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Parking Effects on Aircraft Reliability and Flight Performance

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Aviation Management Program – Class of 2020

EMBRY-RIDDLE
Aeronautical University
CENTRAL & SOUTH AMERICA

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A Capstone Project Submitted to Embry-Riddle Aeronautical University in Partial Fulfillment of the Requirements for the Aviation Management Certificate Program

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This Capstone Project was prepared and approved under the direction of the Group's Capstone Project Chair, Dr. Leila Halawi
It was submitted to Embry-Riddle Aeronautical University in partial fulfillment of the requirements for the Aviation Management Certificate Program

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Abstract

Group: 5

Title: Aircraft Parking Effects on Reliability and Flight Performance

Institution: Embry-Riddle Aeronautical University

Year: 2020

During the pandemic period caused by Coronavirus (COVID-19) in 2020, the airlines have parked or stored their fleets partially or wholly worldwide. The International Air Transport Association (IATA) estimated a major downsize in approximately 65% of the worldwide airline fleet's airline operational activity at the end of April 2020. With that said, mechanical and electrical systems, when stopped during long periods, can deteriorate by corrosion, contamination, discharge, and oxidation (Boeing, 1998). During the aircraft parking or storage process, it is not different (Airbus, 2020). This study aims to understand how much the aircraft performance and reliability are affected by parking and storage processes when these processes are correctly applied following the aircraft manufacturer's manuals and instructions. The research is applied regarding the study's nature, exploratory in front of the study's objective, quantitative in light of the research approach since all reliability databases are numeric. The study group will apply a t-test statistical tool to compare the averages among the reliability and operational database. The results suggest a real impact on the aircraft's technical performance that stopped in the parking process during this critical period for airlines. The post-pandemic findings show more than 20% of worsening in the average of failure reports in general and identify worsening in pre-established subgroups according to the aircraft's downtime or age. It was also identified

aircraft systems that should focus on the engineering and support areas in the return of operations, by the considerable increase in failures.

Resumo

Grupo: 5

Título: Efeitos do Parking das aeronaves na Performance de voo e Confiabilidade

Instituição: Embry-Riddle Aeronautical University

Ano: 2020

Durante o período de pandemia causado pelo Coronavírus (COVID-19) em 2020, as companhias aéreas estacionaram ou armazenaram suas frotas de forma parcial, ou total, ao redor de todo o mundo. A Associação Internacional de Transporte Aéreo, da sigla em Inglês IATA (International Air Transport Association) estimou uma redução de aproximadamente 65% da atividade operacional da frota aérea mundial no final de abril de 2020. Desta forma, os sistemas mecânicos e elétricos, quando parados durante longos períodos, podem se deteriorar por corrosão, contaminação, descarga e oxidação (Boeing, 1998), e durante o processo de estacionamento ou armazenamento de aeronaves, não é diferente (Airbus, 2020). Este estudo tem como objetivo compreender o quanto o desempenho e a confiabilidade das aeronaves são afetados pelos processos de estacionamento e armazenamento, mesmo quando esses processos são corretamente aplicados seguindo as instruções e manuais do fabricante da aeronave. A pesquisa é aplicada quanto à natureza do estudo, exploratória frente ao objetivo do estudo, quantitativa à luz da abordagem da pesquisa, uma vez que todas as bases de dados de confiabilidade são numéricas. O grupo de estudo aplicará uma ferramenta estatística de teste t para comparar as médias entre o banco de dados de confiabilidade e operacional. Os resultados sugerem um impacto real no desempenho técnico das aeronaves que pararam no processo

de estacionamento neste período crítico para as companhias aéreas. Os achados pós-pandêmicos mostram mais de 20% de piora na média dos relatos de falhas em geral e identificam piora em subgrupos pré-estabelecidos de acordo com o tempo de inatividade ou idade da aeronave. Identificamos também sistemas de aeronaves que devem focar nas áreas de engenharia e suporte no retorno das operações, pelo aumento considerável de falhas.

