Atlântica – Instituto Universitário

Master’s Thesis in Management and Technology of Aircraft Maintenance

Smartlink effectiveness and advantages to technical dispatch of Netjets CAMO

Author: Gabriel Vicente Oliveira Delgado

Dissertation supervised by Professor Doctor: Rui Carvalho

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This dissertation was developed as part of a study in a curricular internship through a protocol established between Universidade Atlântica and Netjets Europe.

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Thanks to

I am emotional and on the leading edge of my professional career. In this final step of completing my academic studies, I would like to say much more than thank you, even if it was possible to find any word that could express my gratitude to every one of my family members who helped me get this far.

With this meaningful thought constantly present in my mind, I will have to use the thank you words to express my tremendous gratitude and love for my mother and father. They are the persons that are and always will be there in my long journey on this life path and are the ones who I know, by absolute sure, love me as well. Thank you, Mother. Thank you, Father. And thank you to both of my grandfathers who witnessed the start of my Master´s and, unfortunately, could not see its ending. Fortunately, my grandmothers can, and I am very thankful to them. Thank you, godmother and godfather, who supported me each step and in every way possible. Thank you, aunts and cousins.

I would also like to thank Netjets CAMO Family, which I found during the curricular internship, always supportive and ultra-helpful in guiding me in these crucial baby steps I have made over the past months. I would like to leave a personal thank you to Paulo Pestana, Koen Vons, Bruce Turner, António Vilela, João Salgueiro, Vitor Manaças, Célia Félix, Paulo Reis, João Caleia, Rui Girão, Fernando Graça, Paulo Fernandes, and all the others not mentioned, that helped me in all the ways possible.

And why am I on the leading edge of my professional career? Well, as an air particle that flows over the aerofoil shape of aeroplane wings, it starts its path on the leading edge, where it starts to gain speed until the aerodynamic centre. This point where the lift is located is the point where my professional career will reach its peak.

Again, an emotional Thank you because the word is too small to express the gratitude that I have at this moment. Thank You.

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Resumo

Na aviação executiva, a CAMO dos operadores aéreos procura ter acesso à maior quantidade de informação possível relativamente à operação das suas aeronaves. A CAMO, a organização responsável pela gestão da aeronavegabilidade das aeronaves do respetivo operador aéreo, deve assegurar que a manutenção das mesmas está em conformidade com os seus respetivos programas de manutenção, baseados nos originais do respetivo fabricante.

Os fabricantes de aeronaves atuais procuram satisfazer as necessidades da CAMO através de várias ferramentas para auxiliar na manutenção de aeronaves e para seu próprio consumo interno, de forma a melhorar, e alcançar níveis de fiabilidade mais precisos. O seu principal objetivo não basta apenas pelo acesso a essa informação, mas consegui-lo de uma forma mais rápida. Diferentes formas de olhar para estas ferramentas podem ser abordadas ou adotadas por diferentes fabricantes de aeronaves. Uma dessas ferramentas é o SmartLink, desenvolvido pela Bombardier. O Smartlink pode ser caracterizado por permitir e fornecer um novo olhar para as falhas que podem ocorrer em todas as fases de voo do Challenger 350, uma aeronave também desenvolvida pela Bombardier. O fabricante afirma que o sistema permite melhorar a forma de como a manutenção de aeronaves é realizada nos dias de hoje. O uso destas ferramentas ambiciona melhorar a forma de como as intervenções de manutenção de aeronaves é realizada, e deve ser analisada com base na sua eficiência, eficácia e velocidade de transmissão de informação para os operadores. Esta dissertação desenvolve um estudo sobre o Smartlink e as suas vantagens para o despacho técnico da CAMO da Netjets Transportes Aéreos, SA.

Esta decorre de uma breve introdução à manutenção de aeronaves, seguida de uma introdução a documentação da aeronave Challenger 350, introdução ao Sistema Smartlink, reporte do sistema, apresentação de resultados, conclusões e potenciais futuros estudos.

Palavras-Chave

Manutenção Aeronáutica, CAMO, Operador aéreo, OEM, Dados de voo, Falhas.

Abstract

In executive aviation, the CAMO of an air operator seeks to obtain as much information as possible regarding their aircraft operation. CAMO, or continuing airworthiness management organisation, is responsible for ensuring the airworthiness of an aircraft and must ensure that their respective aircraft maintenance programs follow the originals of the respective manufacturer.

Current aircraft manufacturers seek to satisfy the CAMO requirements with various tools that assist in aircraft maintenance and retrieve data regarding the aircraft that can be very useful to the manufacturer. All this is to improve and achieve more accurate aircraft knowledge and reliability. Conventional methods to extract data from the aircraft are through the QAR for FDM or FOQA analysis. Still, this data can be classified as insufficient when the objective is to incorporate it and analyse it in an aircraft technical dispatch scenario.

Bombardier developed a tool called Smartlink. It can provide a new look to failures that may occur in their aircraft's flight phases, the Challenger 350. The manufacturer claims that the system improves aircraft maintenance performed nowadays. These tools aim to improve aircraft maintenance interventions based on their efficiency, effectiveness, and data transmission speed to the operators. This dissertation consists of a study about the Smartlink and its benefits for the technical dispatch of Netjets Transportes Aéreos, SA. CAMO.

It gives a brief introduction to aircraft maintenance, followed by an introduction to the Challenger 350 aircraft documentation, an introduction to the Smartlink System, a system report, results presentation, conclusions, and potential future studies.

Key Words

Aircraft Maintenance, CAMO, Air Operator, OEM, Flight Data, Failure.

Index

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Index of abbreviations and acronyms

AAIP- Approved Aircraft Inspection Program

ADC- Air Data Computer

ADS-B- Automatic Dependent Surveillance-Broadcast

ADS-C- Automatic Dependent Surveillance - Contract

AHC- Altitude Heading Computer

AHMS- Aircraft Health Monitoring System

AHMU- Aircraft Health Monitoring Unit

AMM- Aircraft Maintenance Manual

ANAC- *Autoridade Nacional de Aviação Civil*

AOC- Air Operator Certificate

AOG- Aircraft on Ground

APU- Auxiliary Power Unit

ARINC- Aeronautical Radio, Incorporated

ATA- Air Transport Association

AW- Advisory Wire

BCU- Brake Control Unit

C/M- Condition monitoring

CAME- Continuous Airworthiness Management Exposition

CAMO- Continuous Airworthiness Management Organization

CAS- Crew Alerting System

CDB- Customized Database

CDU- Control Display Unit

CMR- Certification Maintenance Requirements

COFA- Certificate of Airworthiness

DC- Direct Current

DCMP- Direct Current Motor Pump

DCU- Data Concentrator Unit

DME- Distance Measuring Equipment

DOA- Design Organization Approval

EASA- European Aviation Safety Agency

ED- EICAS Display

EGPWS- Enhanced Ground Proximity Warning System

EICAS- Engine Indicating and Crew Alerting System

ELT-Emergency Locator Transmitter

FAA- Federal Aviation Administration

FADEC- Full Authority Digital Engine Control

FCU- Flight/Flap/Fuel Control Unit

FDE- Flight Deck Effects

FDR- Flight Data Recorder

FGC-Flight Guidance Computer

FIREX- Fire Extinguisher

FL- Flight Level

FMC- Flight Management Computer

FOQA- Flight Operations Quality Assurance

FQGC- Fuel Quantity and Gaugin Computer

FSU- File Server Unit

GNSS- Global Navigation Satellite System

GPS- Global Positioning System

H/T- Hard Time

HSTECU- Horizontal Stabilizer Trim Electronic Control Unit

IAPS- Integrated Avionics Processor System

IASC- Integrated Air System Controller

IEC- IAPS Environment Controller

IMRBPB- International Maintenance Review Board Policy Board

INOP- Inoperative

IOC- Input/output Concentrator

IPC- Illustrated Parts Catalogue

IRS- Inertial Reference System

ISC- Industry Steering Committee

ISI- Integrated Standby Instrument

JAA- Joint Aviation Authorities

LCD- Liquid Cristal Display

LDU- Lamp Driver Unit

LRU- Line-Replaceable Unit

LTE- Long-Term Evolution

MCC- Maintenance Control Centre

MDC- Maintenance Diagnostic Computer

MEL- Minimum Equipment List

MENA- Middle East / North Africa

MFD- Multifunction Display

MMEL- Master Minimum Equipment List

MOQA- Maintenance Operational Quality Assurance

MP- Maintenance Procedure

MPD- Maintenance Planning Data/ Maintenance Planning Document

MRBR- Maintenance Review Board Report

MSG- Maintenance Steering Group

MSI- Maintenance Significant Items

MTBF- Mean Time Between Failures

MTOW- Maximum Take-Off Weigh

NAA- National Aviation Authority

NM- Nautical Miles

O/C- On condition

OEM- Original Equipment Manufacturer

Part-145 MRO- Maintenance Repair and Overall Organization

PBA- Pushbutton Annunciator

PBN- Performance-Based Navigation

PFD- Primary Flight Display

PSE- Principal Structural Elements

PSEU- Proximity Sensor Electronic Unit

QAR- Quick Access Recorder

RALT- Radio Altimeter

RDC- Remote Data Concentrator

REO- Repair Engineering Order

RIU- Radio Interface Unit

S/T- Soft Time

SATCOM- Satellite Communication

SB- Service Bulletin

SECU- Spoiler Electronic Control Unit

SLP- Smartlink Plus

SPC- Secondary Power Centre / Stall Protection Computer

SRM- Structure Repair Manual

SSI- Structural Significant Items

SSID- Service Set Identifier

SVS- Synthetic Vision System

TAWS- Terrain Avoidance/Awareness Warning System

TCAS- Traffic Collision Alerting System

TCH- Type Certificate Holder

TDR- Transponder

TLA- Throttle Lever Angle

TSS- Traffic Surveillance System

vQAR- Virtual Quick Access Recorder

WHTC- Window Heat Temperature Controller

WO- Work Order

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1. Introduction

1.1. Generalities

This project allows the aviation industry to enrich the practical and theoretical knowledge of aircraft maintenance, further optimise its application on data-based decisions, and increase the industry´s general safety standards. The current aircraft maintenance relies on the different aircraft manuals and OEM data to develop their aircraft maintenance programmes. However, each operator can develop various maintenance programs for the same aircraft type due to the kind of safety standard applied. There are two types of maintenance methods Preventive/Scheduled maintenance and Corrective/Unscheduled maintenance. [1] Each operator has, typically, an aircraft maintenance control centre. In the company´s maintenance department, this team is responsible for the unscheduled maintenance tasks, while scheduled events are controlled by the maintenance scheduling and planning team. When an unscheduled event occurs, the aircraft goes into a Part-145 MRO, and the troubleshooting is done with the help of the aircraft manuals and OEM if necessary.

Smartlink is a Bombardier system that records aircraft data and EICAS messages in between flights and in flight. This allows the CAMO, and the aircraft maintenance control centre of the CAMO, to receive this data while the aircraft is still in the air. This allows for a diagnosis and solution to the problem as quickly as possible.

1.2. Scope

The scope of the thesis is based on an internship study to analyse the effectiveness and advantages of Smartlink on maintenance operations of the Netjets Europe CAMO. The aeronautical industry is motivated never to jeopardise material assets or human lives. With this in mind, it’s essential that the sector prioritises the safety of aircraft operations and promotes safety cultures within all current aircraft-related companies, including manufacturers, operators, air services, surveillance services, maintenance, etc. This makes it one of the world's most regulated industries. Because of this, the industry is responsible for ensuring that the maximum value of safety-related practices is retrieved, in-flight and on the ground, so that we can be confident that we reach our desired destination.

Modern-day technologies rely a lot on data; the more data available, the more precise the diagnosis applied, and therefore the more reliable the action. When it comes to aircraft maintenance, it is essentially important to make a correct diagnosis. The industry has to ensure a continuous safety high standard and guarantee that flight operations can be almost sure that an aircraft is available to make a booked flight, ensuring that the aircraft flies, because no aircraft is profitable on the ground.

1.3. Motivation

Motivation comes naturally since this internship study and dissertation are entirely innovative, allowing the industry to increase further its data-driven decisions and actions for better and more precise aircraft maintenance. This concept of a system to record and transmit daily aircraft data is not new, and each OEM is following this market trend to implement and have this kind of system available to their customers. The system Smartlink supplies a lot more information to the CAMO about eventual technical faults and aid in the identification and troubleshooting of a defect (Bombardier Claim). I was responsible for implementing this system in the regular maintenance operations of Netjets. Usually, the aircraft goes into a Part-145 MRO to fulfil the tasks listed in a pre-required WO; it can be created merely based on the evaluation of a fault, cross-checking with all the available data from pilot reports, aircraft history, etc.; The CAMO can use the Smartlink to more accurately determine the cause and provide additional troubleshooting aid to the Part-145 MRO, which can increase the technical dispatch reliability, a minimised AOG risk, with an uplift of the safety standards for the commercial operation of the plane.

1.4. Objectives

This dissertation focuses on an analysis of the effectiveness of the Smartlink system and what significant advantages the system brings to the technical dispatch of Netjets Europe. These may be the increment in the reliability accuracy of specific life limit parts and components, increment in the troubleshooting reliability and the increment in the technical information of aeroplanes. To achieve this objective, it is necessary to understand the system and how it works, understand how Netjets Europe handles technical dispatch and see where the system can show its effectiveness in the supply chain. To adapt the approach to the daily operation of Netjets Europe is necessary that its correct implementation in the company is successful.

Bombardier claims that the Smartlink can have a crucial impact on the technical dispatch due to MDC code reporting. In the case of an event, the system reports to the CAMO and the OEM, and by the time the aircraft maintenance technician reaches the aircraft, it already knows what has happened to the plane. Before this, the OEM has to analyse the data of the flight and aircraft systems and develop troubleshooting options and solutions according to the issue, based on data-driven decisions. One of the primary indicators of the system´s effectiveness is the system reports of faults and the cross-checks with the actual Aircraft Technical Logbook entries made by the flight crew or vice versa. Another indicator of the system´s effectiveness in troubleshooting is whether it can accurately and reliably provide the OEM and CAMO with the data it needs. It will also be analysed all the advantages that can be named of the system in all the dispatch actions of the aircraft.

This study of the system will have a direct impact on it because suggestions for improvement were provided to the OEM of the system regarding the system operation on the Challenger 350 fleet. These suggestions were implemented in the development program of the system. This document was provided to the OEM (Document in the annex). These suggestions include multiscale graphs and charts, improvements in the search of parameters, suggestions for the creation of a library of parameters for better user parameter identification and search, lollypops CAS messages on the full flight analysis, etc. It is also worth noticing that the system is already working on the Bombardier Global 7500 aircraft and is being retrofitted to the Challenger 350; however, this retrofitted process is not easy because these are two completely different aircraft with different architectures; therefore, all sorts of inputs of data are provided in different ways and are treated in different ways, as well.

1.5. Methodology

As previously referred to, this thesis is based on a study in a curricular internship in Netjets Europe CAMO. It is focused on the analysis of the effectiveness of the Smartlink system and its advantages to technical dispatch on the company´s maintenance operations. The dissertation will have the following methodology:

a) Data retrieval

Which consists of retrieving the current aircraft data transmitted through the system to the Netjets CAMO. All the non-system related information, like pilot reports, aircraft technical log openings, current deferred MEL items, fault history aircrafts analysed, etc., are also considered.

b) Analysis of data

Data analysis starts when all the data available is retrieved and at the exact moment when a fault is acknowledged. Then a complete system report allows the CAMO to retrieve all the data from the pre-selected fault parameters, which engineers may want to analyse. At this point, a cross-check with the non-related system information, like pilot reports, troubleshooting manuals, etc., is made. The vice-versa process is also applicable.

c) Smartlink Data Effectiveness

The best way to analyse the system´s effectiveness is to check if the system information has helped troubleshoot a designated fault. If so, what time did it take to get to the correct troubleshooting vs the same amount of time if the system was unavailable.

In the case of the OEM help being necessary, one indicator of the system´s effectiveness can be if the system can accurately and reliably provide the OEM data it needs, to take further conclusions and to better advise in the troubleshooting of the fault. All the advantages that can be named of the system in all the dispatch actions of the aircraft will also be referred to.

d) Results presentation

Presentation of results that were retrieved through the analysis of the data and the effectiveness calculated in the aircraft with the system is installed. The advantages for the technical dispatch provided by the system are presented and discussed in this step.

e) Conclusions

Conclusions retrieved through the study and writing of this dissertation regarding the system's overall functionality and mode of operation, as well as the potential impact that the system may have in a real operational scenario.

f) Future Works

Proposal of future works regarding the work developed and on the study performed to allow this dissertation to be written regarding the Smartlink system.

1.6. Thesis Structure

This dissertation is structured in the following way:

- Aircraft Maintenance- This attempts to deliver to the reader a basic introduction to the concept of aircraft maintenance and how it is performed in the industry.
- Challenger 350- A brief introduction to the aircraft, its documentation and manuals.
- Smartlink- Brief description of the System in analysis and its reports to the CAMO.
- Effectiveness analyses & advantages- System effectiveness analyses and the system's advantages to the CAMO.

1.7. Introduction to Chapter 2

The following chapter summarises how aircraft maintenance works in the Netjets CAMO, what aircraft maintenance methodology is used, documentation and manuals of the aircraft where the system is installed, and how technical dispatch works. In what cases are specific procedures necessary to fulfil certain technical goals and needs that may be found during assessing discrepancies with the aircraft under the CAMO organisation.

