, a second and independent certified B1 technician was present to assess and confirm the correctness of the maintenance performed.

5.8. In this step, the independent inspection should only be able to detect if the aileron cables were secured, properly connected, free of movement and correctly assembled and locked. The independent inspection step therefore would only validate the correctness of the assembly (it was not an operational check).

5.9. But in this particular case, because of the design of the system and the fact that the aileron cables are not distinctively and permanently marked, the cables can be assembled in any position, and the unorthodox design requiring the upper cable on the fuselage torque tube to be reverted to the lower cable on the wing quadrant and vice-versa, making it virtually impossible to detect by visual inspection that the cables were incorrectly installed.

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

5.10. The approved OEM maintenance data for this specific task is also complex and, in this instance, insufficient to help the technicians to assess an incorrect/correct assembly.

5.11. In accordance with OGMA's approved procedure, the first technician (the "authorised person") would sign the task after completion in the Single Check (SC) field and only after that the second technician (the "independent qualified person") would sign for the Double check on the DC field in the work card (Independent Inspection).

5.12. The technician that performed the Independent Inspection ("independent qualified person") was a fully Licensed Engineer (B1 technician) which is over and above EASA Independent Inspection requirements, that only requires the inspector to be knowledgeable and qualified to perform the Independent Inspection.

5.13. In addition to EASA Independent Inspection requirements, OGMA's Independent Inspection (Double Check) requires the inspector to follow the entire execution of the task, if needed, in order to assure correct execution throughout all task steps. OGMA's intent is for the inspector to have full knowledge, qualifications and authorizations to check all steps of the tasks, thus ensuring a higher level of inspection standard.

5.14. However, during the internal investigation carried out by OGMA it was concluded that although the "independent qualified person" is not directly involved in the performance of the maintenance task to be inspected (thus qualifying as an "independent qualified person"), the fact that the inspector has to follow the entire execution of said task might lead to the undesirable perception that the inspector is part of the task (*i.e.* "herd mentality" risk), thus not guaranteeing the highest level of independence when performing the inspection.

5.15. After the event OGMA revised its Independent Inspection (Double Check) procedure in order to increase the independence level of the "independent qualified person".

5.16. Nevertheless, it is clear that the design could impair any independent inspection from visually detecting the cables inversion (the Independent Inspection under review was a visual inspection and not an operational check).

5.17. Furthermore, the operation of the flight control system is verified separately by performing the operational check, as required in another step of the work card, and as would happen at every MRO.

5.18. The operational check was performed by another set of qualified technicians, at a different moment and therefore constitutes a fully independent inspection. Nevertheless, the operational check was not able to identify the aileron inversion.

5.19. Although OGMA has detected points for improvement on the level of independence of the visual inspection for the correctness of the assembly (which led to improvements being made by OGMA), OGMA considers the issues identified above related with the aircraft design, available technical materials and Part 147 training syllabus significantly contributed to the "independent qualified person" not detecting the cable inversion. This is not addressed in the report.

5.20. We have also showed that the operational check performed to assess the correctness of the system functioning was fully independent as required, and that this was performed in another step of the work card.

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

5.21. It also must be highlighted that the procedure to use the 100% follow up double check inspection as the independent inspection was discussed and agreed with the operator and accepted as complying with the Operator's Duplicate Inspection concept. This also complies with ANAC's requirements.

5.22. An additional final independent inspection (not a follow up double check) was performed by OGMA before the aircraft RTS following the procedure detailed in the AMM for the flight controls operational checks.

5.23. The independent inspections and other operational checks only failed to detect the aileron cables misconfiguration due to human error potentiated by the insufficiency of the technical information included in the AMM and SBs and on the Part 147 training course (which relies on the technical materials provided by the OEM) and not because the error-capturing procedure by itself being used by OGMA was lacking in anyway.

5.24. It took 5 days for the investigators, assisted by the MRO, the OEM and Operator's technicians (all of them having the very big "advantage" of knowing in advance that something was significantly wrong with the flight controls), using the poor technical instructions available, to identify the point where the cables were incorrectly routed. Hence, the problem was clearly difficult to identify for all stakeholders (even with additional knowledge to that available to the OGMA's technicians), which difficulty arises from the issues identified above relating to the design, technical publications and training.

5.25. This clearly demonstrated that the flight control inversion was not clearly detectable during the maintenance tests contrary to what is suggested/implied in the Report. It also underlines that just the use of technical information was not sufficient for the investigators to detect the control cable inversion. In fact, colour coding and physical tracking of the cables was necessary to determine the inversion by the investigators.