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Chapter I

Introduction

During the pandemic period caused by Coronavirus (COVID-19) in 2020, the airlines have parked or stored their fleets partially or wholly worldwide. Per Airbus (2020) and Adrienne *et al.* (2020), this pandemic scenario called for different measures and reactivity to provide practical support to the aircraft operators while keeping the highest safety levels even during the aircraft's ground period.

International Air Transport Association (IATA) estimates a major downsize in airline operational activity of approximately 65% of the worldwide airline fleet at the end of April 2020, which also decreased the revenue passenger per kilometers (RPK) of about 40% for the domestic travel and about 60% of the international flights (IATA, 2020).

Boeing (1998) states that during the parking or storage process, the aircraft systems lack of operation and regular functioning and maintenance can cause many issues such as loss of component mechanisms lubrication, fuel tank contamination, batteries discharge, portable water contamination, hydraulic system contamination, and several other systems and/or components (such as tires, oxygen cylinders, hydraulic systems and pressure loss in the shock struts of the landing gears). Airbus (2020), Adrienne *et al.* (2020), and Parker (2020), on the other hand, said that never in the history of aviation have airlines had to ground so many aircraft, so quickly, due to COVID-19 pandemics, and the impacts to the airlines and aircraft are unmeasurable.

Since the low volume of airfare sales during the pandemic period demands parking and storage processes, the aircraft manufacturers release articles and workshops related to performing both processes properly. In addition to the best practices, the maintenance interventions are described in the aircraft maintenance manuals. On the other hand, during this pandemic, the airlines are slowly returning some aircraft to operation, either for freight or passenger operations (CNBC, 2020). Sooner or later, the entire world fleet, with its adjustments, will return to operate with the aircraft that is on the ground.

Project Definition

Following Boeing (1998), Airlines' experience brings reliability greater and lower levels of faults found after maintenance checks for airplanes in regular service than planes used sporadically, such as infrequent charter flights parked/stored airplanes. When an airplane is in service, the flight crew's responsibility is to monitor the airplane performance. This includes the cabin systems; the maintenance staff executes maintenance (corrective, preventive, or predictive). Finally, the onboard systems and avionics are running diagnostics to monitor the aircraft's operational results. The regular operation keeps its systems and components functioning, lubricating, moving the parts, which makes a greater airworthiness level (BOEING, 1998).

IATA (2020) states that guaranteeing aviation airworthiness is an essential part of airline operations safety. On the other hand, the preservation and storing challenges to the continuity of airplane airworthiness in the conditions of prolonged inactivity of the worldwide fleet are abundant (IATA, 2020). With that said, the capstone research question is: What is the effect of parking and storage on aircraft performance and reliability?

This capstone aims to understand how much the aircraft performance and reliability are affected by parking and storage processes when these processes are correctly applied following the aircraft manufacturer's manuals and instructions. This capstone will analyze a Brazilian Airline's reliability data to comprehend if the number of aircraft faults increases or decreases after a parking or storage period, upon service return, compared to the period before the aircraft stops operating.

Project Goals and Scope

The noted research intends to analyze a Brazilian Airline's reliability and operational data. The data is structured per revenue cycles, pilot reports (PIREPS), preventive reports coming from support areas, and Operational Interruptions (greater than 15 minutes) in a pre and post-pandemic period and selecting a group of aircraft that had to be parked or stored for strategic company reasons.

The research will understand global fleet operational, maintenance, and engineering strategies for better performance from operational reliability. Thus, the outcome of the study may result in reducing delays, cancellations, Aircraft on Ground (AOG), operating costs that at this moment are paramount for all airlines.