2. Aircraft Maintenance

2.1. Maintenance Methodology used in the Aviation Industry

Different methodologies and methods can characterise aircraft maintenance by the type of aircraft considered and its operation. These methods and procedures are described in detail in documents and legislation released by the authority responsible for the plane or the head of the registration state. When registration of an aircraft is made under the enforcement of the European Union, it is mandatory to follow several requirements applied by EASA, for that specific aircraft and the type of operation, commercial or non-commercial. [2][3] The aircraft category classification also defines the requirements; complex motor-powered aircraft or non-complex motor-powered aircraft. [2][3] For complex motor-powered aircraft maintenance, the CAMO is responsible for its airworthiness and must follow a maintenance methodology approved by EASA. [3][4][5][6][7] One of the methodologies approved and widely used nowadays for complex motor-powered aircraft with commercial operation is MSG-3. [8][9][10]

Netjets Europe Maintenance department follows this document developed by the industry. MSG-3 or Maintenance Steering Group `Operator/Manufacturer Scheduled Maintenance Development´ has its primary objective to address a methodology to be used for developing scheduled maintenance tasks and intervals, which will be acceptable to the regulatory authorities, the operators, and manufacturers. [11] The aim is to pinpoint and quantify the reliability of the aircraft systems and components, avoiding unnecessary maintenance tasks to achieve increased efficiency. To do this, it is essential to follow several principles. These are: [11]

- Maintenance only effective if task applicable.
- No improvement in reliability by excessive maintenance.
- Needless tasks can also introduce human error.

- Simpler complex aircraft systems lead to more straightforward component maintenance.

- Monitoring is generally more effective than hard-time overall, also known as Condition-based maintenance or CBM.

- Reliability is only improved by modification.

- Maintenance may not be needed if part failure is cheaper.

With this in mind, MSG-3 is then used to develop the initial maintenance requirements for modern commercial aircraft, which are published as a Maintenance Review Board Report (MRBR). [10][11] It consists of two volumes, the 1st for fixed-wing aircraft and the 2nd for rotorcraft. Its application to the scheduled maintenance of the aircraft proceeds alongside the type certification process for that complex powered aircraft. [11]

Maintenance requirements for aircraft are documented in the Maintenance Planning Data (MPD) document. This document, subdivided by ATA chapters, ATA Chapter 04, describes the Airworthiness Limitations and ATA Chapter 05, Time Limits/Maintenance Checks. [10][11]

The document started in 1968 with the development of scheduled maintenance for the Boing 747, with great success. It was then known as MSG-1. Over time, MSG-2 was introduced and developed for the planned maintenance of primary 1970s aircraft, like the L1011 or Lockheed TriStar and the DC-10 or McDonnell Douglas DC-10. The significant change to the document consisted of process orientation and a bottom-up approach, also introducing the relatively new concept of condition monitored maintenance. [10][11]

There were initial flaws in the MSG-2 document, which led to the release of MSG-3, correcting the previously identified issues. Published in the 80s, it introduced the top-down approach, focusing on the consequences of failure instead. The document expected the assessment of functional shortcomings and consequent failures into two basic categories, SAFETY and ECONOMIC. MSG-3 was, unlike MSG-2s, task orientated, and this eliminated the confusion associated with the different interpretations that could be retrieved from the document like condition monitoring, on condition and hard time. Another significant improvement was made considering the concept of damage tolerance and additional supplemental inspection programmes. [10][11]

Since then, regular amendments have been made to the MSG-3 document, the most recent from 2015. The latest version introduced elements related to the structural health monitoring systems because of issue papers emitted by the international maintenance review board policy board, IMRBPB. [11]

The Industry Steering Committee or ISC appoint specialist Maintenance Working Groups that carry out detailed maintenance analyses based on the MSG-3 process, later developing an appropriate series of maintenance task and actions to submit to ISC for approval. [11]

The MRB acts as a regulatory authority that monitors the development and approves the aircraft´s initial maintenance programme. The ISC submits the complete maintenance schedule to the MRB for correct approval, and after this very same approval, the MRB defines it as a Maintenance Planning Document (MPD). [11]

One thing that is most valued is the experience accumulated in aircraft type certificates. TCH, or Type certificate holder, the manufacturer and the various operators will seek to improve and further develop the MPD throughout the aircraft´s life expectancy. All this is because usually, the initial MPD released by the OEM is conservative, and task intervals may be increased if the life expectancy of specific components also, by experience, shows that these periods can be increased without compromising the safety and integrity of the aircraft. [10][11] This can also be applied if parts are modified throughout their lifetime to gain a longer Mean Time Between Failure or MTBF interval to increase their life expectancy. However, all these modifications must be approved by the regulatory organ responsible for the oversight, whether the components through changes or to the MPD.

Once the oversight authority has approved, the MPD will evolve and become the Aircraft Maintenance Manual, that later will become the Aircraft Approved Inspection Program, specified for that operator. [11]

The MSG-3 fundamental goal is to identify maintenance tasks that are effective and efficient to brand-new aircraft so that its design and operation meet a satisfactory level of safety and reliability throughout its life expectancy. For this to be possible, the MSG-3 process is applied in the following four sections: [11]

- Systems and Powerplant (including components and APU)
- Aircraft Structures
- Zonal Inspections
- Lighting/High-Intensity Radio Frequency (L/HIRF)

All the designated sections have their different and specific methodologies and logic diagram. This is important in the Systems, and Powerplant section, which requires the identification of Maintenance Significant Items (MSI) before correctly applying the maintenance methodology and logic diagram to determine the correct maintenance tasks and intervals applied. Similarly, the Aircraft Structures section divides the aircraft into workable areas and zones, identifying Structural Significant Items or SSIs that allow the identification of Principal Structural Elements or PSEs. A failure in a PSE is always considered to have a catastrophic effect on the overall structure of the aircraft. The other subjacent structural elements are referred to as Other Structures or OS. As in Systems and Powerplant, the MSG-3 document provides methodologies and logic diagrams to develop the inspection task for structural parts. All the regulatory guidance relative to damage tolerance and fatigue evaluation is found in JAR 25.571. [8][11]

Other issues to be accounted for regarding tasks and intervals mentioned in the MSG-3 are addressed in the Certification Maintenance Requirements or CMR. These are usually identified during the aircraft systems safety assessment, typically from latent failures or combined events that may or not demand additional tasks at different intervals to the MRB report. [11]

2.2. Technical dispatch [12]

Technical dispatch is applied to any CAMO in a maintenance procedure or MP. All the maintenance procedures of the CAMO must be nominated and described in a specific document, also known as CAME. The CAME, or Continuous Airworthiness Management Exposition of the CAMO, is the exposition of the CAMO and how it is structured. EASA mandates, for the CAMO approval, to be an organisation responsible for assuring the airworthiness of aircraft, the direct NAA approval for this document. [3][4][5][6][7][13] General maintenance procedures listed and accounted for in this exposition allow any CAMO personnel to understand how the several MPs work and how to apply them. When a discrepancy in the aircraft is detected by its flight crew or maintenance personnel, the technical dispatch MP is used. The Technical dispatch of the aircraft describes and enforces several procedures to be followed. In general, all these procedures are similar in every CAMO, but there can be some deviations. The figure1 presents a flow chart allows visualising better how this process works and what

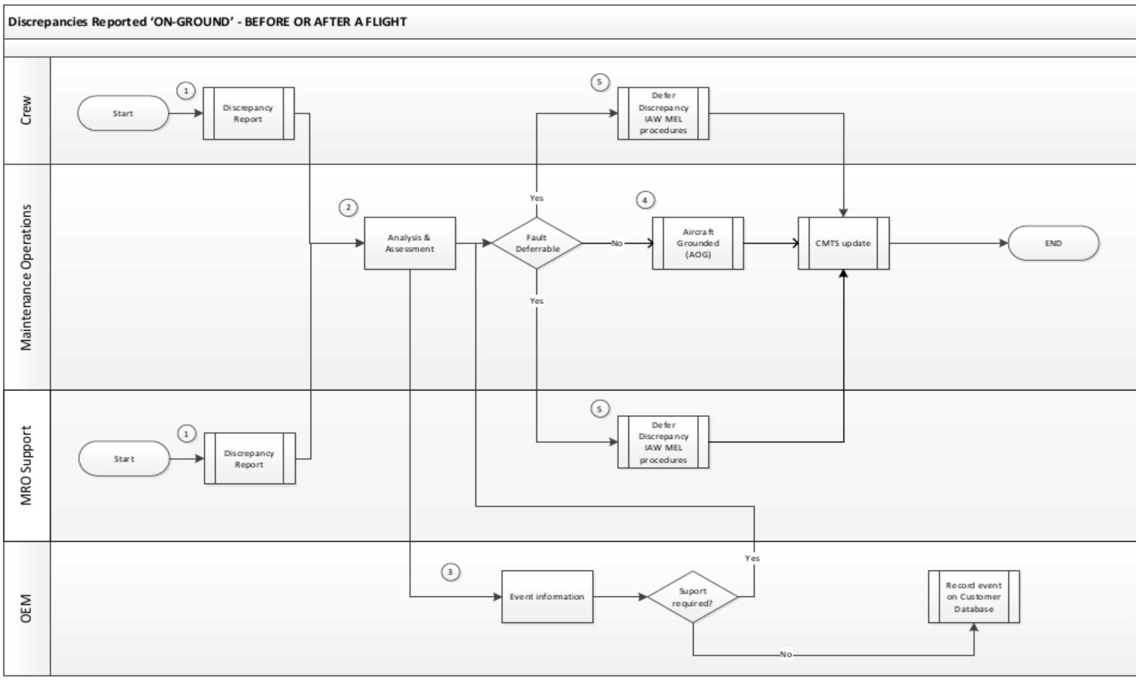


Figure 1- Technical Dispatch Flow Chart

parts are involved in assessing the detected discrepancy.

The Process starts with the aircraft's discrepancy reported by the flight crew or maintenance personnel. This report is made and forwarded to the AMCC, which first analyses the fault and the correct assessment. This can include the plane being grounded because the discrepancy report does not permit, according to the Minimum Equipment List or MEL from the aircraft, to perform a commercial flight. This can happen because the discrepancy report presents safety risks or other problems that represent safety concerns. After the assessment and analysis of the fault, the AMCC also reports the discrepancy to the OEM of the aircraft. In this case, there might be the need to require OEM support. In the case of OEM support, it is reported in the maintenance tracking system of the CAMO; if not necessary, the discrepancy is registered in the customer database. Whether the aircraft is grounded or not, a Technical Log must be made to report the disparity in the maintenance tracking system. The technical log of an aircraft is a system for recording and subsequent rectifying defects and malfunctions identified during aircraft operation and between scheduled maintenance events. It is also used for recording flight safety and maintenance information which the operating crew need to know. After registration of the discrepancy, there might be the need to require a Permit to fly. Permit to fly is a procedure that allows an aircraft to fly to a maintenance centre. This will enable the discrepancy to be physically assessed directly in the plane when maintenance is unavailable in the current aircraft airport. If aircraft maintenance is available, the issue is addressed and recorded in the event database of the CAMO.

2.3. Permit to Fly [14]

Permit to fly MP is a process regarding a CAMO maintenance procedure when it is necessary to move an aircraft to perform and access a maintenance issue. Usually, it is applied when no maintenance is available at the current aircraft site. It is necessary to fly the aircraft to another location where it can perform maintenance actions to address the reported issue. This process is essential because the plane in the possible current situation deviates from its type certificate and does not fully comply with the applicable airworthiness requirements for a commercial flight, although the fact that is possible to perform a safe flight under specified and previously defined conditions which must be described in the CAME of the CAMO.

The procedure consists of the approval of the flight conditions applied, followed by the issue of the permit to fly document.

Certain conditions must be applied to issue a permit to fly, and there are two distinct possibilities for giving the permit to fly.

It can be issued by the national civil aviation authority, in Portugal ANAC, or *Autoridade Nacional de Aviação Civil*, when the approval of the flight conditions is not directly related to the safety of the design of the aircraft.

Or

The permit to fly is issued by the CAMO per the provisions of Part M, M.A.7.11(c), also referred to in the CAME, when the approval of the flight conditions are safety of the design-related and approved by EASA or a DOA (EASA Part-21 Subpart J). In exceptional circumstances, which can happen, it is also possible for the national authority in which the aircraft is registered to issue the permit to fly.

As referred, to issue a permit to fly, it is necessary to meet specific flight conditions requirements, which can include:

1) The aircraft configuration(s) for which the permit to fly is requested.

2) Any condition or restriction necessary for the safe operation of the aircraft, including:

(a) The conditions or restrictions on itineraries, airspace, or both, required for the flight(s).

(b) Any conditions or restrictions on the flight crew to fly the aircraft.

(c) The restrictions regarding carriage of persons other than flight crew.

(d) The operating limitations, specific procedures or technical conditions to be met.

(e) The specific continuing airworthiness arrangements, including maintenance instructions and the regime under which they will be performed.

3) The substantiation that the aircraft is capable of safe flight under conditions or restrictions of point (2), usually a "No Technical Objection" or similar document from the Type Certificate Holder.

4) Crew acknowledgement (Permit to Fly- Placement of on confirmation form) and the maintenance actions, if required, regarding aircraft configuration recorded in the Aircraft Technical Log to ensure the aircraft configuration remains within the established conditions.

To conclude this chapter, it is vital to understand how the technical dispatch is done, the requirements to issue a fly permit, and the methodology used to apply maintenance to the aircraft accurately.

The following chapter is made an introduction to the Bombardier Challenger aircraft, its variants, what is the ATA Code chapters and all the necessary documentation to be able to fly the aircraft commercially.

3. Challenger 350

The Bombardier Challenger 350 aircraft is a slightly improved version of the existing Bombardier Challenger 300. Bombardier Aerospace, a Canadian company, specialises in manufacturing corporate jets. The CL 300 or Challenger 300 is a 3.200 NM range jet and was announced at the Paris Air Show in 1999. [15] Having its first flight in August, the aircraft only received its type certificate approval from the Canadian Authorities in late May of 2003. [15] It was introduced to service in early January 2004. [15] Supercritical swept wings characterise their design with a fixed leading-edge with a 27% of sweep angle. It has 1.15 meters winglets designed to reduce cruise parasite drag by 17%. [15][16] The aircraft can climb up to FL 410 in 18 minutes with 455 Kg of fuel burn at its MTOW or Maximum Take-Off Weight. The fuselage and the wing are semi-monocoque structures made of aluminium, and its winglets are fabricated in composite materials. [15][16]

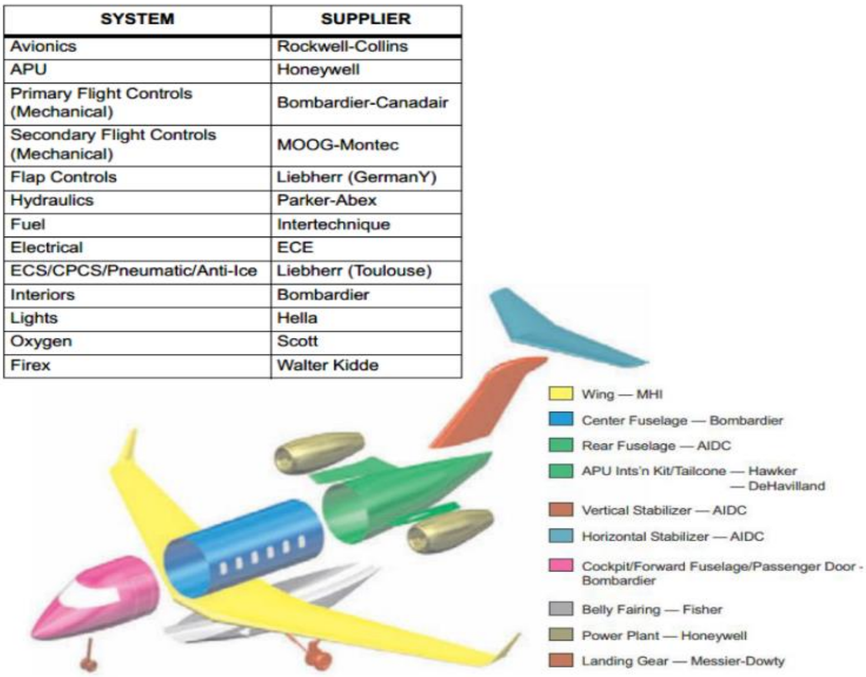
Regarding the flight control surfaces, the outboard ailerons are mechanically actuated; the elevators and rudder are hydraulic with mechanical backup. [15][17][18] Fly-by-wire spoilers augment roll control that acts as speed brakes and dumps lift on the ground. [15][17][18] The flaps are single-slotted fowler flaps with four positions to increase wing surface; these are 0/10/20/30. [15][17][18] The avionics suit of the aircraft is the Rockwell Colling Pro line 21, which includes 4 LCD Multi-Function Displays, EICAS, MDC or Maintenance Diagnostic Computer, EGPWS, TCAS and ELT. [15][17][18]

The Challenger 350, as referred to previously, is an improved version of the 300, with the same structure frame design, and entered service in May of 2014. [15][19] The significant upgrade allowed the users to have a more luxurious interior, with the interior being redesigned to suit customer needs better and with 20% larger windows. [15][19] The aircraft received its type certification from the Canadian authority in early June 2014. [15][19] The “relatively” new aircraft allowed Bombardier to claim 58% of the market share for super mid-segment jets. [15] The new powerplant suffered modifications to increase take-off thrust with the same flat rating, durability, and reliability. [19] The wing was strengthened, and the winglets were redesigned to increase efficiency and maximum fuel load. [15] Since the winglets have a less acute angle, the transonic drag is reduced, allowing an increase in wing area and aspect ratio. [15] Major Maintenance intervals are generally fixed at 600 hours. [15]

The Bombardier Challenger 350 has two Honeywell AS907/HTF7350B turbofan engines capable of producing 7530 lbf (33.495 KN) of take-off thrust. [18][20] According to Honeywell this powerplant is very reliable, with maintenance also considered in its design. [18][20] According to Honeywell, all the crucial line-replaceable units can be replaced in 20 minutes, and simplified access to the engine also significantly decreases maintenance time. [15][18][20] The engine itself has a dry weight of 1364 lbs (618.7 kg), 34.2 inches (0.86868 m) of fan diameter and a bypass ratio of 4.2:1. [15][20]

The powerplant's aircraft material breakdown comprises aluminium alloys, alloy steels, stainless steel, titanium, and composites.