5.26. Whilst OGMA accepts that the independent inspection not identifying the mis-installation can be regarded as a contributory factor, its contribution to the incident must be put in context (*i.e.* by reference to other issues *e.g.* the technical publications) so that it is understood there were other reasons why it did not succeed in identifying the mis-installation. At the moment, the draft report indicates, incorrectly, that OGMA's procedure itself was flawed. OGMA also strongly disagrees with the conclusion in the draft report that the independent inspection was a "probable cause" of the incident, when other factors impacting on the inspection are taken into account.

- Commission Regulation (EU) No 1321/2014 of 26 November 2014

AMC M.A.402 Performance of maintenance

*(a) All maintenance shall be performed by qualified personnel, following the methods, techniques, standards and instructions specified in the M.A.401 maintenance data. Furthermore, an independent inspection shall be carried out after any flight safety sensitive maintenance task **unless** otherwise specified by Annex II (Part-145) **or** agreed by the competent authority.*

- Annex II to ED Decision 2016/011/R

AMC3 145.A.48(b) Performance of maintenance ERROR-CAPTURING METHODS

(a) Error-capturing methods are those actions defined by the organisation to detect maintenance errors made when performing maintenance.

(b) The organisation should ensure that the error-capturing methods are adequate for the work and the disturbance of the system. A combination of several actions (visual inspection, operational check, functional test, rigging check) may be necessary in some cases.'

AMC4 145.A.48(b) Performance of maintenance INDEPENDENT INSPECTION

*Independent inspection is **one possible** error-capturing method.*

CONCLUSION: Independent Inspection is only **one** of several error-capturing methods allowed, as long as other error-capturing methods have been duly approved by the relevant aviation authority.
OGMA used adequate error-capturing methods **duly approved by ANAC** and the **Operator**. We feel that OGMA is **wrongfully criticized** in the Report for using the approved error-capturing methods.

6. Safety Management System not mandatory to MROs until 2022/23 at the earliest

*- Notice of **Proposed Amendment 2019-05 (A) Embodiment of safety management system (SMS) requirements into Part-145** and Part 21*
*The European Union Aviation Safety Agency (EASA) developed this NPA in line with Regulation (EU) 2018/11391 (Basic Regulation) and the Rulemaking Procedure2. This **rulemaking activity** is included in the European Plan for Aviation Safety (EPAS)3 under RMT.0251. The text of this NPA has been developed by EASA based on the input from a focused consultation group (FCG). It is hereby submitted to all interested parties for **consultation**.*
*The opinions will include a **proposal for transition measures** for **organisations** and authorities to **adapt to the new requirements**. The European Commission, along with the EU Member States, will validate it. At this stage of the project, a **transitional period** of **two years after the Regulations enter into force** is suggested.*

CONCLUSION: OGMA is heavily criticized throughout the Report for not having fully implemented an adequate Safety Management System (SMS). However, it should be noted that OGMA is **not legally required to do so**, and such legal obligation is **only in place** for the **OEM and Operator**.
The requirement for the implementation of SMS by Part 145 organizations is, in 2020, still at the rule making phase **without** any EASA regulation being **approved or having entered into force**. EASA has also suggested a 2 year transitional period once the said regulation is enacted, which means that the implementation of the SMS shall not be required before 2022/2023 (at the earliest), 4 to 5 years after the incident has occurred.
OGMA, however, is **ahead of its legal obligations** and already started the implementation of said SMS. OGMA should be praised for its action and not criticized. Furthermore, not being a legal requirement OGMA's SMS should not be a focus of the report and cannot be deemed to have had any impact whatsoever on the incident.

7. Discrepancies found in the signing-off of work cards

CONCLUSION: OGMA accepts that discrepancies occurred in the signing-off of work cards (recording deficiencies). However, the evidence collected clearly shows that the work cards were indeed completed and signed by the technicians who effectively performed the tasks (albeit at a later date). OGMA fully rejects the statement included in page 82 of the Report that the work cards were signed by different technicians as this is clearly contrary to the evidence collected.
Said statement should be **withdrawn** as it is not only incorrect but also detrimental to OGMA's international reputation and, even if it was to be true (which is not accepted) it would have no bearing on the incident being, for that reason, irrelevant for the investigation.
"

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

Comentários da investigação à posição da AMO acima transcrita:

A investigação de segurança é um processo técnico conduzido com o único objetivo de prevenir acidentes e compreende a recolha e análise de evidências, de forma a determinar as respetivas causas e, quando apropriado, emitir recomendações de segurança.

Em conformidade com o Anexo 13 à Convenção sobre Aviação Civil Internacional (Chicago, 1944), o Regulamento (UE) n.º 996/2010 do Parlamento Europeu e do Conselho, de 20 de outubro de 2010, e ainda com o n.º 3 do art.º 11.º do Decreto-Lei n.º 318/99, de 11 de agosto, o processo de investigação de segurança e o correspondente relatório não são conduzidos nem têm como propósito a atribuição de culpas ou de responsabilidades.