The research's scope is to analyze a Brazilian Airline's reliability and operational data of the narrow-body fleet (Airbus A319, A320, and A321), representing 80% of the airline fleet, and 39% if we consider the entire group fleet (with other subsidiaries). The researchers will exclude the wide-body fleet composed of Airbus A350, Boeing 767, and Boeing 777 aircraft. All subsidiaries fleets due to the differentiation of the aircraft systems and their complexities. In addition to the operational reliability database being different, different information is stored, and additional accesses are required.

Figure 01 represents the research scope compared to the total airline fleet. The outside circle represents the whole group fleet, including the Brazilian fleet and other subsidiaries; the middle ring represents the Brazilian's fleet only. Finally, the inner circle represents this capstone's fleet scope: the Brazilian fleet's A320 family fleet.

Figure 01: Research scope - A320 fleet of a Brazilian airline that is part of a large group of South American companies.

Definitions of Terms

ATA Chapter or ATA 100 - It is a standardized numerical reference to define and classify each commercial aircraft system;

MAREP - Maintenance Report. A technical issue was reported by maintenance staff in the aircraft Log Book.

OI - Operational Interruption. Flight delays (> 15 minutes, Cancellations, Flight Interruptions as Air Turnbacks, Diversion, Rejected Takeoffs) due to technical reasons.

OR- Operational Reliability (Operational Interruptions rate per 100 revenue flights).

PIREP - Pilot Report. A technical issue was reported by the technical crew in the aircraft Log Book;

Revenue Cycle or Revenue Flight A flight carrying one or more revenue passengers;

List of Acronyms

AC – Advisory Circulars;

AOG - Aircraft On Ground;

AMM – Aircraft Maintenance Manual;

APU- Auxiliary Power Unit;

ATA – Air Transport Association;

FAA – Federal Aviation Administration;

IATA – International Air Transport Association;

LRU – Line Replacement Unit;

MPD – Maintenance Planning Data;

MRO – Maintenance, Repair and Overhaul;

OEM – Original Equipment Manufacturer;

RTS – Return to Service;

SIL – Service Information Letter;

SMS - Safety Management System;

Chapter II

Review of the Relevant Literature

Operational Reliability

In the early days of aviation, the analysis of dependability for maintenance planning was not an issue as maintenance was executed when needed (Tiassou *et al.*, 2013). Maintenance was conducted in a corrective way instead of preventive or predictive. Later on, in history, the need to improve aircraft systems dependability started being in the light. The aeronautical authorities worldwide initiated to require maintenance programs for aircraft operations (Tiassou *et al*., 2013).

Following Zio *et al.* (2019), having a high level of reliability requirements determined by the aeronautical authorities is not simple for the aviation segment, mainly considering all the manufacturing scale and complexity of the new aircraft types and technologies. The new type of airplanes, such as Boeing 787 and Airbus A350, for instance, comprises more than 5 million parts. These parts are designed and fabricated over different countries, through different cultures, thousands of employee involvement in all the steps of manufacturing, from the design to the flight tests and commercialization, where it is estimated a total amount of 10 million labor hours in all the mentioned manufacturing process (Zio *et al.,* 2019).

Operational reliability is defined as the unscheduled service interruptions measurement caused by technical issues at the aircraft systems and its components, associated with further required maintenance (Saintis *et al*., 2009; Sun *et al*., 2015). For Saintis *et al*. (2015), there is some type of different interruptions, as follows:

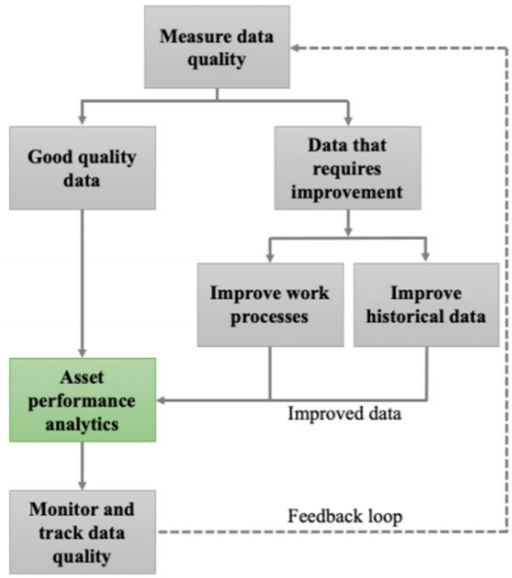
- flight cancellations (the aircraft is technically inoperative to depart);
- takeoff delays (the aircraft departs out of scheduled departure time);
- in-flight turn-backs (the aircraft needs to come back to the departure airport).
- air diversions (the aircraft needs to land at a different airport from the destination);