This complex aircraft has several suppliers in its construction and assembly because Bombardier does not produce all the aircraft parts.



SYSTEM	SUPPLIER
Avionics	Rockwell-Collins
APU	Honeywell
Primary Flight Controls (Mechanical)	Bombardier-Canadair
Secondary Flight Controls (Mechanical)	MOOG-Montec
Flap Controls	Liebherr (GermanY)
Hydraulics	Parker-Abex
Fuel	Intertechnique
Electrical	ECE
ECS/CPCS/Pneumatic/Anti-Ice	Liebherr (Toulouse)
Interiors	Bombardier
Lights	Hella
Oxygen	Scott
Firex	Walter Kidde

Figure 2- Aircraft systems and their suppliers [17]

For a better understanding and further comparison of both aircraft, the Bombardier Challenger 300 and Bombardier Challenger 350, they are put side to side in the figure 3, which analyses capacity, engines, range, speed, airfield performance, ceiling, and weights. [17]

	CHALLENGER 300 AIRCRAFT	CHALLENGER 350 AIRCRAFT
CAPACITY		
Crew	2	2
Typical seating	8 TO 16	8 TO 10
ENGINES		
Model	Honeywell HTF7000 AS907-1-1A	Honeywell HTF7350 AS907-2-1A
Takeoff thrust	6826 lb (flat rated) ISA + 15°C	7323 lb (flat rated) ISA + 15°C
RANGE		
Maximum	3065 NM	3200 NM
	(NBAA IFR reserves, ISA, 8-passenger/2 crew and maximum fuel)	
SPEED		
Normal cruise speed	0.80 Mach (459 kt, 528 mph, 850 km/h)	0.80 Mach (459 kt, 528 mph, 850 km/h)
High speed cruise	0.82 Mach (470 kt, 541 mph, 870 km/h)	0.82 Mach (470 kt, 541 mph, 870 km/h)
Maximum operating speed	0.83 Mach (478 kt, 550 mph, 885 km/h)	0.83 Mach (478 kt, 550 mph, 885 km/h)
AIRFIELD PERFORMANCE		
Balanced field length (±3%)	4810 ft (1466 m) (SL, ISA, MGTOW)	4835 ft (1474 m) (SL, ISA, MGTOW)
Landing distance (±3%)	2600 ft (792 m) (SL, ISA, MLW)	2710 ft (826 m) (SL, ISA, MLW)
CEILING		
Maximum certified altitude	45,000 ft (13,716 m)	45,000 ft (13,716 m)
Initial cruise alt (MGTOW)	41,000 ft (12,497 m)	41,000 ft (12,497 m)
WEIGHTS		
Maximum ramp weight	39,000 lb (17,690 kg)	40,750 lb (18,484 kg)
Maximum takeoff weight	38,850 lb (17,622 kg)	40,600 lb (18,416 kg)
Maximum landing weight	33,750 lb (15,309 kg)	34,150 lb (15,490 kg)

Figure 3- Aircraft Performance [17]

The figure 4 describes the dimensions of the Challenger 350 aircraft.

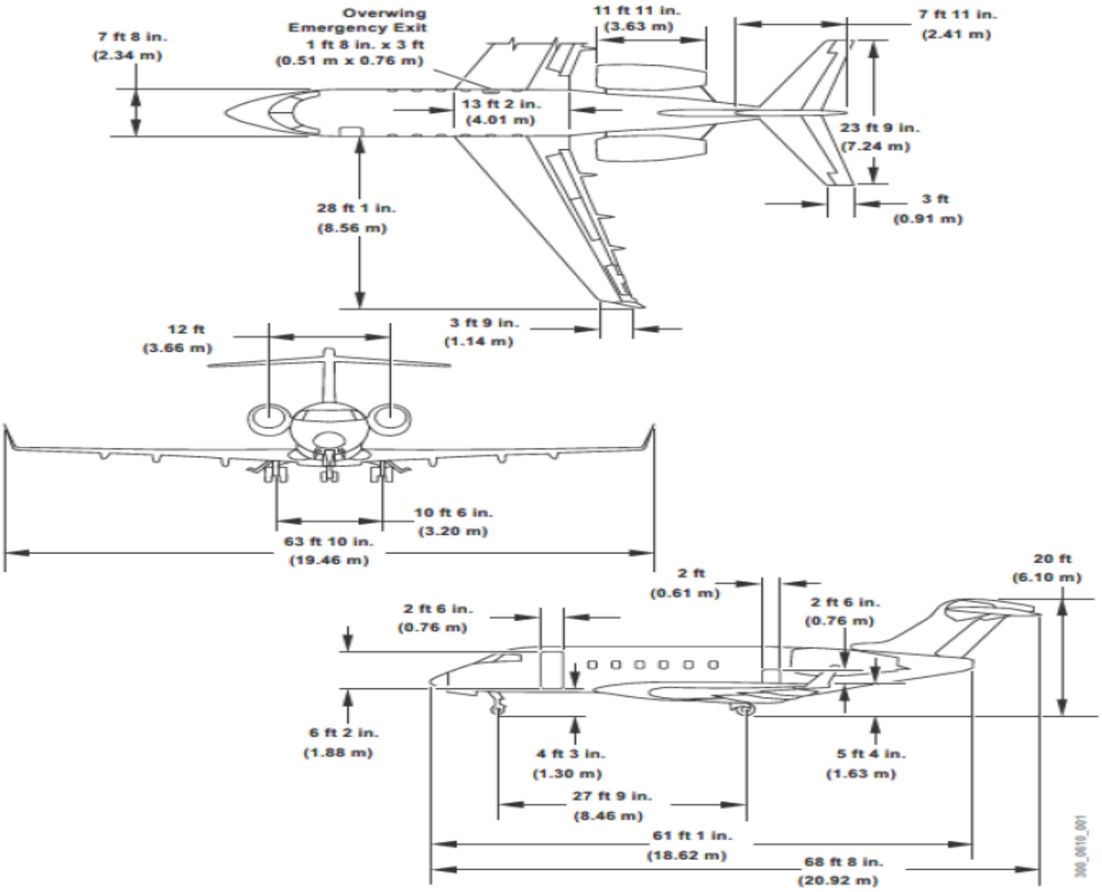


Figure 4- Aircraft Dimensions [17]

3.1. ATA 100

ATA 100 is a reference system developed by the Air Transport Association in June 1956. [21] It is a numbering system that contains common referencing standards for commercial aircraft systems description and all system-related information, components, block diagrams, wiring diagrams and all technical information regarding a complex aircraft system. [21] This standard numbering system allows for a better understanding, communication and easy learning for maintenance technicians, engineers, pilots, etc., and it is the base for any reference made in almost all daily aircraft operations, manuals, documentation, etc. The significant advantage of this system is that chapter numbers for a system are the same in all aircraft, meaning there is no room for confusion when talking about a reference number chapter. Because of this, all technical personnel knows what system is being referred to and can easily understand all the proper documentation and information regarding the aircraft´s systems. The chapter format is based on Chapter numbers, like (24) and section, for instance (24-30). Example: ATA 24-30 refers to Electrical power-DC Generator.

The figure 5 lists all aircraft systems and their ATA code chapter. [22]

Chap.	Subject	Chap.	Subject
00	Air Vehicle General	51	Standard Practices – Structures
04	Airworthiness Limitations	52	Doors
05	Time Limits/Maintenance Checks	53	Fuselage
06	Dimensions and Areas	54	Nacelles and Pylons
07	Lifting, Shoring, Recovering and Transporting	55	Stabilizers
08	Levelling and Weighing	56	Windows and Canopies
09	Handling and Taxiing	57	Wings
10	Parking and Mooring	60	Standard Practices – Propeller or Rotor
11	Placards and Markings	61	Propellers and Propulsors
12	Servicing	62	Main Rotors
14	Air Vehicle Loading and Offloading	63	Main Rotor Drives
15	Aircrew Information	64	Tail Rotor
16	Change of Role	65	Tail Rotor Drive
18	Vibration and Noise Analysis and Attenuation	66	Folding Blades and Pylon
20	Standard Practices – Airframe Systems	67	Rotors Flight Control
21	Environmental Control	70	Standard Practices – Engine
22	Auto Flight	71	Power Plant
23	Communications	72	Engine
24	Electrical Power	72	Engine turbine/turboprop – Ducted fan/Unducted fan
25	Equipment and Furnishings	72	Engine Reciprocating
26	Fire Protection	73	Engine Fuel and Control
27	Flight Controls	74	Ignition
28	Fuel	75	Air
29	Hydraulic Power	76	Engine Controls
30	Ice and Rain Protection	77	Engine Indicating
31	Indicating and Recording Systems	78	Exhaust
32	Landing Gear	79	Oil
33	Lights	80	Starting
34	Navigation	81	Turbines
35	Oxygen	82	Water Injection
36	Pneumatic	83	Accessory Gearboxes
37	Vacuum	84	Propulsion Augmentation
38	Water and Waste	91	Charts and Diagrams
41	Water Ballast	93	Surveillance
43	Tactical Communications	94	Weapons Systems
45	Central Maintenance System (CMS)	95	Crew Escape and Safety
46	Systems Integration and Display	96	Missiles, Drones and Telemetry
47	Liquid Nitrogen	97	Image Recording
48	In-Flight Refuelling Tanker	98	Meteorological and Atmospheric Research
49	Airborne Auxiliary Power		

Figure 5- ATA Chapters [22]

3.2. Aircraft Documentation

Every aircraft to be able to perform commercial flights has to have its certificate of airworthiness, also known as COFA. [4] The COFA is a formal document issued by the NAA to certify that the aircraft is airworthy to perform flights. [4] It is only possible to achieve the requirements to get NAA airworthiness approval if the plane conforms to the certificated type design and is in a safe flight operation. [4] Without this document, the aircraft cannot fly unless they have a valid COFA. [4] Not all aircraft are obliged to have a COFA to fly because this depends on the operation type and the aircraft type. [4]

The COFA has to be re-validated yearly, either by the NAA or by the CAMO twice, until it has to be re-validated by the NAA again. [4]

For the aircraft to be airworthy, the following six items have to be fulfilled: [4]

1. Aircraft Maintenance Program
2. Components
3. Technical documentation
4. Pending anomalies
5. Repairs
6. Modifications (Mandatory and Non-Mandatory)

There is always a lot to consider regarding aircraft technical documentation; being one of the most regulated industries in the world, it is expected that all the aircraft information be written and specified in several documents. They are generally set to a type of aircraft and contain all aircraft-related information. Some of the most important documents that can be appointed are the AMM or Aircraft Maintenance Manual, IPC or Illustrated Parts Catalogue, MMEL or Master Minimum Equipment List, SRM or Structures Repair Manual, Troubleshooting Manual, etc.

For understanding this dissertation, only three manuals are accounted for, due to being the most crucial to understanding the work developed. They are the AMM, which later will become the AAIP specific for an operator, MMEL and Troubleshooting Manual. Their designation changes from the regulator to the regulator, but its core is essentially the same; for instance, the AMP is a European or EASA designation for the maintenance program of the aircraft, but AAIP or Approved Aircraft Inspection Program is the same for FAA (American regulator) designation. They both contain the same information but different “names”.

3.2.1. AMM

The AMM, as referred to previously, is the aircraft’s maintenance manual. There was a general introduction to the AMM concept, stating that the AAIP document changes from operator to operator due to their needs and focus. Usually, the document includes lubrication, servicing and regular maintenance tasks. [23] Not all operators consider specific maintenance tasks to be safety crucial or necessary to perform at more frequent intervals (Soft Time). An even clear example of this is the consideration that certain operators consider passenger comfort essential during flight and others value low-cost prices for aeroplane travel. So, the AAIP can change from aircraft to aircraft and operator to operator. However, AMM maintenance tasks are crucial to the aircraft´s safe operation (Condition Monitoring or On-Condition), and these are present in every AAIP regardless of the operator´s focus or the needs of their customers. These tasks are designated in the MPD referred to in the introduction of this dissertation, and many more; everything depends on the safety of the operation and the type of maintenance applied to each component or part. As referred previously, maintenance tasks can be divided according to each piece or part and its role in the aircraft systems.

Maintenance tasks can be:

- On Condition / O/C

On-condition maintenance is a preventive task of components consisting of the piece or part installed in the aircraft to stay in the plane until it becomes INOP for any reason. However, they are monitored by maintenance tasks described and included in the AMM or AAIP of the operator. The monitoring of these “On Condition” components is made through inspections that can be done in many different ways, always being described and referring to which check is necessary to the element and how to do it, according to OEM recommendations. The component or parts is removed before failure in regular operation. [24]

- Condition Monitoring / C/M

The engineers monitor Condition Monitoring components in the CAMO organisation. These components are generally crucial to aircraft operation and require special attention to their condition. C/M components are generally engines, APU, landing gear, etc. These are changed according to their state and verified through general and overall inspections. Typically, these parts and components have specific intervals to realise their examinations and are monitored through their reliability and analysis of failures and as indications of deterioration. [24]

- Hard Time / H/T

Hard Time components or parts require specific maintenance task intervention at specific intervals per OEM recommendation. H/T can be divided into two categories: Life Limit Parts or LLP and periodic inspections. Life Limit Parts are parts or components with limited life expectancy. They must be substituted independently of the condition of the part or component at the specific previously defined OEM interval definition. Components that are H/T but with the periodic inspection are components that suffer inspections regarding their condition and only in case of INOP or failure are substituted. [24]

- Soft Time / S/T

These components are not crucial to the aircraft´s operation and usually are related to passenger comfort or cabin appearance. These suffer maintenance tasks by the operator's choice and priority according to specific intervals, which may be adjusted to the aircraft´s operational needs and maintenance schedule. These components or parts may or may not have OEM interval recommendations. [24]

3.2.2. MMEL / MEL

MEL, or Minimum equipment list, is a document which provides for the regular operation of the aircraft, subject to a specific condition, with particular equipment inoperative, previously prepared by an operator to fly in conformity with or more restrictive than the Master Minimum Equipment List or MMEL established for the aircraft type certificate. [9][25]

The MMEL is a list defined for an aircraft type by the OEM of its type design with approval of the state of design. It identifies items that may be unserviceable or inoperative at the beginning of a flight. [9][25] The MMEL may be associated with special operating conditions, limitations and specific procedures to fly the aircraft safely.

The MEL must be previously approved by the national operator authority responsible for the airworthiness certificate. [9][25]

In the case of any discrepancy, before commercial aircraft operation begins found in the MEL, the aircraft is automatically put on the ground and do not take off before the alert of the planes is cleared.

One way for the items inside the MEL to be verified is through EICAS or CAS messages. Usually, in almost every operator, every MEL is subdivided into different chapters; one is the aircraft systems alerting system.

MEL constitution is followed by the components that can be deferred, its description, quantity present in aircraft, quantity that is minimum allowed to dispatch the plane and the due date of the deferred item. These are generally separated into four letters A to D, each one meaning the following:

A- Depends on the "remarks" / Customized Definition.

B- 3 days.

C- 10 days.

D- 120 days.

The due time starts from the date the issue was found/deferred, and after this due date, the case has to be solved for the aircraft to continue to fly; otherwise, the aircraft enters an AOG state. In some instances, an extension of the MEL due date can be requested from the NAA, requiring prior approval. [9][25]

To dispatch the aircraft, the MEL also has a classification of actions and procedures necessary to release the plane: maintenance or operational actions/procedures. Maintenance actions/procedures require a maintenance technician to perform maintenance tasks in the aircraft, and operational actions/procedures require the chief pilot to take precautions and consider that the aircraft is flying with limitations if authorised by the operator CAMO of the aeroplane.

In the following subchapter, we can find a brief explanation of how the troubleshooting of an aircraft fault is addressed; these can be but are not limited to an aircraft problem or defect deferred from the MEL document.

3.2.3. Troubleshooting

The troubleshooting manual of the aircraft is based on OEM documentation that is used to solve any discrepancies found before and after the flight operation of the plane; in the case of a discrepancy/fault becoming regular and not when it is not resolved with referred troubleshooting, the OEM intervention is necessary to solve this issue.

Troubleshooting of almost every aircraft nowadays is done through the reading and retrieval of information and fault codes of the maintenance diagnostic computer onboard the aircraft, ATA Chapter 45- Onboard Maintenance System, and with available information, perform a cross-check with the troubleshooting manual for the solution.