De acordo com a secção 16.4 do citado Regulamento (UE) n.º 996/2010 e com as secções 6.3 e 6.4 do Anexo 13 da Convenção sobre Aviação Civil Internacional, o GPIAAF enviou o projeto de relatório final para efeitos de obtenção de comentários relevantes e fundamentados quanto a eventuais erros factuais que o relatório pudesse conter, como fase prévia à aprovação do relatório final. Não são esperadas opiniões, considerações, conclusões ou atribuição de responsabilidades.

Contudo, com vista a assegurar transparência sobre o processo de investigação em relação às partes envolvidas e ao público em geral, igualmente segundo as mencionadas normas e recomendações internacionais ainda que não obrigatórias, a investigação decidiu incluir neste relatório os comentários e posição da AMO.

Não sendo requerida qualquer resposta formal ao conteúdo e formato dos comentários recebidos, são ainda assim, apresentadas seguidamente algumas notas para elucidação do leitor quanto a afirmações não fundamentadas ou enviesadas

Investigation comments to AMO position expressed above:

The Safety investigation is a technical process conducted with the sole purpose of accident prevention and comprises the gathering and analysis of evidences, in order to determine the causes and, when appropriate, to issue safety recommendations.

In accordance with Annex 13 to the International Civil Aviation Convention (Chicago, 1944), Regulation (EU) No. 996/2010 from the European Parliament and Council (20th OCT 2010) and article 11, No. 3 of Decree-Law nr. 318/99 (11th AUG 1999), it is not the purpose of any safety investigation process and associated investigation report to apportion blame or liability.

According to section 16.4 of the aforementioned Regulation (EU) 996/2010 and to sections 6.3 and 6.4 of Annex 13 to the Convention on International Civil Aviation, GPIAAF sent a draft version of the final report seeking comments from the entities involved on the event, expecting their significant and substantiated comments over factual errors that the report text may had, as a previous step for the final report version approval. No opinions, considerations, conclusions or responsibilities apportion were expected.

However, to ensure transparency over the investigation process to the involved parties and to the public, also following the applicable international mentioned regulations even if not mandatory, the investigation decided to include in this report the AMO's position and comments.

No formal reply is required to the supplied text format and contents, however a few notes are presented below for reader clarification on the non-supported or biased statements made by

Anexo VI: Comentários da OGMA, S.A. ao projeto de relatório final

Appendix VI – OGMA, S.A. comments to the draft final report

feitas pela AMO, claramente fora do âmbito do processo de consulta ao projeto de relatório:

- As extensas referências EASA relativamente ao enquadramento regulatório do operador não são aplicáveis a um operador do Cazaquistão. A AMO utilizou indevidamente a regulamentação que é mencionada no projeto de relatório como referência e boas práticas;
- A referência EASA aos aspetos de certificação do tipo da aeronave, nomeadamente os requisitos CS 25.671, são extensamente cobertos no relatório;
- São feitas diversas referências às organizações de formação Part 147 e *syllabus*. Não existem requisitos de treino básico que cubram instruções AMM específicas. Não se vislumbrou o racional deste tópico. A gestão da formação foi extensamente discutida no relatório, nomeadamente na secção 2.1.1 onde é detalhado um ciclo de formação da AMO;
- O comentário 5.24 é factualmente incorreto.
- A AMO expressou, sob a forma de comentário, várias referências ao SMS em uso na organização, que não sendo obrigatório, dá cumprimento a determinados requisitos legais, como o sistema de reporte e tratamento de ocorrências.
- As discrepâncias encontradas nos documentos de trabalho representam as evidências visíveis e tangíveis de um deficiente sistema de garantia de qualidade discutido nas seções do relatório dedicadas à AMO.

the AMO, clearly out of scope regarding the provided draft report consultation process:

- The extensive EASA references to operator regulatory framework are not applicable to a Kazakhstan air operator. AMO misused the draft report mentioned regulations, intended as references and best practices;
- The EASA reference to the aircraft type certification issues, are extensively covered in the report, namely the CS 25.671 requirements;
- Several mentions are made to Part 147 training organizations and syllabus. No requirements exist to such type basic training to cover specific AMM instructions. No rational was found over this topic. The training management were extensively discussed on the report, chapter 2.1.1 detailing an AMO training cycle;
- Comment 5.24 is factually incorrect.
- AMO expressed, as a comment, several references to SMS in use in the organization, which, although not mandatory, is used to comply with legal requirements, such as the occurrence reporting system.
- Discrepancies found in the work documents were the visible and tangible evidences of a deficient quality assurance system discussed on the report sections dedicated to the AMO.

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