To have useful data analysis for asset reliability monitoring, Lukens *et al.* (2019) defined a data quality best practices workflow, presented in figure 2, for utilizing maintenance data performance analytics. Data that is "sufficiently-good" for asset performance analytics can be used immediately, while work processes to improve insufficient data can be put into place (Lukens *et al.*, 2019).

Sun *et al.* (2015) brought the idea of operational reliability assessment by time-varying characteristics and variables diversity, focusing on each machine of aircraft or engines. The noted evaluation to identify the reliability asset level in service, for Sun *et al.* (2015), is called Prognostics and Health Management (PHM), which can be considered a technological advance made to improve the reliability and safety of components or systems.

Lukens *et al.* (2019) determine the first step of a reliability data model workflow is to quantify the data in terms of areas of "sufficiently-good data" and data that is "poor" and requires improvement. The places where the data quality is identified as "sufficiently-good" can be immediately used for asset performance analytics initiatives by generating specific metrics and identifying poor-performing assets. On the other hand, for the determined low data quality, start putting work process improvements that ensure that the wrong data areas turn into the right regions, which can then feed into the asset performance analytics. All the mentioned processes described in the last two paragraphs are summarized in figure 2.

Figure 02: Reliability data model (Lukens *et al.*, 2019)



For the airlines, Saintis *et al.* (2009) said that unscheduled aircraft interruptions represent a high direct cost in terms of taxes (airport), fuel consumption, flight crew and passengers hotel and public accommodation, financial reimbursement and/or compensation, flight delays, line replacement units (LRU) parts replacement, flight cancelations. This type of issue also brings some indirect costs, such as but not limited to, customer loyalty program impact, loss of image, lack of aircraft availability, etc. With that said, aircraft reliability is closely followed by the airlines' in-service aircraft and aircraft and significant components manufacturers (SAINTIS *et al.*, 2009).

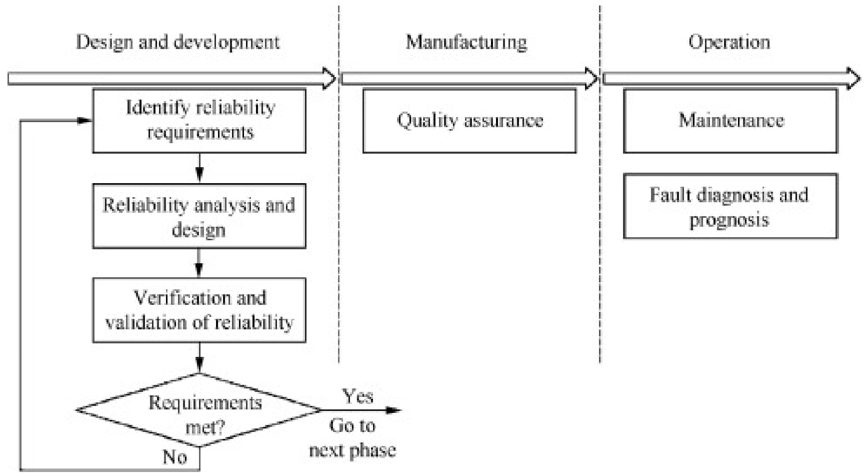
Another reliability model is presented by Zio *et al*. (2019), where the authors called civil airplanes' reliability lifecycle. The noted model can be summarized in three steps, which are:

1) Design and development - In this phase, it is designed solutions for systems and components to satisfy the requirements from all the different aspects of the plan. At the end of this phase, there is needed verification and validation to ensure the solutions meet the requirements.