The Troubleshooting manual provides information regarding any fault reported. This information usually is separated by the following topics:

- Message Overview
- Message Description
- System Description
- Schematic Diagram
- Wiring Diagram
- Possible causes
- Troubleshooting Tips
- Quick Links
- Troubleshooting Recommendations

Fault troubleshooting can be performed in several different ways, depending on what information is available; these can be by ATA chapter, MDC codes, message CAS colour, tips, or observed faults.

To conclude, this chapter was essential to retrain that aircraft have several documents regarding different areas of aircraft maintenance, what is ATA Chapters, aircraft manuals, what is the MEL of an aeroplane and how troubleshooting is done.

The following chapter deepens into the Smartlink and how it works, followed by a brief system description and a quick review of the web-visualisation tool. The web visualisation tool allows for the data analysis and graphical visualisation of different flight parameters for further system use, which may include the data necessary for a correct troubleshooting analysis of fault events.

4. Smartlink [26]

4.1. AHMS and SLP

4.1.1. AHMS

The Smartlink system is a conjunction of two different parts. The Aircraft Health Monitoring System (AHMS) and SmartLink Plus (SLP) services. The AHMS monitors and records aircraft data. Recorded data is separated into two different types of data parameters. Continuously recorded parameters and FDE recorded parameters. The continuous parameters are self-explanatory and are a record of all the parameter values throughout the whole flight of the aircraft. The FDE parameters are only the values within a few seconds before and after an alert is displayed in the EICAS display (Event Parameters). The system´s main component is an LRU named Aircraft Health Monitoring Unit or AHMU, directly connected to different aircraft systems/buses that contain all the information and data necessary for its purpose. These buses are ARINC 429 and ARINC 717. These connections are the same inputs that go to the IAPS or Integrated Avionics Processor System. The IAPS is responsible for retrieving all the sensor data of the aircraft to data treatment, and posture connection to the MFDs in the cockpit and other aircraft systems, like the FDR via ARINC 717; all other aircraft connections are made via ARINC 429. This LRU is connected to the Aircraft Wi-Fi unit (avWiFi) and the aircraft cellular module (avCM) LTE to transmit the flight data. The figure 6 helps to understand the AHMU and the other components:

Figure 6- AHMU and Surrounding Components

The SLP is the web service that allows for the data visualisation, download and treatment of all the sensor values and variables retrieved by the AHMU, as well as the visualisation of all CAS messages processed in the IAPS that appeared in the MFDs to the flight crew since electrical power is established prior take-off with a few minutes for boot the system and after landing until power is off.

Bombardier, the OEM of the system, claims the following advantages of the system:

- The system reduces ambiguity over what happened for both operator and Bombardier supporting, the operator in case of a discrepancy being identified either by the system itself or the flight crew.

- The system allows Bombardier to understand its fleet better and provide services adapted to the fleet´s operational reality.

- Reduces time required to get access to data and increases the speed with which troubleshooting is done

- Increases dispatch reliability and, consequently, aircraft availability

Throughout this dissertation, all these claims will be verified according to the system´s capability, and the results will be presented in Chapter 5.

The system functionality is based on three concepts: Bulk Data Transfer, In Flight Notifications and Smartlink Plus Visualisation.

- Bulk Transfer:

Bulk data transfer consists of uploading/downloading all the data retrieved in previous aircraft flights with the system on Board. This type of transfer is specified as the system's full data report, characterised by the physical download of flight data to a computer via Ethernet cable or flight data transfer via Wi-Fi or Cell mobile connection. The bulk transfers of data occur via Wi-Fi when the nearest Wi-Fi network SSID previously configured or stored in the Customer Data Base of the system fulfils a stable connection to the AHMU, and the system detects Weight on Wheels state as well as Parking Brake in the "on" condition. The Cell mobile connection provides an alternative to this method. It allows for partial bulk transfers when a Wi-Fi connection is unavailable due to no previous CDB Wi-Fi SSID configuration or when there is no Wi-Fi connection in the apron where the aircraft is moored or parked. The Cell connection and automatic bulk data transfer occur when the AHMU detects that the aeroplane is in a Weight on Wheels state and with aircraft speed below X knots. When both connections are available, the system will always take precedence to make the bulk transfer via Wi-Fi over Cell. The manual transfer of the data is achieved via Ethernet cable through a maintenance port directly connected to the AHMU. Software connection between both systems software, AHMU and maintenance computer, is assured through an Operational Ground Program. The Operational Ground Program has a user interface to configure the AHMU CDB. It allows for the manual data transfer of complete flight reports recorded in the last six months. The AHMU automatically bulk transfers data recorded via what means is available between 2 minutes before engine on and 2 minutes after engine off.

The automatic bulk transfer feature of the system is always available if either connection is established, Wi-Fi or Cell. The avWiFi is powered whenever the aircraft power is applied and controls the wireless connections using its dedicated inputs. The radios of the avWiFi are enabled only when the parking brake is set "on". When the aircraft lands, the AHMS will first attempt to connect to pre-programmed Wi-Fi credentials (Precedence over Cell) with the aeroplane in the weight-on-wheels condition. If the aircraft is in a Bombardier centre, the transfer will be directly done through the Bombardier network. When Wi-Fi is unavailable, the Cell will attempt a connection when the avCM is powered and active with Weight on Wheels. Suppose the automatic bulk transfer is not successful. In that case, manual intervention is needed to download the full data reports, access the full flight CAS alert messages, and all the non-bulk transferred data parameters recorded by the AHMU before engine "on" and engine "off".

The system interfaces with several aircraft systems. This connection and interface are achieved through the connection of the different system´s LRUs to the same ARINC 429 bus, except for the FDR connected through the ARINC 717 data bus. All these inputs are directly retrieved through the same data bus that serves as an input to the IAPS.

The system interfaces with the following LRUs:

ADC	AHC	APU	BCU	CDU	DCU	DME	ED	FADEC
FCU	FGC	FIREX	FMC	FQGC	FSU	GPS		HSTECU
IASC	IOC	IRS	ISI	LDU	MDC	MFD	PFD	PSEU
RALT	RDC	RIU	SECU	SPC	SVS	TAWS	TDR	TSS

Table 1- AHMS and its interfacing LRUs

- In Flight Notifications:

In-flight notifications are based on the FDE parameters reports, EICAS CAS messages, and Take off/Landing notifications. All these are transmitted and sent via SATCOM. The System also can communicate warnings regarding all states of flight and CAS messages via e-mail directly to the operator. The system report does not send and transfer full data reports in flight. This feature is only available for historical flights.

The following subchapter describes the system visualisation tool, how it works, a brief description of its features, and a graphic interface description, which allows for the data visualisation of the different parameters.

4.1.2. Smartlink Plus Visualisation

The system as referred to is divided into two separate products, which are the AHMS itself, the LRU physically present in the aircraft and the web service that allows for the visualisation of all the aircraft data, which is transmitted via bulk transfer for historical flights and in-flight report via SATCOM to the visualisation of the FDE parameters and in-flight CAS notification messages.

To access the web visualisation tool, it’s necessary to enter a specific website based in a cloud and enter the authorised user credentials of the OEM.

Once entering is allowed, the user will be presented with a fleet view. This page demonstrates all the current user aircraft that possess the system onboard. On this page, the user has filters and tools to help search for a specific aircraft and to access its data. These tools can change according to the aircraft´s current condition, like in-flight or on the ground, and also filters the aircraft by the amount of warning, caution and advisories CAS messages displayed to the flight crew, in the current flight state or on the previous flight. It’s also possible to manually search the aircraft by its serial number or current tail registration. The view of aircraft can also be presented in a grid where all aircraft are displayed in rows. The figure 7 illustrates the fleet view of the system:

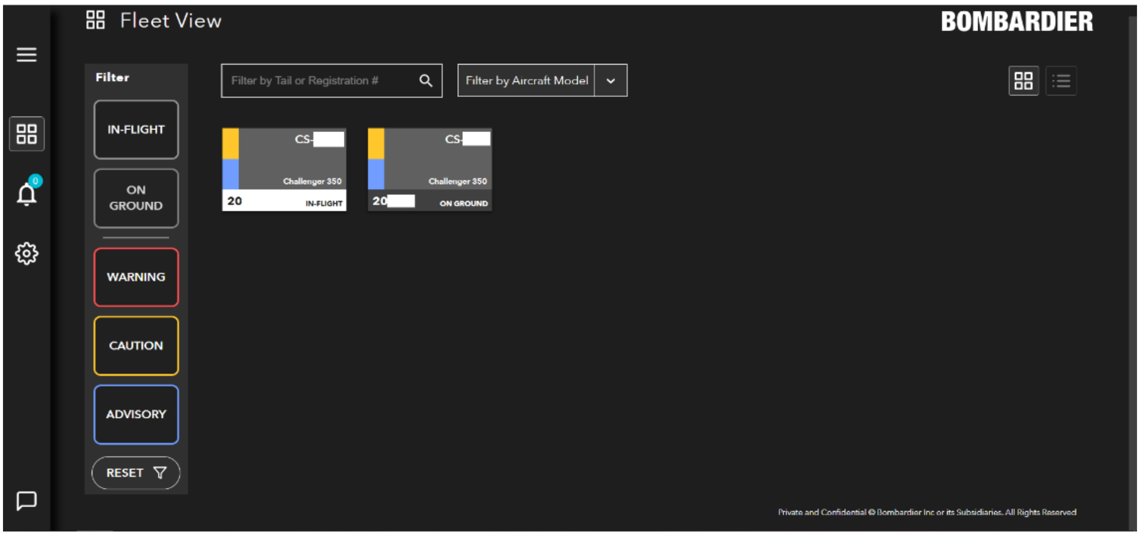


Figure 7- Fleet View

In the figure 8, it is possible to see the grid view of the fleet view:

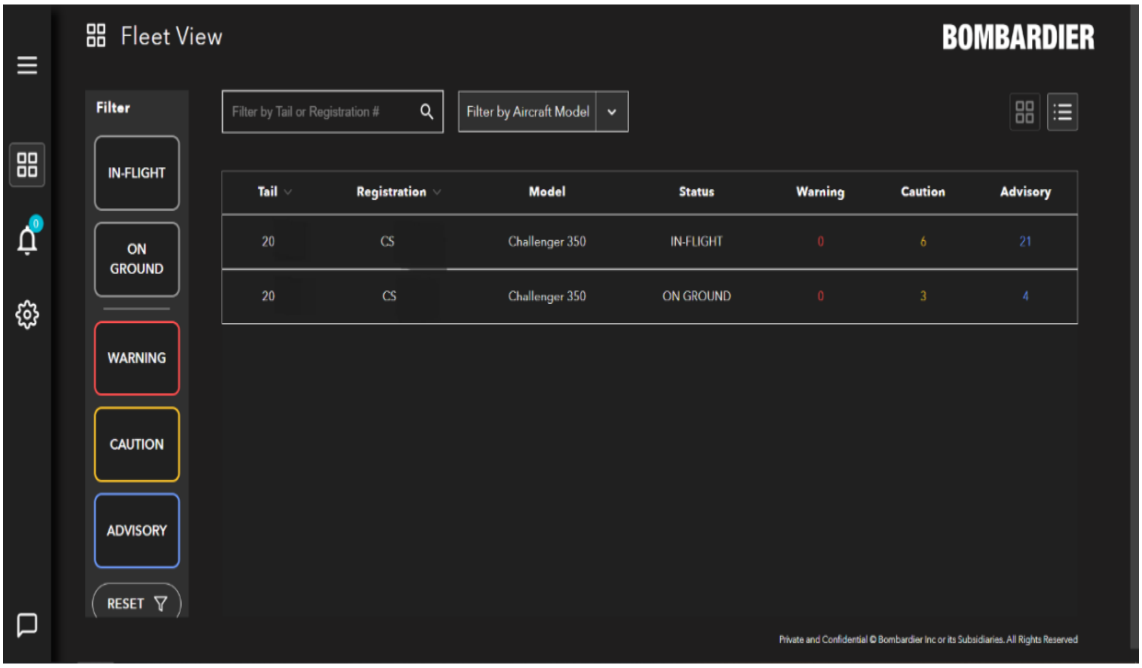


Figure 8- Fleet View Grid Page

The fleet view, as referred to, offers a general idea of all the aircraft and their current state. However, to better understand and adequately see and analyse the current aircraft state and deepen the system´s data, it’s necessary to enter the specific aircraft page regarding one aircraft. To access this page, the user must click on the aircraft card presented on the fleet page.

On this aircraft page, the user is immediately presented with the current in-flight report of the aircraft. This report presents the user with general flight information like the date and time of the flight, departure and arrival airports, time of flight, etc. The in-flight report has two states of flight information: actual current aircraft information regarding a flight that the aircraft is taking at the present moment or the previous flights transferred by the system.

The following figures 9 and 10 give a better perception of the aircraft page and its tabs of general flight information.

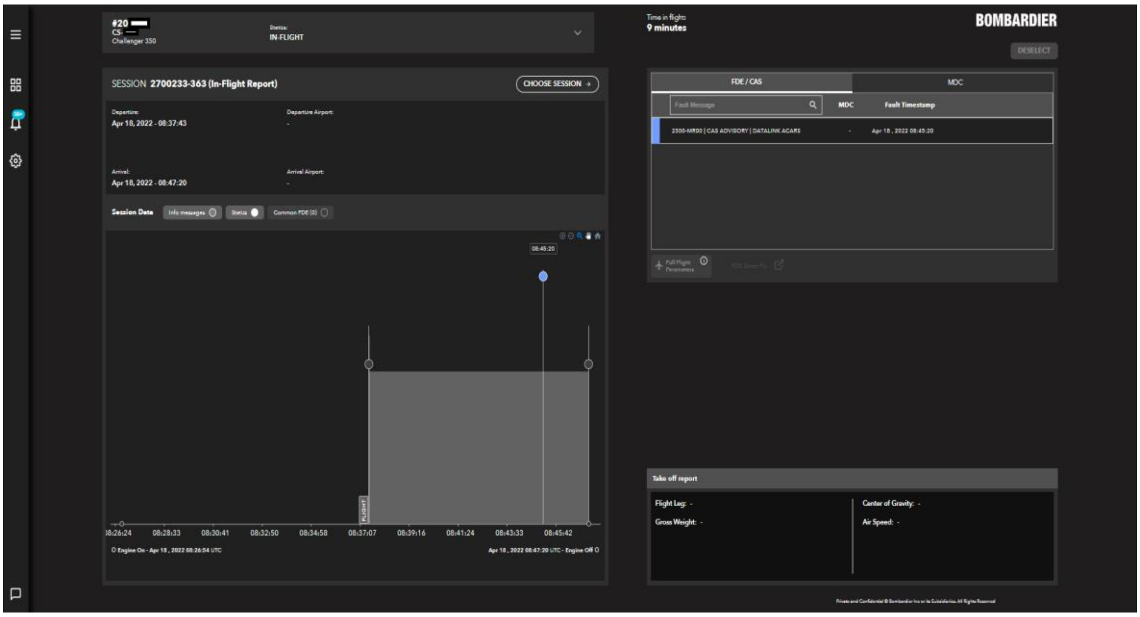


Figure 9-Aircraft flight Information

In this tab of general flight information, there is a button that allows the user to extend this information to get the airframe hours and cycles of the aircraft and correspondent both engine hours and cycles.

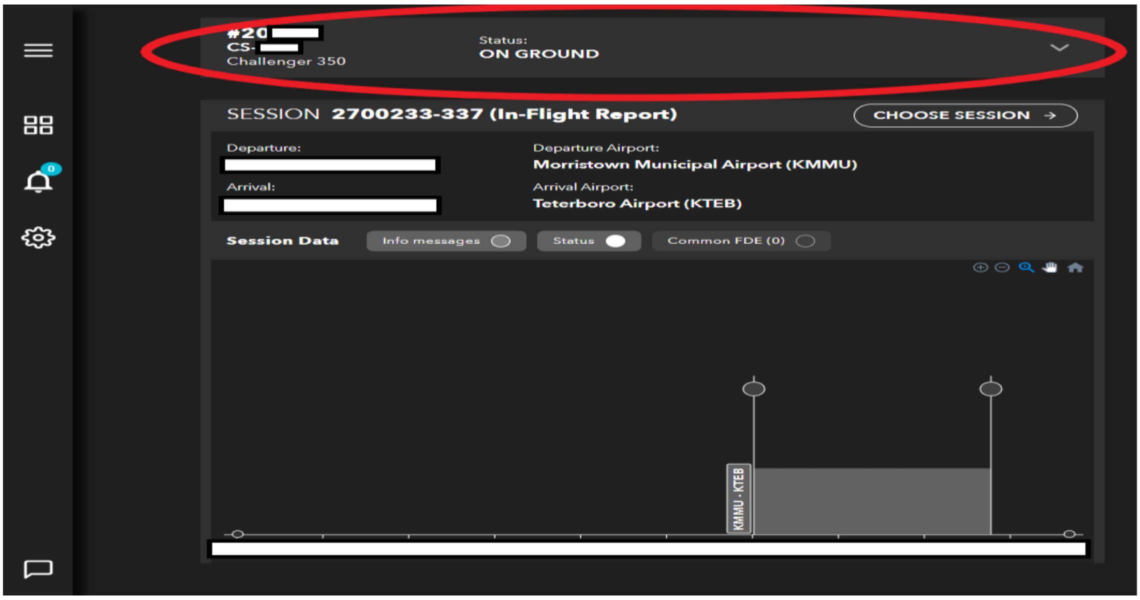


Figure 10-Extended

These values are editable to match the countable operator´s actual hours/cycles. Still, some deviation may occur due to a system shutdown or maintenance action to the Smartlink system itself.

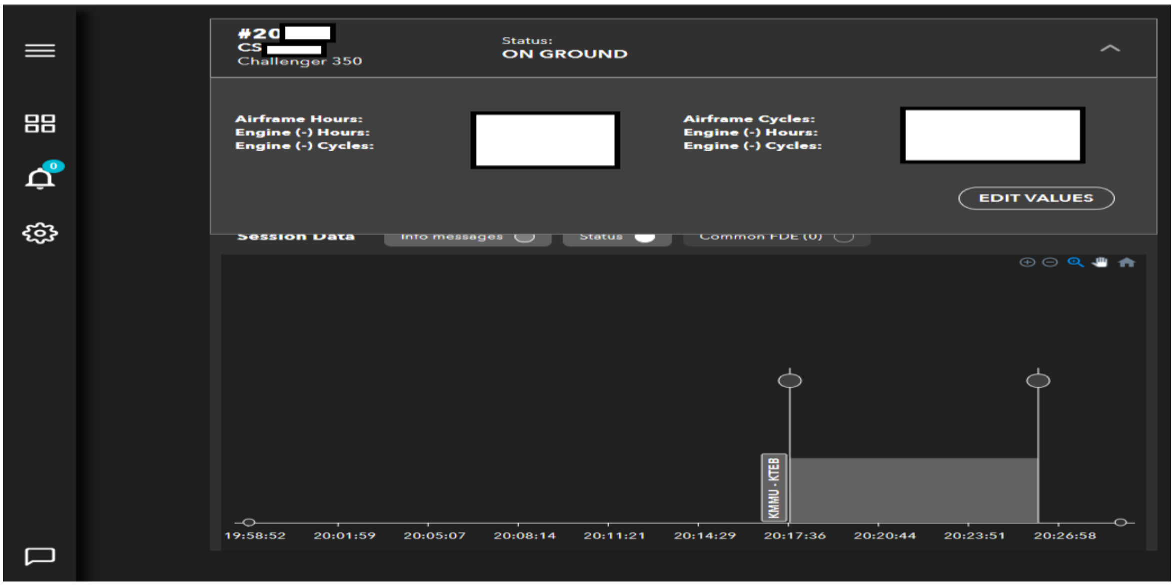


Figure 11- Aircraft Hours/Cycles & Engine Hours/Cycles

There is also a button to choose the aircraft session. This allows the user to access the system´s previous flight history and historical sessions recorded by the system.

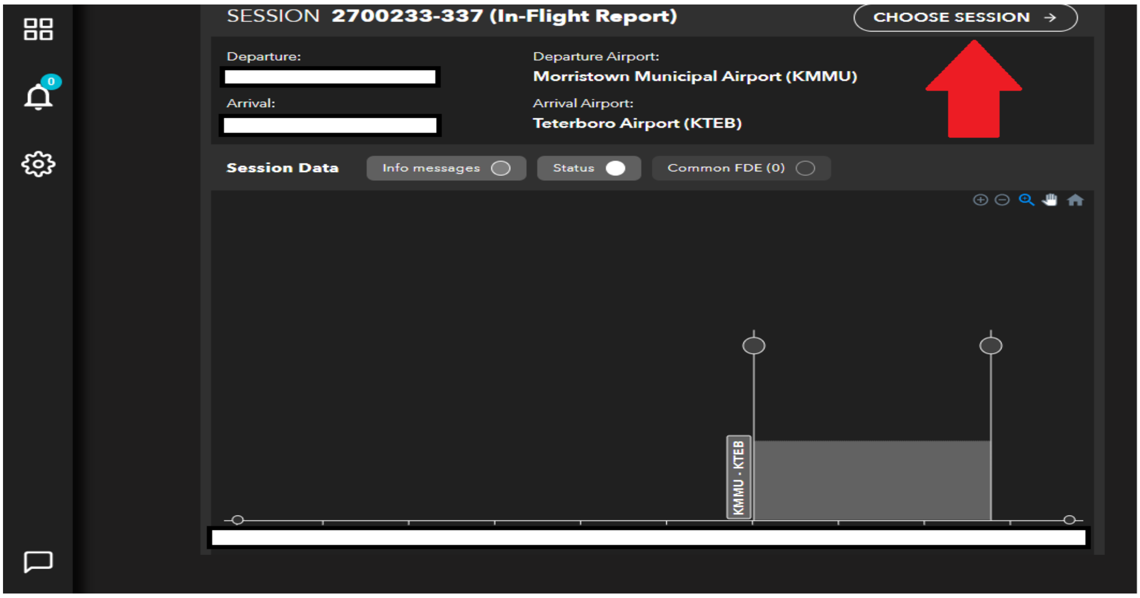


Figure 12- Choose Session

In figure 13 is displayed flight information, a flight profile presents all the flight FDE/CAS notifications in lollypops chronologically, helping the user to understand the flight profile itself better and giving a better time perception of the events.

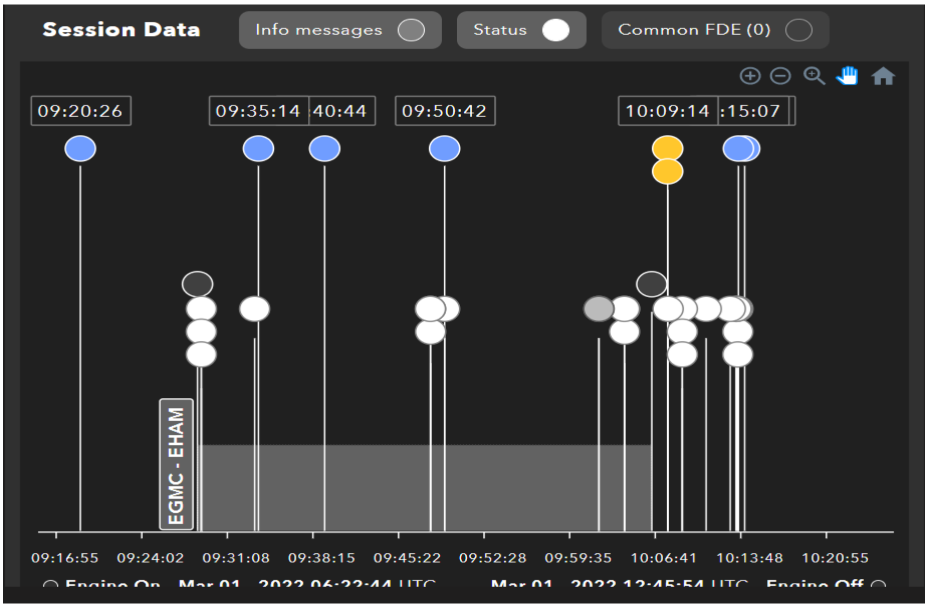


Figure 13-Flight Profile

Each lollipop is defined by an associated colour described in the table 2:

Lollypop Colour	**Meaning**
Black	Take-off or Landing
White	Status CAS Message
Grey	Info Message
Cyan	Advisory CAS Message
Amber	Caution CAS Message
Red	Warning CAS Message

Table 2- CAS Colour Meaning

Besides the current in-flight report is also possible to find the other two tabs of information. FDE/CAS / MDC report and a take-off report. In the FDE/CAS and MDC report, it’s possible to see all the EICAS alert messages displayed, starting on the engine start until the engine complete stops. In the MDC tab, it’s possible to find the MDC fault code associated with each fault the system has reported.

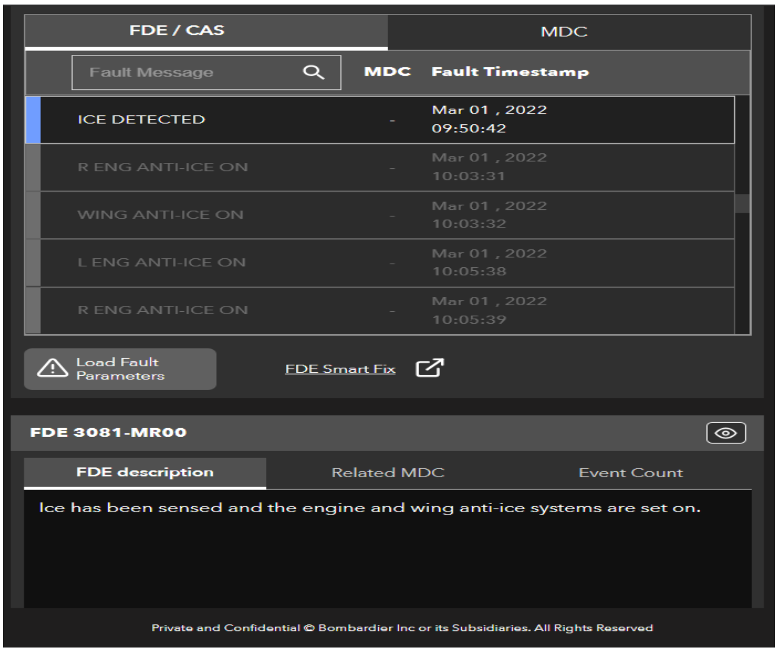


Figure 14- FDE/CAS Messages

The Take-off Report demonstrates general flight information like MDC Flight Leg number, the aircraft´s Gross Weight, Centre of Gravity in percentage and Airspeed.

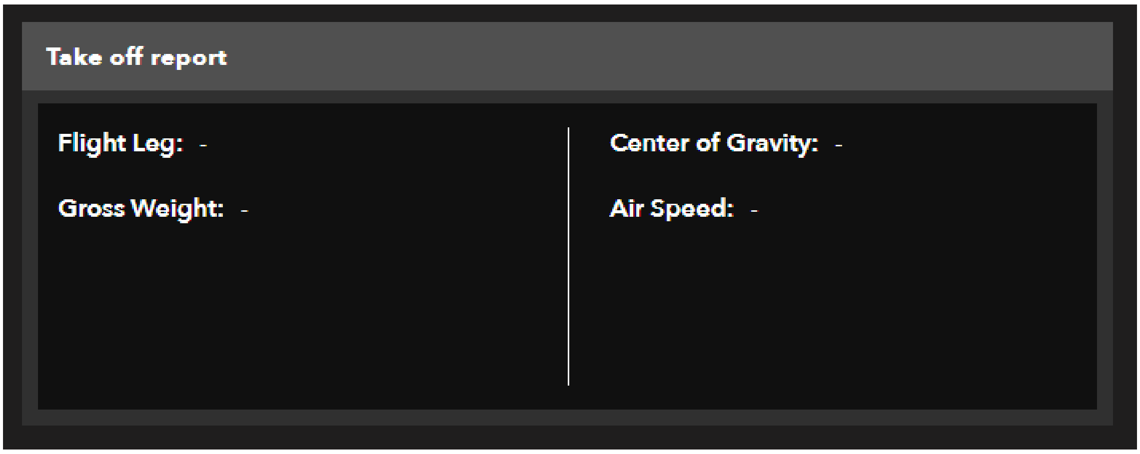


Figure 15- Take Off Report

The analysis and visualisation of the flight data are separated, as referred previously, into two different categories, FDE parameters and Continuous parameters. To analyse FDE parameters (fault-specific parameters) is necessary to select the fault the user wants to study and click on load fault parameters. The figure 16 gives a better understanding of this.

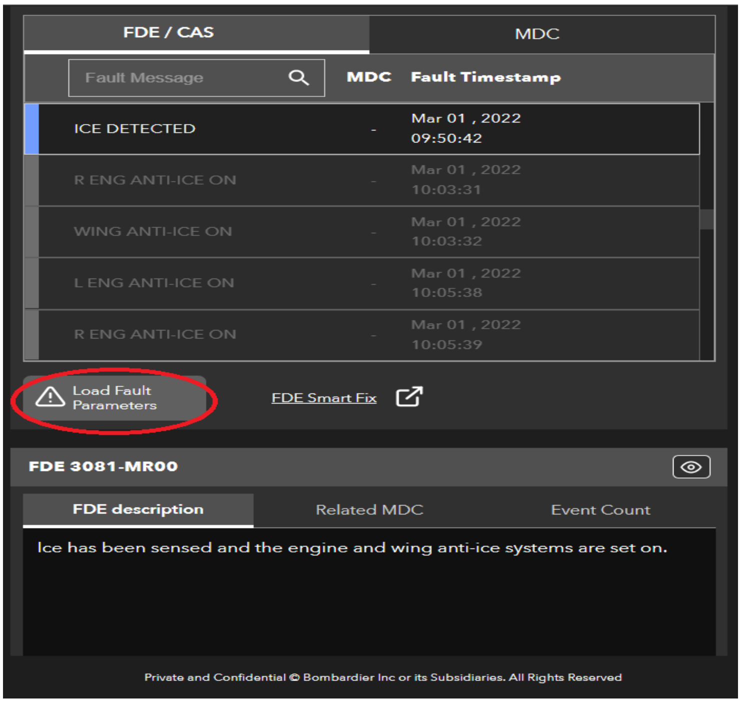


Figure 16-FDE Fault Parameters

The right side of this button is clickable and directs the user to the Bombardier troubleshooting website, directly to the preselected fault troubleshooting resolution.

By default, Bombardier chooses the best suitable FDE parameters with system-related fault information and data. These can vary according to the system in analysis, but consistently above 50 different parameters are considered.

Regarding the continuous parameters, in the full flight analysis, it is left to the user consideration to which selection better suits the fault characteristics and flight condition of the aircraft when the fault event happened, further helping in better understanding what caused the fault and consequent troubleshooting.

Both types of parameters can be selected. The web visualisation tool redirects the user to another page upon selecting fault parameters or a full flight report. The user can choose the parameters he wants to analyse on this page. All the parameters are described by ATA number, parameter alpha-numeric code, parameter description, unit and type (Continuous or FDE). The figure 17 helps to visualise this page better.

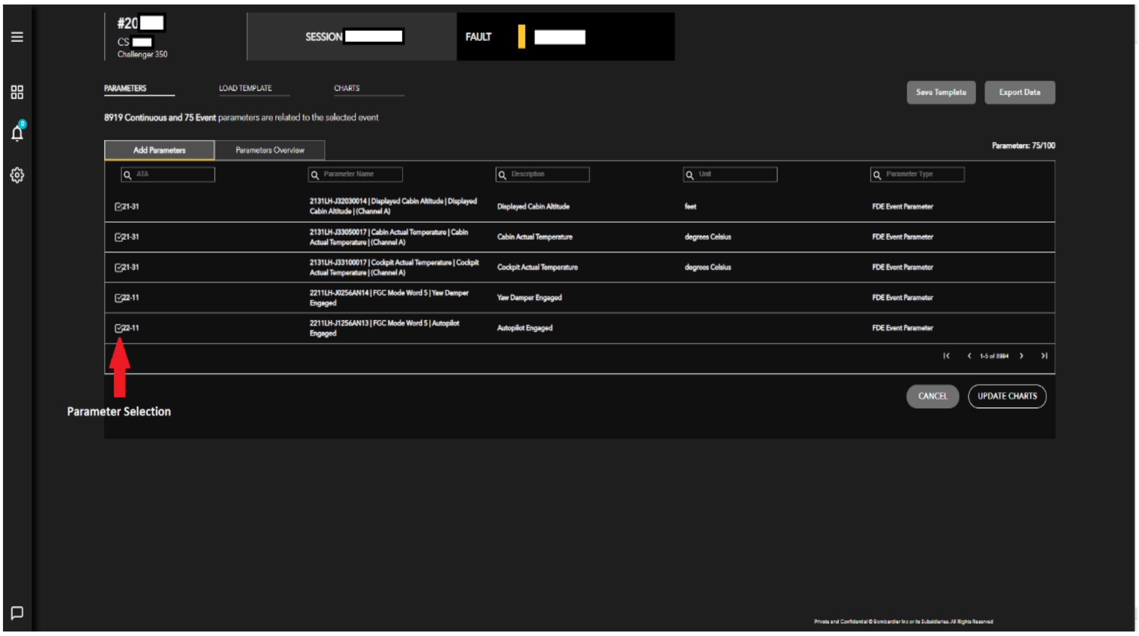


Figure 17- Parameter Selection

The parameters name follows a logic diagram for the user to understand better which parameter he is selecting. This is because, at first sight, and without any proper definition, the user may mislead to believe that some parameters are repeated. However, this is not true because there are systems in the aircraft that contain redundancy, and the system can capture all these cases, so it's necessary for the user to know the system parameter logic to better suit its needs and to better select the correct parameters for troubleshooting purposes.

Upon this selection, all the parameters will be treated and converted to a chart. To visualise these charts, the user must click on "Update Charts", and every time adding a new parameter, this process must be repeated.

In Parameters Overview, it’s possible to see what parameters are loaded and delete them if necessary. The system also allows the user to create a template of parameters for further use or team share. The figure 18 gives a better perception of this tab.