2) Manufacturing - The manufacturing phase starts with manufacturing the airplanes following the requirements defined in step 1.

3) Operation - After design and development, and manufacturing, the planes enter into service with the airlines, and the operation phase begins. Figure 03 illustrated the three steps just presented.

Figure 03: Life cycle reliability model (Zio *et al.*, 2019)



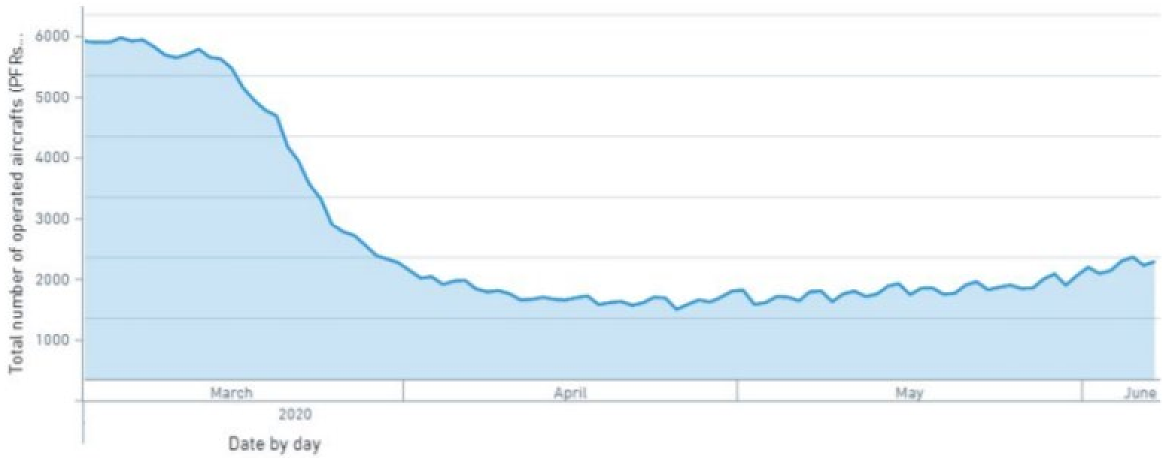
Aircraft Parking and Storage

After a new commercial airplane enters into service by the manufacturer, leaving the design and tests phase, the maintenance program required by the aviation authorities on their aeronautical regulations are needed to take place at the airlines.

The airline's maintenance program, in addition to the requirement made by the Original Equipment Manufacturer (OEM) on the Maintenance Planning Data (MPD), ensures the aircraft performance keeps within the parameters as expected during the design of the aircraft, thus being able to attend the operational performance parameters (Zio *et al.*, 2019).

Considering the actual scenario due to the pandemic period caused by COVID19, the airlines were forced to reduce their operations drastically (PARKER, 2020). As a result, we're able to meet demand using a small percentage of their current fleet. This is a strategic decision to preserve finances in a scenario that foresaw a severe economic threat (AIRBUS, 2020). Figure 04 shows the reduction of operated aircraft by the airlines worldwide per day after the pandemic started. It is possible to see the decline of about 65% of the flights from the beginning of May to the middle of June of 2020.

Figure 04: Number of Operating Aircraft Reduction (Airbus, 2020)



Due to the reduction of operating aircraft, following IATA (2020), Airlines must preserve their equipment correctly, and considering the scenario, there are two different preservation types, which are Parking and Storage.