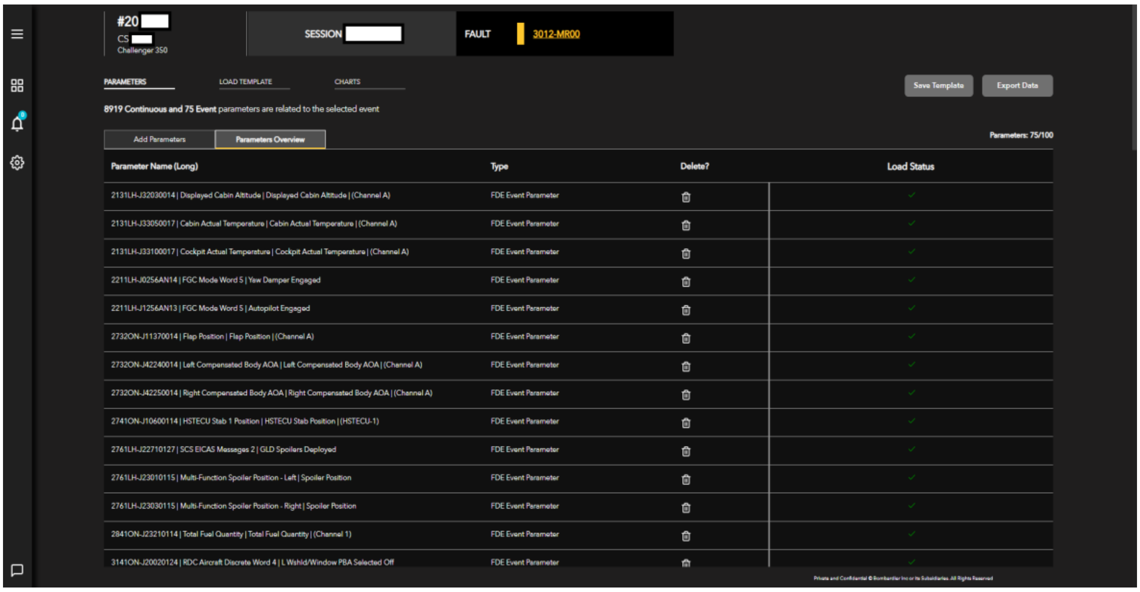


Figure 18- Parameter Overview

After this parameter load has been successful, the page automatically changes to visualise the parameters charts. Each chart considers different parameters, but system logic arranges them by related parameters or parameters with the same unit of measurement (Speed, Angle, Temperature, Altitude, etc.). On the left side, it is possible to see what parameters are being considered, their alpha-numeric code, the associated LRU, the possibility of removal of the parameter in specific, and the parameter chart colour. This possibility to unselect parameters allows the filtering information to have a clearer view of the charts.

There is also the possibility to perform a download of the data to an Excel CSV file of the graph data, which allows further deep analysis. In the figure 19, it’s possible to visualise an example of this chart visualisation to have a clearer view of this feature.

Figure 19- Graphical Charts

In this chapter, it was possible to understand the system itself, how it works, its different features, its main system components, a brief system visualisation tool description, and how this visualisation tool works. All this is necessary to deepen the system knowledge to understand better how the effectiveness analysis can be achieved and highlight the possible technical advantages that the system may or may not provide to the operator.

The following chapter intends to describe two faults per aircraft system and compare the fault events reported by the system and those reported by the flight crew, to later perform a cross-check between both reports, system report and actual aircraft technical logbook entry, that allows the operator to perceive all the system reports better, and in result check for occasional false fault alerts.

4.2. Smartlink Report

Smartlink started reporting all the aircraft flight data in February of 2022 in two distinguished Netjets Challenger 350 aircraft. From this point on, these aircraft are characterised as aircraft A & B.

4.2.1. Aircraft A

Since system activation on aircraft A, it has reported several faults with associated related data. Usually, all EICAS CAS alert messages can be related to the faulty component associated with the system. However, it's important to highlight that this may not always be the case. Some faults reported through the system require a more profound analysis, with the troubleshooting manual providing a guideline for resolving or identifying a faulty component.

4.2.1.1. L Window Heat Fail

In early March, the system first reported an L Window Heat Fail Caution EICAS alert message in flight. This fault condition was then reported as per standard CAMO operator procedure of discrepancies found during the flight to the AMCC, which received and retrieved the information, took action, and started monitoring the issue. In figure 20, it is possible to see the first system report of this fault:

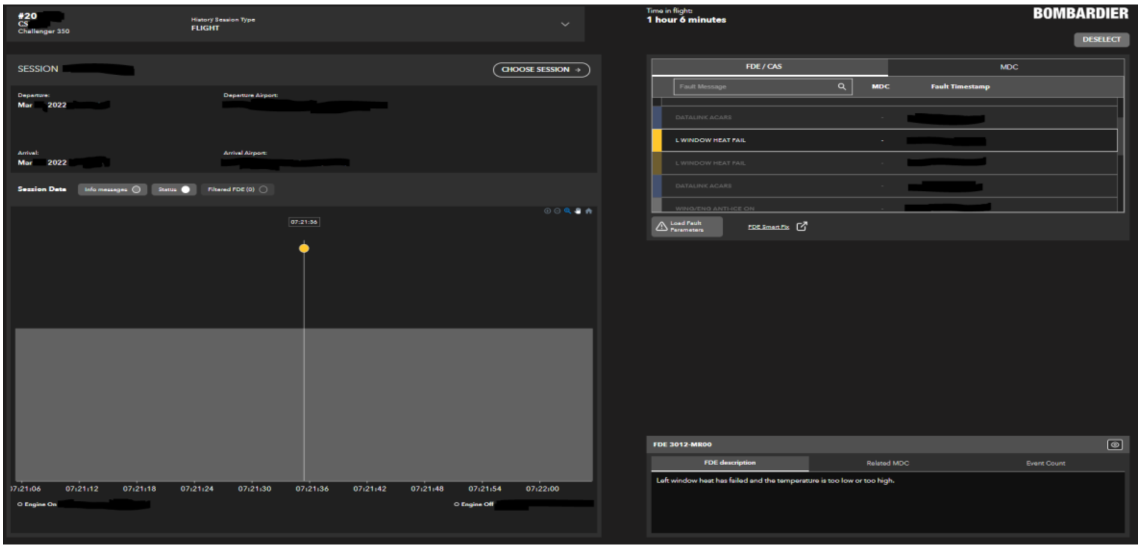


Figure 20- 1º Report L Window Heat Fail

This fault it’s characterised as intermittent due to the defect being cleared after a certain amount of time. The flight crew can also clear the message by pushing a PBA button. An ATL entry was made upon aircraft landing, and the troubleshooting was done at a Service Centre.

The troubleshooting manual, in this case, references the entire window heat system chapter, ATA 30- Ice and Rain Protection.

Message description of the fault:

“The Amber “L WINDOW HEAT FAIL” caution CAS message indicates the respective window heat has failed, and the temperature is too low or too high. “

“The respective windshield controller has sensed temperatures out of tolerance.”

The troubleshooting manual also presents possible causes for this fault event. These can be the following:

- Loose Ground Stud Terminal
- Left Window Temperature Controller
- Left Side Window
- Left Secondary Power Centre
- Associated Wiring

Tips are also available. These include Advisory Wire/Service Bulletin issued by the OEM. In this specific case, Bombardier has an Advisory Wire regarding this issue. AW300-30-0328.

The standard procedure upon any failure is to retrieve MDC codes and, according to the fault code, intervene in the system. With this in mind, all the codes retrieved in this concrete situation refer to the left window temperature controller failure. Upon this fault code being displayed, the troubleshooting manual advises the replacement of the controller.

The troubleshooting performed at the service centre resulted in substituting the Left Window Temperature Controller LRU. Since the aircraft is relatively recent and the fault at this point was only reported once, it is not expected to have the issues described below in the AW, so it was not taken into account. A functional test was performed and shown satisfactory, so the ATL entry was cleared, and a release to service process started.

4.2.1.1.1. AW300-30-0328

The AW refers to:

ATA: 30-41

Information Type: Maintenance Operational

Effectivity: Challenger 300 (20003-20500)

Challenger 350 (20501-20999)

Subject: Windshield Heat Fail CAS Messages

The description of the AW refers to an increase of Windshield Heat Temperature Controllers (WHTCs) being removed for Windshield Heat Fail CAS messages; Bombardier launched an investigation to determine the root cause. The initial study revealed that most of the Window Heat Temperature Controllers were either found “No Fault Found” or showed failed MOSFETs (power supply of the windshield heaters) that were likely caused by a voltage surge or an overcurrent condition.

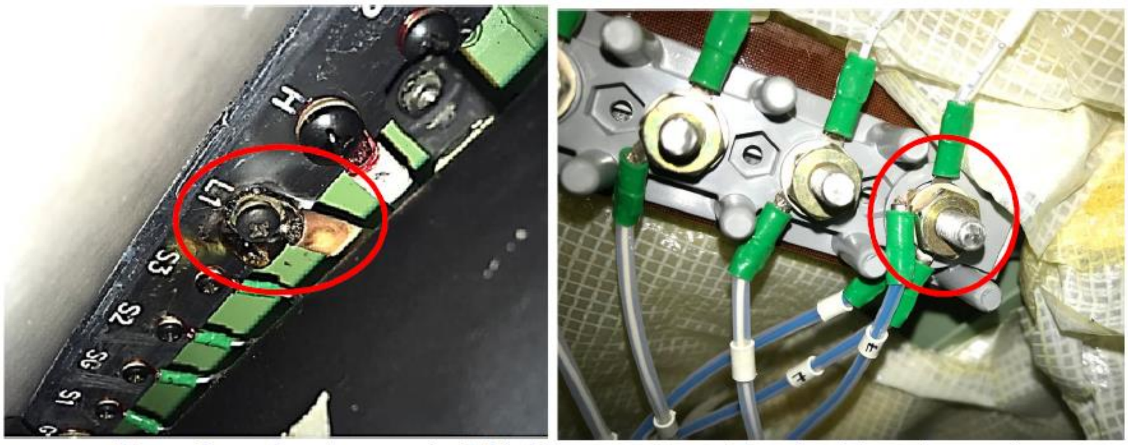
During the investigation, a series of tests were conducted to find the cause of the voltage surge and overcurrent. The analysis did not reveal any issues with the controller; however, it was observed that when any lug in the circuit was under-torqued, it would generate a higher current draw on the MOSFETs.

Some operators who experienced the Windshield Heat Fail CAS messages were asked to inspect all connections in the window heat temperature controller’s circuit and report their findings. The observations revealed some anomalies in the circuit. Overheating and/or arcing was observed on the power relays of the Secondary Power Centre, on the lugs and terminal studs of the window heat temperature controller´s, on the terminal blocks and on the windshield connectors.

The following figures 21 and 22 show the severity of this problem with major concerns to aircraft safety.

Figure 21- AW Overheat

Figure 22-AW Lug and Stud Damaged



Sign of overheat on a windshield connector – Terminal lug stressed

Figure 23- AW Terminal Lug Stressed

As a resolution action to prevent and solve this issue, Bombardier claims that to determine the root cause of a Windshield Heat Fail CAS message, it is recommended to inspect the electrical connections of the system circuitry as follows (even if the WHTC is confirmed at fault after swapping or replacement):

- Verify the torque value of the screws on the windshield contacts and the resistance of the windshield sensors and heater elements.
- Verify the electrical connections at terminal blocks and ground studs.
- Verify the torque of the nuts on the WHTC studs.
- Perform the bonding check on the WHTC.
- Inspect relays in the Secondary Power Centre for signs of overheating.

4.2.1.1.2. Intermittent Fault

After the resolution of the issue and consecutive release to service of aircraft A, it performed a couple of flights, and the fault appeared again. This means that the discrepancy was still present in the aircraft and a new action was necessary to clear it. However, the CAMO already knew about this problem and could take a different approach and course of action to the fault resolution.

The fault data show that the issue was only present in-flight, therefore not present before the take-off of the aircraft. The problem itself is a grounding item not deferrable by the MEL of the aeroplane; however, since the fault only appeared to the flight crew in flight, it was not necessary to defer the issue, besides knowing it was present, so that the aircraft could continue flying. Issue resolution was then scheduled for the next scheduled maintenance of the aircraft.

Upon this scheduled maintenance, the CAMO requested the service centre to perform the indications and actions present in the AW. The service centre could not find any problems described in the AW and proceeded to substitute the Window Heat Controller again. Due to the aircraft characteristics, the window heat controllers are permutable between left and right systems. The once-replaced controller was placed on the right side with a new one installed on the left side. Once again, a functional test was performed, and the results were satisfactory.

After this maintenance intervention, the aircraft made one flight and was grounded due to the fault not being cleared with the complete shutdown. Because of the intermittent problem and the double substitution of the controller, it was clear that the controller itself did not represent the significant discrepancy for the fault to be triggered.

To solve the issue, the CAMO requested support from the OEM Bombardier. Bombardier immediately answered the problem's needs using the Smartlink as the primary troubleshooting tool. With this analysis, Bombardier requested a sensor resistance reading of the sensors inside the window frame, with the aircraft pressurised to replicate flight conditions. According to the troubleshooting manual, the resistance reading should be equal to the figure 24.

Condition	S1 - SG (Resistance)	S2 - SG (Resistance)	S3 - SG (Resistance)
at 65°F	339 ±3 Ω (nominal)	339 ±3 Ω (nominal)	339 ±3 Ω (nominal)
at 80°F	350 ±4 Ω	350 ±4 Ω	350 ±4 Ω
OPEN Circuit	> 500 Ω	> 500 Ω	> 500 Ω
SHORT Circuit	< 212 Ω	< 212 Ω	< 212 Ω

Figure 24- Sensor Resistance

This procedure was then implemented, and the results concluded that Sensor 2 was misreading but a few Ohms. With this, Bombardier issued an REO to disconnect and cap the faulty sensor until window substitution (with a pre-determined due date). The REO was applied, and the aircraft was released to service with the issue clear and with no recurrence. The window was replaced one month after.

Consider below the block diagram of the system to better understand the issue and the system itself.

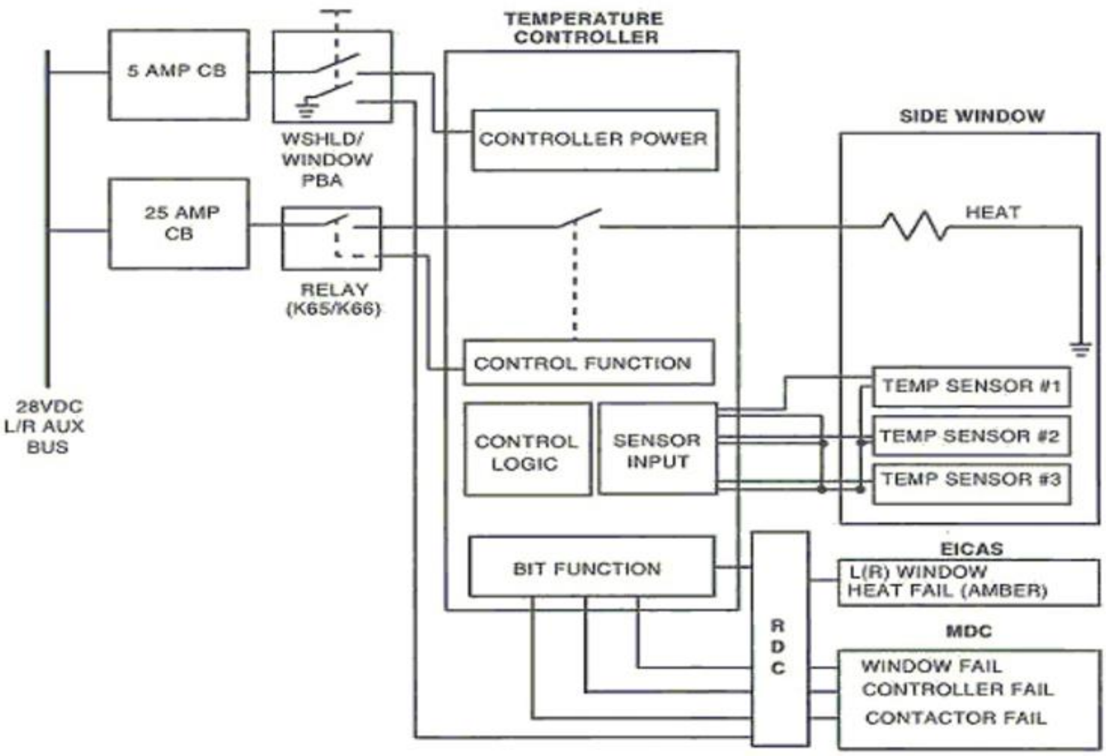


Figure 25- L Window Block Diagram

4.2.1.2. IAPS Fan Fault

Aircraft A flight crew in mid-May, at a certain point in its operation, reported and issued an ATL entry regarding an IAPS Fan Fault unable to clear without a complete aircraft shutdown. The issue was addressed at a service centre per standard technical dispatch procedure. This discrepancy is a clear example of the system flaws and it was not reported by the bulk transfer of the system. Therefore this is considered in the effectiveness analysis of the system for aircraft A.

According to the troubleshooting manual regarding ATA 31-45:

Message description of the fault:

“The cyan “IAPS FAN FAULT” advisory CAS message indicates the IAPS Environmental Controller has detected high temperatures or a faulty fan.”

- *The IEC monitors the temperature transducers in the left and right quadrants. If either temperature transducer reaches + XX º C, then the IEC turns on the cooling fan.*
- *In the Event of cooling air failure, a ground/open over temperature discrete output is opened, indicating that the hottest point in the power supply has reached its maximum safe internal operating temperature (XX º C)*
- *If Operation continues in an over-temperature condition, the power supply automatically shuts itself down within X minutes.*
- *Operation resumes only when the PWR internal temperature falls below + XX º C and the primary power source has been interrupted and re-established.*

Possible causes presented are the following:

- Integrated Avionics Processing System (IAPS) Environmental Controller (IEC)
- Associated Wiring

With all this information in the manual, the final recommendation is to replace the IAPS Environmental Controller.

Since the issue was adequately reported and addressed, the service centre, as per the troubleshooting manual recommendation, substituted the Environmental Controller of the IAPS system.

This Fault was not reported in the Smartlink System of the aircraft through the web visualization tool bulk transfer of data. Therefore, it was not present in the system, and the CAMO did not consider any data. The issue was solved purely as per technical dispatch procedure without Smartlink assistance.

This does not mean, however, that the system did not capture the fault, but due to the system's characteristics, it was not reported via web visualization. The fault may be present via manual download, although this was not possible to confirm.

4.2.2. Aircraft B

System activation on aircraft B becomes a specific time after activation on aircraft A. Due to this later delivery, the system CDB was updated with a new version. From its early release, the aircraft B system has faced some issues regarding its user interface and data display, with no airport of departure and arrival being presented and other general information missing. However, the system core of EICAS alert messages the report was working in the equal form to the system in aircraft A, so these initial problems were not system function crucial.

4.2.2.1. ADS-B Out Fail

With the regular operation of the aircraft, the system reported several advisories messages like Cabin Call, Datalink ACARS or other “more informative” messages. Whoever this is not always the case, and the system can also report faults in the aircraft, but something unknown in that specific situation made the EICAS trigger the flaw. These are classified as false faults alerts. Within this particular case, the system reported an ADS-B Out Fail CAS message several times on the aircraft’s flights. The figure 26 allows for better visualisation of the fault.

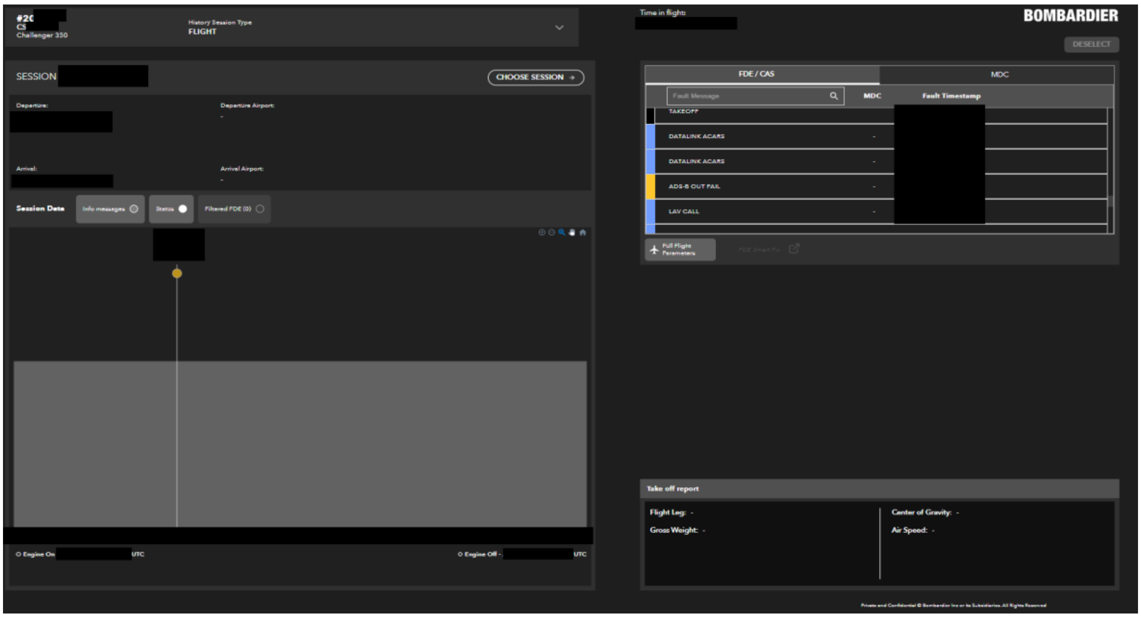


Figure 26- ADS-B Out Fail

Using the system, the CAMO realised that the fault was triggered due to GNSS degradation. From this point, it was essential to know where the aircraft had flown for this GNSS degradation.

GNSS, by its characteristics, is the foundation of Performance Based Navigation (PBN), automatic dependent surveillance-broadcast (ADS-B) and automatic dependent surveillance-contract (ADS-C), providing an ordinary time reference used to synchronise systems, avionics, communication networks and operations. Due to all these features, aviation relies heavily on GNSS for area navigation and precision approach.

ICAO released a safety advisory document regarding known issues, which states that in MENA states, GNSS degradation can happen with jamming of the signal to take into place, completely blocking all satellite signals. [27]

After looking at the previous flights of aircraft B, the CAMO realised that the aircraft had flown to certain MENA States. When flying to MENA states, the aircraft's operator already acknowledges that GNSS degradation can happen due to significant satellite interference in these areas. The fault was considered a false alert with the information from the ICAO safety advisory.

4.2.2.2. Wing Anti-Ice Leak

With the regular operation of Aircraft B, a Wing Anti-Ice Leak Warning CAS message was displayed on the system. With the concern of a warning message, the CAMO immediately tried to understand if the crew had reported the issue. This fault was identified along with other Anti-Ice Caution messages throughout the system, and the flight crew reported an L Engine Anti-Ice Fail. As per the recommendation of the troubleshooting manual after MDC code retrieval, a functional test was made to access the engine issue. The results were satisfactory, meaning that the system was properly working, and, therefore, not necessary to intervene on the engine.

The Wing Anti-Ice Leak warning CAS message was associated with other Anti-Ice CAS messages. Since it was a false alert, identified as false in the maintenance action of the engine, the aircraft was released to service and an investigation was taken into place to understand what happened and why the faults were associated. The figure 27 reveals this CAS message.

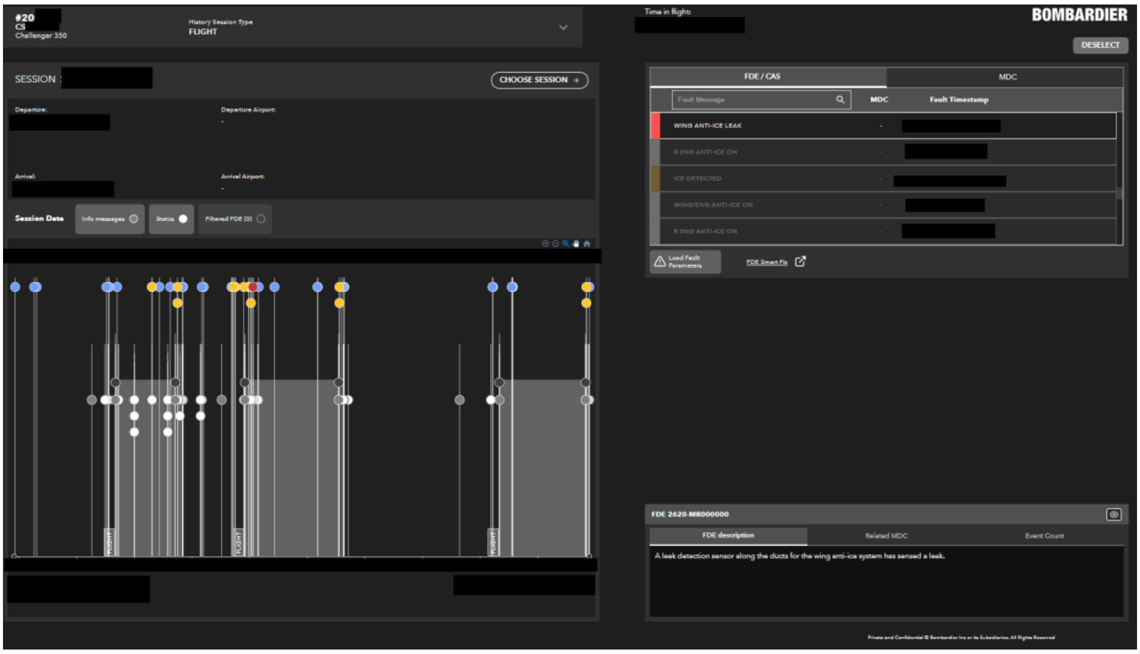


Figure 27- Wing A/I Leak

In the troubleshooting manual, there is an Advisory Wire related to the Wing Anti-Ice Leak CAS message during the climb, AW300-36-0008, which states the following:

“Some Aircraft intermittently experience a “Wing Anti-Ice Leak” warning CAS message during climb at max power while the wing anti-ice system is in operation. Investigation has revealed that in some conditions, the temperature inside the outboard leading may reach the set point of the Leak Detection Elements, thus initiating the message, and the system automatically switches off. To assist Operators in determining if the “Wing Anti-Ice Leak” Warning is false, the ref. XX AFM procedure allows turning the system off and resetting after 2 minutes to clear the CAS message in flight.”

The CAMO cannot confirm if this procedure was applied, but the message was no longer present after 1 minute and a couple of seconds later. The Smartlink system reported that the CAS message was displayed in climb and TLA position on max power angle.

With all this information, the CAMO had all the information necessary to classify this fault as a false alert. The L Engine Anti-Ice Fail functional test came satisfactory, leading to the CAMO conclusion that everything was working properly in the aircraft's Anti-Ice systems.

The following chapter considers the results presentations of the system´s effectiveness in the fault report and the advantages of the system´s approach to technical dispatch.

5. Results Presentation

5.1. Smartlink Effectiveness

System effectiveness is analysed by comparing alerts provided by the Smartlink system web visualisation tool and the actual log book entries reports fulfilled by the flight crew of each aircraft.

Calculations are done in the following way:

$$Smartlink\ Effectiveness(\%) = \frac{Faults\ reported\ in\ both\ systems\ (Smartlink + ATL\ Entrys)}{Faults\ reported\ by\ the\ flight\ crew\ (ATL\ Entrys)} * 100$$

It´s important to note that the Smartlink system records and transmits all EICAS CAS alert messages displayed to the flight crew. These alerts can be “false alerts” because the EICAS systems can trigger a fault even with the pull of a Circuit Breaker, not meaning that the fault is real, but the system has been turned off. Still, the fault is reported, besides being a false positive. The flight crew is aware of this nuance that can happen in the EICAS system. The Smartlink system is not yet ready to filter these false alerts and they are all reported. For the effectiveness analysis, a comparison between the Smartlink system and the ATL of the aircraft is necessary to correctly identify the real alerts and to cross-check the information necessary for the correct assessment of the fault.

5.1.1. Aircraft A Smartlink Effectiveness

On Aircraft A, the system reported the following CAS alert messages:

ADS-B Out Fail	ADS-B Out Fault
APU Gen. Overload	Brake Fault
Config. Flaps	CVR Fail
Datalink Fail	Eng. Mach Hold Fail
FD1 Fail	FDR Fail
FLT Spoilers Deploy	Gear
Gear Disagree	L Engine Oil Chip
L Fuel Collector Low	L Window Heat Fail
L Wing Anti-Ice Low Temp.	R Eng. Anti-Ice Fail
R Fuel Collector Low	Rudder Limiter Fault
Spoiler Fault	XPDR 1 Fail

Table 3- Aircraft A Smartlink Reported Faults

In the same timeline until this point, the flight crew reported 3 log book entries; all others were false alerts. Comparing the reports from the system and flight crew, only one was reported in both systems.

Take into consideration the equation for the calculation of the Smartlink Effectiveness in Aircraft A:

$$Smartlink\ Effectiveness = \frac{1}{3} * 100 = 33.33\ \%$$

This value is bellow expected. It should always be 100% due to all faults captured by the system must be present in the web visualization tool. This does not mean, however, that the system did not capture these faults, but due to the system’s characteristics, they were not reported via web visualization tool. The remaining faults may be present via manual download, although this was not possible to confirm.

5.1.2. Aircraft B Smartlink Effectiveness

On Aircraft B, the system reported the following CAS alert messages:

ADS-B Out Fail	ADS-B Out Fault
APU Gen. Overload	Bleed Loop Fault

CVR Fail	Datalink Fail
Download Fadec	EFIS Comparator INOP
Eng. Sync Fail	FDR Fail
Flaps Fault	Fuel Imbalance
Gear	IASP Fan Fault
Inboard Brake Press Low	L Eng. Anti-Ice Fail
L Eng. Anti-Ice Fail ON	L Engine Thrust Fault
L Fadec Fail	L Fuel Collector Low
Outboard Brake Press Low	Park/Emer. Brk Press Low
Prox. Sys Fault	R Bleed Fail
R Bleed Loop Fail	R Engine Thrust Fault
R Hyd. Press Low	R Wing Anti-Ice Fail
Spoiler Fault (Advisory)	Spoiler Fault (Caution)
Stab Trim Fault	Stall Protect Fail
TAWS Basic Fail	TAWS System Fail
TAWS Terr. Not Avail	TAWS Windshear Fail
Trim Air Loop Fail	Wing Anti-Ice Fail
Wing Anti-Ice Fault	Yaw Damper Fail

Table 4-Aircraft B Smartlink Reported Faults

In the same timeline until this point, the flight crew reported two log book entries; all others were false alerts. Comparing the reports from the system and flight crew, two were reported in both systems.

Take into consideration the equation for the calculation of the Smartlink Effectiveness in Aircraft B:

$$Smartlink\ Effectiveness = \frac{2}{2} * 100 = 100\ \%$$

5.1.3. Overall System Effectiveness

With the results retrieved for the Smartlink Effectiveness in both aircraft, it is possible to calculate the overall system effectiveness. This calculation is done in the following equation below:

$$Overall\ Smartlink\ Effectiveness = \frac{Aircraft\ A\ Smartlink\ Effectiveness + Aircraft\ B\ Smartlink\ Effectiveness}{2}$$

Taking into consideration the above equation is possible to achieve the following result:

$$Overall\ Smartlink\ Effectiveness = \frac{33.33\ \% + 100\ \%}{2} = 66.665\ \%$$

It´s essential to consider that all these calculations are based on actual system reports from the time of this dissertation writing. These results may not transmit the full system's effectiveness, or the release of further updates may eliminate the nuance behind these results due to the system´s constant improvement.

5.2. Smartlink advantages to the technical dispatch

Current Smartlink report and data visualisation take about one day to reach the operator, being the fastest communication of the system through e-mail notifications with an average operator reaching 2 hours. To be acceptable and operator usable, the system must provide a report within 15 minutes of the unscheduled event, along with available MDC codes already present in the brief report. The system must also provide additional generic data such as Altitude, Speed, Outside Air Temperature, etc. With this quick data transmission, the operator has a time window to coordinate with the service centre, about the present fault, along with all the related data, which in turn allows for the service centre to send an Aircraft Maintenance Technician to the aircraft for the fault correction, with the previous knowledge of the fault itself, before physically being present in the aeroplane and if necessary with the correspondent LRU to substitute in a hypothetical scenario. Nowadays, the reality is different. The system currently does not report MDC codes. With this considerable delay in data transmission, the AMCC can't use the system to reduce the aircraft's downtime. The additional generic data is considered in the system but currently does not report it. The take-off report is also a supplemental addition of information, with Gross Weight, Airspeed and Centre of Gravity. This feature is present in the web visualisation tool but not working on the Challenger 350 at the present moment.

With all this taken into consideration, and in the system´s current state, two advantages can be highlighted, which may improve the technical dispatch of the aircraft. All these are considered at the time of this dissertation writing and may not reflect the later stages of the SmartLink system. The advantages at the present moment are:

- Troubleshooting
- Reliability

5.2.1. Troubleshooting

The troubleshooting of any discrepancy or fault found in-flight or on the ground is achieved using the troubleshooting manual released by the OEM of the aircraft. When any nuance is located in the manual or troubleshooting actions do not eliminate the faults from the aircraft, OEM support is required. This support is provided with previous OEM experience and applicable knowledge. However, for this support to be truly effective, the OEM must access all kinds of information and variables available at the moment of the support to the service centre. It is at this moment that the wide variety of reports is taken into consideration. If the Smartlink report is available, the OEM can more accurately troubleshoot any faulty condition faster than a non-available Smartlink report state.

When this Smartlink data is considered, it can impact the aircraft's downtime when provided in a short amount of time. This has already been proved since this data provided significant help to the OEM of the aircraft and the Smartlink in troubleshooting the previously mentioned fault present on the Aircraft A "L Window Heat Fail", which allowed for the identification of the faulty window sensor. The Smartlink helped the OEM of the aircraft to perceive and conclude that the fault only happened when the aircraft was in its cruise flight phase and therefore recommended performing the AW referenced previously in the troubleshooting manual, with the aircraft pressurised, correctly identifying the faulty window sensor.

If the Smartlink data were not available for some reason, the aircraft would probably have stayed on the ground a lot longer than it was, and the correct sensor identification would not be possible in a short time. On the first time that the service centre performed the AW by the recommendation of the CAMO, a presumable final stage of the resolution was the anticipated removal and substitution of the entire window, not taking into consideration the AOG state time that the aircraft was on the ground, the new window transportation, and all the logistics associated with the event, as well, as the loss of significant revenue to the company, leading in the worst case scenario to several flights delays or cancellations.

One of the key features presented by the OEM of the Smartlink is that it can significantly reduce downtime and improve troubleshooting, with the possibility to remotely access and visualise all MDC codes stored in the MDC throughout the flight of the aircraft. However, this feature is currently unavailable due to the certification processes not being finished in the corresponding documentation. The STC of the system is not yet EASA approved for this feature; therefore, the Smartlink components are not physically connected to the MDC.