For IATA (2020), aircraft parking and storage alternatives described by the aircraft manufacturers for the respective type of aircraft are part of the Aircraft Maintenance Manuals (AMM) Chapter 10, Parking, and Mooring. On the other hand, the OEM's latest changes and flexibilities for such possibilities may need to be tracked through other OEM specific documents. These documents are not limited to Service Information Letters (SIL) since these records are not in the AMM, not even in even temporary revisions

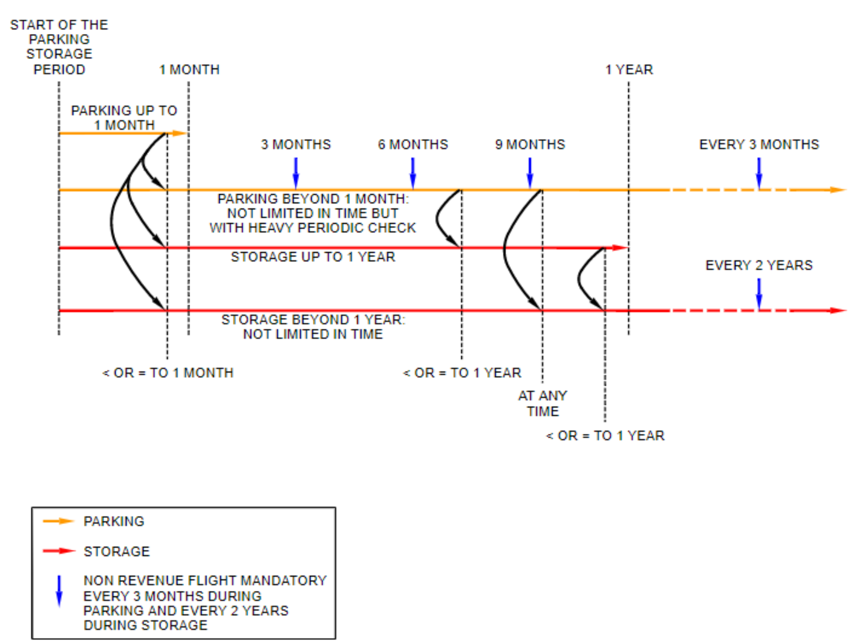
Airbus (2020) explains that parking is a procedure to preserve the aircraft's up to 6 months without operating the aircraft. This shorter period of disruption in operations requires a reduced number of systems to be maintained. The pros of this type is the reduced number of systems preserved. Also, in the case of service return, it is easier and faster than the Storage procedure. Cons of parking are that recurrent checks are requested, like engines and APUs run periodically and inspections on specific systems that consume maintenance Manpower of the airline.

According to Airbus (2020) and Bertrand *et al*. (2020), storage procedure is considered when the aircraft will be out of service for up to 2 years. Once the aircraft do not operate for a more extended period, this type of preservation is more complicated than a parking process. More systems will be preserved, engine lubrication lines and fuel lines must be drained, and several additional procedures are needed. The pros of this procedure, Bertrand *et al.* (2020), are that recurrent inspections and engine runs are not desired so that the maintenance workforce can be allocated on operational aircraft. The con of a stored procedure is that it is more complicated than parking, and the desired actions to put the plane back to operation takes more time than the other method.

Parking and storage procedures behave as internal variances; these variances are directly related to the complexity of maintenance tasks desired during this period. Airbus considers four different types of preservation that can be applied to aircraft based of operator convenience, they can be divided into:

- Parking period of not more than 1 month in flight-ready condition.
- Parking period of more than 1 month in flight-ready condition.
- Storage period of not more than 1 year.
- Storage period of more than 1 year.

Figure 05: Parking and Storage Chart (Airbus, 2020)



Besides the preservation period of the aircraft, each preservation possibility's main difference is the maintenance tasks related to each one and the complexity to return the aircraft to an operational condition whenever necessary. For example, recurrent engine runs are necessary on parking procedures, which involves manpower, planning, fuel, and more interaction with the aircraft.

For storage, the period is recommended for engine removal and storage of them in a controlled environment, which reduces maintenance personnel interaction with the component.

The aviation industry infrastructure, by Bertrand (2020), was surprised by the pandemic scenario, since following the author, it is not optimized to accommodate all the airlines fleet simultaneously at the same time, having all the airplanes parked or stored outside of their familiar hub locations or flight destinations.

Lack of space became critical during the pandemic period in 2020, considering service network stations, MRO facilities they customarily use for maintenance purposes only, are overloaded with airplanes, and because this space is less costly than airport slots (IATA, 2020).

Airlines' challenge is to balance and select which type of preservation procedure will be adopted, considering involved costs, periodic checks, availability of spaces, and the expected return to service based on global economic recovery after the COVID-19 pandemic (IATA, 2020).

The return to service (RTS) is a phase where the airlines must carefully coordinate, considering all possible risks and mitigation measures to identify its safety management systems (SMS). The continued monitoring of all maintenance interventions due to the aircraft and its components is essential for the airworthiness post parking or storage periods (IATA, 2020; AIRBUS, 2020).

During this preservation period, it is quite common for the airlines to cannibalize parts from one aircraft in parking or storage to keep others in service flying. It is additional attention to point out on the RTS that should be given to address any aircraft released appropriately to be checked if any components/parts that were removed were replaced and adequately installed and tested, if required (IATA, 2020).

Summary

This chapter introduces operational reliability and operational report analysis concepts essential for the aviation industry, where operators monitor flight delays, air turnbacks, and any operational disruptions caused by the aircraft by itself. Based on statistical data and constant monitoring, evaluates, and proposes equipment improvements.

Due to market retraction due to Covid-19, another critical aspect is the storage and parking procedures used by airlines to maintain aircraft preserved during this period. This chapter also explains the different preservation types proposed by manufacturers and the main difference considering the return to service of the aircrafts.

Chapter III

Methodology

The noted capstone is applied research regarding the nature of the study. Following Habib *et al.* (2014) and Biddix (2019), used analysis means a course that is designed to understand a phenomenon and apply the results of the research to solve, or to propose a solution, to a current research issue within an organization, or an industry in general.

On the other hand, related to the research's objective, it is considered exploratory since exploratory for Habib *et al.* (2014) is undertaken to explore new ideas or concepts following the conceptual models, hypothesis, and empirical evidence. Since the COVID-19 pandemic had repercussions in an unprecedented crisis for the aviation industry, which resulted in an extraordinary number of aircraft going through the parking and storage processes, it is understandable that the methodological approach chosen by this capstone presents itself as adequate, since exploratory studies are indicated when the phenomenon to be studied is unprecedented. There are still no hypotheses firmly tested on the subject (Leavy, 2017).

Table 01 shows the research study with specific keywords of this capstone in academic sources as listed, and no significant educational material was found.

Table 01: Exploratory research on academic sources over the capstone subject

Academic Source	**Research date**	**Keywords and/or combination of keywords**	**Amount of relevant findings**
Embry Riddle Hunt Library	September 05, 2020	Aircraft performance affected by parking; Aircraft performance affected by storage; Aircraft reliability changing by parking; Aircraft reliability changing by storage; Airline parking and storage impacts on aircraft performance;	One research (BERTRAND *et al.,* 2020)
Google Academic	September 5, 2020	Aircraft performance affected by parking; Aircraft performance affected by storage; Aircraft reliability changing by parking; Aircraft reliability changing by storage; Airline parking and storage impacts on performance; Aircraft Parking and Storing;	Three types of research (IATA, 2020) (AIRBUS, 2020) (BOEING, 1998)

It used studies related to this paper's central idea, such as aircraft reliability, parking, storage, aircraft performance, and operational reliability. When searched separately from the "parking and storage effects on aircraft performance and reliability," all the noted keywords were found academic material and cited along with this study.