The system is suffering significant updates to its current state to improve and stabilise the platform. When all the considerations above related to this matter, change, and an update to the system allows for the system stabilisation, the MDC codes to be transmitted, the generic aircraft data and take-off report transmitted, with the system speed improvements to the 15 minutes mark, the Smartlink can fully reach its potential as a game changer tool when the matter is aircraft maintenance and troubleshooting.

5.2.2. Reliability

The significant amount of data that Smartlink can record and transmit may have a considerable impact and use if correctly applied to the reliability analysis of components and life limit parts and, subsequently, the overall reliability of the aircraft. However, for this information to be correctly applied and to obtain any result or conclusion, it’s necessary to have a reliable historical record of data regarding each applicable fault in the aircraft. The OEM of the aircraft may be the responsible organ to perform the data treatment of the Smartlink system, to better suit the aircraft maintenance intervals of components or life limit parts using the MSG-3 methodology in a reversed engineering process.

This is necessary for the OEM to prepare the tool for everyday use better and to know precisely what is the best selection of parameters and subsequent creation of templates, preparing the ground for investigations to be able to exist, applicable to the specific component itself and its reliability, also allowing to an improvement of the design of the component itself.

To maximise the reliability, it’s essential to know how each component behaves to the several structural stresses and loads applied in each applicable different work environment. With this in mind, the Smartlink can provide significant help in understanding this field of study due to the wide variety of flight environments to where the aircraft has previously flown and which the applicable conditions were, always having access to an extensive range of data and parameters.

When the system is fully operator usable, this information can more precisely and accurately complement the data that allow the OEM of the component or aircraft to more accurately determine the respective MTBF. Using everyday operational data, the OEM can solidify the results obtained during the production phase of the aircraft and better suit the MPD following the MSG-3 methodology, reduce maintenance intervals, maximise flight operation time, and never jeopardise flight safety.

The information recorded can even be more critical when considering that it can be used to analyse and compare quality in the assembly lines of the OEM, reliability analysis of safety and non-safety critical components, and all other production quality analyses may be applicable areas.

6. Conclusions

To allow this dissertation to be written, everyday use of the system was necessary to understand the system´s capabilities and defects. Since the system was relatively new on a retrofitted aircraft, the knowledge of a heavy user is much appreciated by the OEM of the system. With this in mind, the OEM required a full report of the system anomalies and suggestions for improvement (Documents in the annexe.) These documents were developed and delivered, and currently, the system is under updates, and in a stabilising phase. After the system is stable in the Challenger 350, the processes should go on system transmission speed and reliability, followed by suggestions given by the CAMO.

Currently, the system is on a series of updates to be stabilised and for its overall reliability to be improved. Based on the previous work done, the current system status has been improving, but it is still not operator usable at the present moment.

It´s possible to conclude that the system has incredible potential regarding all the topics and possible technical advantages initial described by the OEM; however, in the current system state, it’s only used to identify and help in the troubleshooting of specific complex faults, not initially solved with regular troubleshooting, like the concrete example of the L Window Heat Fail. The system is not the primary solution for regular everyday operations regarding technical dispatch. Still, it can be convenient as a background tool for the maintenance operations of the operator.

All the other advantages mentioned can be achieved when all the issues are solved, and the overall system is fully functional as the OEM perceives it.

"One of the things that is critical for the system to be operator usable is the report of the aircraft MDC codes, within the 15 minutes time window, for all the reasons mentioned previously and to effetely bring a significant advantage to the technical dispatch."

Future works

As suggestions for future works, it is recommended to continue the work done in this dissertation with the SmartLink system after the tool is fully functional on the CL 350. This would allow us to perceive the tool's current state and compare it to the expected future state, allowing for the study of the system´s effectiveness and providing feedback support to the AMCC.

The Smartlink tool has incredible potential and can also be used to study reliability if fully functional. Other suggestions for future works that could be appointed may be a reliability study of a specific component, providing suggestions for improved design of the component itself and how to better suit the MTBF to the MPD of the aircraft, and proposing new maintenance intervals for the respective component, if applicable.

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Annexes

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SUGGESTIONS OF IMPROVEMENTS FOR THE SMARTLINK AHMS AND SLP SERVICES

The purpose of this document is to give feedback to Bombardier about the AHMS and SLP to improve the general condition of the system and services.

1. Multiscale graphs and charts.
2. Improvement in the search of parameters
   a. Search tool works for words instead of phrases.
   (*Example: Searching for Hydraulic quantity does not correspond to any parameter and Hydraulic system quantity parameter exists.*)
3. Library of parameters and reference to where the system is capturing parameter signal and value. (LRU is very generic, ideally sensor identification that is capturing the parameter signal).
4. Possibility to select all parameters in the selection of parameters.
   (Only possible with FDE parameters).
   a. For an ATA Chapter for instance, within the 100 parameter capacity of the system.
5. Improvement in the description of the parameters.
6. Export and download different variables and parameters in the same graph.
7. Lollipop CAS messages in the Full Flight Analysis, or the possibility to select which lollipops we want to see in the FF analysis.
8. Availability of "default" templates for "high" level faults.
   a. For the most common ones, because each fault can be specific to the aircraft, template parameter selection must be adapted to each aircraft and situation, however in the first approach to each fault, it would be nice to have this feature available.
9. Possibility of searching specific faults history, in all the aircraft flights; Now it is only possible to search faults per flight.
10. Possibility to upload two or more templates at the same time. It's not practical to have a template with 50 parameters and other with 20 and we cannot add them together.

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11. When maximizing charts in the web-visualization tool FDE parameters description on the charts have no clear distinction between them. For instance on the maximized chart I don't know which one is the left or right generator. Example:

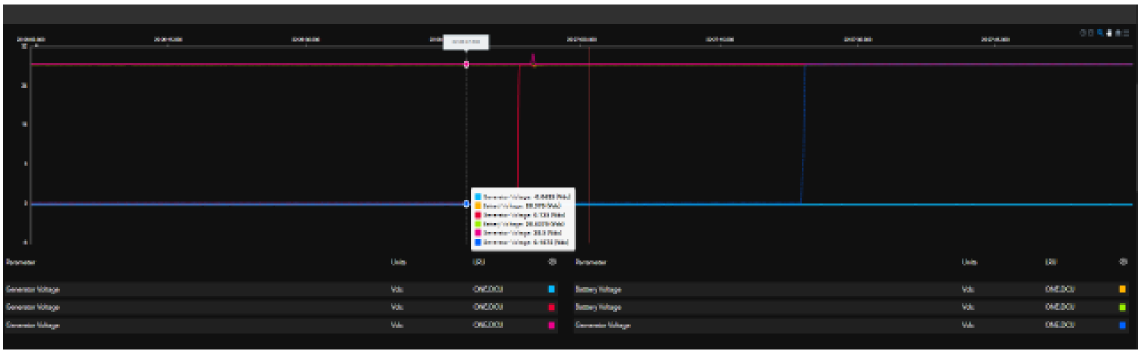
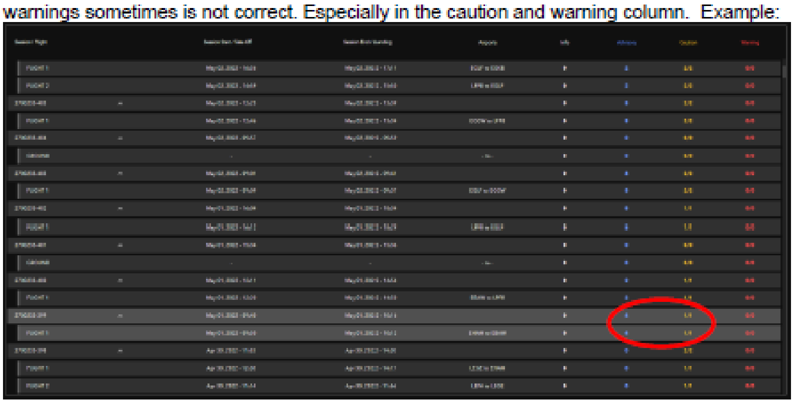


Figure 1- Maximized Chart

VS

Figure 2- Non maximized chart

12. Historical sessions of the aircraft display the session and flights, in the session with all the flights, the list of advisories shows the sum of all the advisories CAS in each flight, this should be reviewed because the number displayed on the list of either advisory, cautions, or warnings sometimes is not correct. Especially in the caution and warning column. Example:



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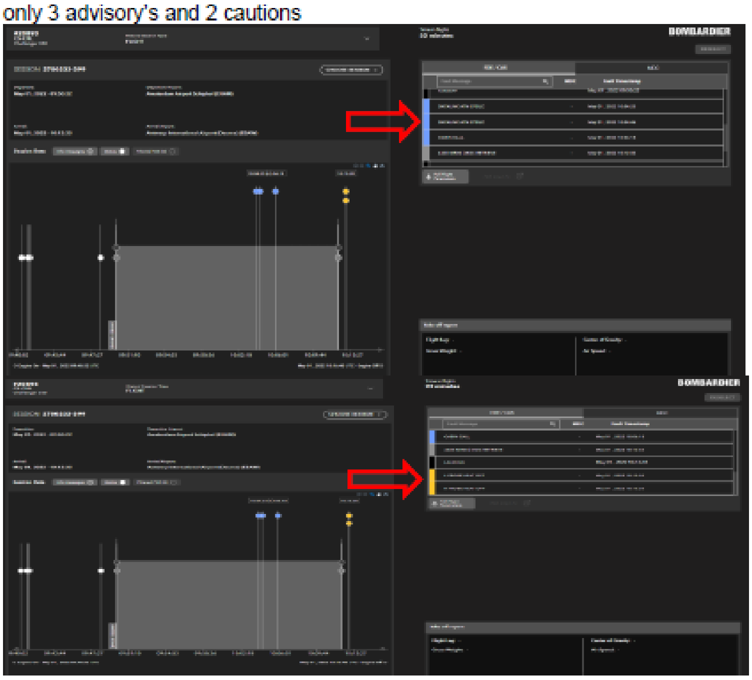
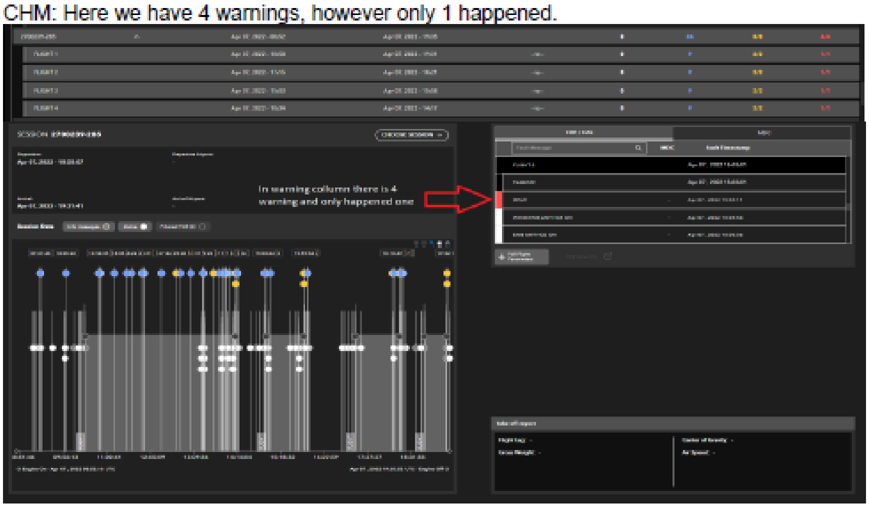
On this flight, there is 4 advisory and 1 caution in the columns, however, there were only 3 advisory's and 2 cautions



This happens in both tails, being worse in CHM.
CHM: Here we have 4 warnings, however only 1 happened.



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Issues Table of Smartlink System

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ID Nº	Issues	Date Opened	Current Status/Remarks	Impact	Resolution	Notes	Date Closed
1	Separation Between Ground and Flight information	01/04/2022	BD Answer: Improving ground and flight session clarity with a new design. *(Suggested that bombardier will separate completely the two types of data through a filter of information.)*	LOW	Closed		17/May/2022
2	No Information Displayed on CS-CHM (S/N 20900)	01/04/2022	CAS messages and data visualization are now visible when the system allows the visualization. However, my maintenance sometimes bugs, and it's only possible to see ground sessions. When this happens current flight session is from January. E-mail notifications working, **it's the only way** to know what happens to the Aircraft.	CRITICAL	Closed		01/July/2022
3	No Departure and Arrival Airports CS-CHM (S/N 20900)	01/04/2022	BD Answer: We should support "null" value for departure and arrival airports. For Global 7500, we should have already displayed the right data. For Challenger 300/350, there is no departure airport and arrival airport in IFR. For historic session, we have searched the parameters to get the airport information.	HIGH	Closed		01/July/2022
4	Event Count not Working	01/04/2022	BD Answer: The event count is now working.	MEDIUM	Closed		01/July/2022
5	MDC Fault Codes	01/04/2022	BD Answer: MDC events are not available through IFR and bulk transfer. Roughly after several months, we should have that available.	**CRITICAL**	Open	BD waiting for STC Mod EASA Approval. Estimated date: September.	

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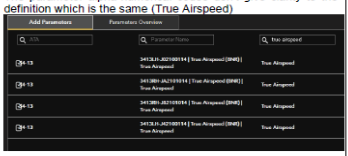
6	System time discrepancies	01/04/2022	General system-generated timestamp due to data issue. (Intermittent). Wrong Arrival Times. It Seems System shuts down in mid-flight or shortly after take-off.	**HIGH**	Open		
7	Parameter not properly working	01/04/2022	FDE Displayed Cabin Altitude parameter is not working. Others seem to be working fine. CDB´s version: CHL: BBD 42-2003-0106 CHM: BBD 42-2003-0106	**HIGH**	Open		
8	Parameters with the same description but different codes	01/04/2022	BD Answer: "More clarification is needed. 1) Need a clarification from customers on what details they want. – Mike and Ebuka will help to follow up. 2) Mike and Chenjin will review the data dictionary to make sure it is easier for users. Customer answer: 1) Parameters name is something like 3445LH-J027…- 3445 is assuming ATA chapter and subchapter and LH is likely Left Handed, but what the following code stand for? Tim Answer: In this example there are 4 parameters, that initially seem like 2 are redundant as only 1ea of LH and RH seem applicable. The parameter alpha-numerical codes don't give clarity to the definition which is the same (True Airspeed) 	**MEDIUM**	Open	BD to release alpha-numeric name logic to NetJets - RELEASED.	

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			NJE Answer: As Tim referred they can be redundant signals, but it would be nice to have that information directly on the parameter selection. (In parenthesis for instance). When searching parameters I expect the display of the correct true parameters, not the redundancy ones, and in this current state, the redundancy signal parameter not being specified as redundant only generates confusion, because there is no way of knowing if it is selecting the true one or the redundant one. BD Released support documentation regarding parameter naming. 2) Where is the data dictionary? In-Development (No date)				
9	E-mail notifications	01/04/2022	Normally, E-mail notifications take about 2 hours to reach us. System data takes about one day of delay and sometimes 2.	HIGH	Closed	E-mail notifications now working.	01/July/2022
10	Template creation	01/04/2022	Online saving of templates not working.	MEDIUM	Closed		23/05/2022
11	Technical Specs Smartlink system	20/04/2022	Waiting Info. (Waiting for more robust data)	LOW	Open	Data transmission speed. Data Size. WAN connections- No limit? Data Storage-How long? (6 Months)	
12	Wi-Fi or Cell connection/ System Speed	20/4/2020	Not happening when it is supposed to. **Huge delays** between aircraft data transmissions. CS-CHM is reporting faster	MEDIUM	Open	Aircraft data transmission should be with WOW and with speed below 60 knots.	

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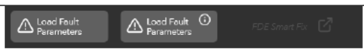
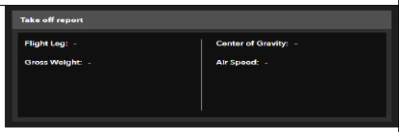
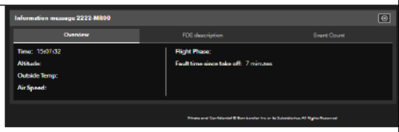
			CS-CHL report is way too slow					
13	Inconsistent Flight Data	20/04/2022	Waiting info. Flights missing or missing Departure and Arrival Airports Inconsistent flight data in both aircraft (CHM & CHL) (Missing Fights or incorrect departure and arrival times and airports).	HIGH	Open	Delayed transmission related. Transmission errors- 50% CHL (Volatile Issue)	
14	Load Fault Parameters Buttons & FDE SmartFix Button not selectable	20/04/2022		HIGH	Closed	Solved.	22/04/2022
15	Take Off Report	03/05/2022		HIGH	Open	Take off Report Not Working Feature not yet implemented. Developed for the G7500.	
16	Information Overview regarding faults	03/05/2022		HIGH	Open	Fault overview general data not available. **Not** all faults have this "overview box". Does not work on the ground.	

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17	Cross-Reference to Improvement Suggestion 11	05/05/2022	Solved.	MEDIUM	Closed	Maximizing charts	20/05/2022
18	Cross-Reference to Improvement Suggestion 12	05/05/2022	Solved.	MEDIUM	Closed	CAS Advisory, Cautions, and Warnings Count	01/July/2022
19	Airframe & Engine Hours	29/07/2022	Web Visualization tool Crashes when editing Airframe & Engine hours/Cycles	MEDIUM	Open		

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