In terms of approach, this research is categorized as quantitative since all reliability databases are numeric. It will be applied to statistical tools to help find the results and test the research hypothesis. For Habib *et al*. (2014) and Biddix (2019), quantitative analysis usually involves collecting and converting all the different types of data into a numerical form to allow the researcher to apply statistical calculations to help on the conclusions of the capstone. According to Leavy (2017), quantitative studies seek to investigate and explain causal relationships, associations, and correlations. Thus, for Leavy (2017), this type of research involves measuring variables to discover possible relationships, correlations, or even to reveal recurring patterns. It is appropriate for studies whose main objectives are to explain or evaluate a given phenomenon.

The research will use the chosen airline aircraft reliability primary data, which for Habib *et al.* (2014) means the type of data sourced directly from the research questionnaire respondents, target users, or raw database without specialist treatment. It will be treated along with academic research. The raw data, as it is also called by Habib *et al.* (2014), can be in the format of figures, numbers, ranks, weights, and several other units depending on the type of the research.

We intend to evaluate and compare the aircraft's performance and their respective systems separated by ATA chapters in the pre-pandemic and post-operative periods.

Such studies generally answer deductive research questions, which reveal how the investigated variables relate to each other and their different effects and how they can be defined (Leavy, 2017). Thus, since the present capstone intends to investigate and scrutinize the different variables present in parking and storage processes and their impact on aircraft performance, it is believed that the proposed methodology fits the type of study and research problem thought in the present capstone.

Thus, it is believed that the capstone will bring light to this unprecedented problem to reveal the importance, need. Possible flaws linked to the process, thus contributing to the expansion of knowledge and greater depth regarding this critical knowledge gap, in addition to the possibility of indicating/ proposing additional actions to maintain the aircraft in parking and storage processes.

In light of performance reporting and analysis, it will be used at this study several concepts relating to aircraft reliability. For FAA (2007), the meaning of reliability is related to the intended functioning for a specific system, subsystem, unit, or part, for a determined period observed under certain operational and environmental conditions" (FAA - AC 20-157, 2007, p.6).

According to the FAA, the safety evaluation should be based and consistent with the reliability evaluation assumptions. This way, the safety evaluation will represent a safe opportunity to use the basic rules and beliefs used by what was advocated in SAE ARP 4761, from the review of several important safety tasks such as fault trees, failure modes and effects analysis, and other tasks (FAA - AC 20-157).

Data Source, Collection, and Analysis

The design envisaged for this work consists primarily of acquiring the necessary data from the airline. The data provided are a List of aircraft that have gone through the parking process; Aircraft flight cycles; a List of failure reports in the aircraft logbook and their appropriate classifications and treatment, List of operational interruptions of the aircraft with their proper categories and treatment.

All data were considered to start on January 1, 2020, until September 9, 2020 (cut-off date defined by those responsible for the work). The authors used the data sources available for the entire company for the study. This is official and controlled information, some of which are handled by the responsible areas.

The revenue cycles performed come from the Operational Control Center, the failure reports (PIREP and Preventive reports opened) will be captured from the maintenance management system in force at the company. This is the Lufthansa Maintenix platform. Operational Interruptions will be provided by the Reliability area, registering, classifying, and generating statistics through the Skywise system.

The authors structured the aircraft list in a table with some classifications for analysis regarding age and parking time. Aircraft registration will not be displayed in this capstone, they are listed in sequential numerical order. You can find the complete table in appendix 01 of this capstone.

1. Failure Reports and Report Rate

One of the parameters to determine a loss in technical performance will be the failure report rate and the pre and post parking period. In this analysis, we consider the technical crew (pilots) and the preventive items opened by the technical support and engineering when any trigger or repeatability criterion is reached. These failures are observed as the result of telemetry monitoring via the Airman system provided by the manufacturer. We excluded Maintenance Reports for this analysis due to no certainty of a technical issue and/or unscheduled failure in their contents. We excluded Ata Chapters not related to an aircraft system as well.

The ATA Chapters considered were:

Table 02 - ATA Chapter list

21 - Air Conditioning	31 - Indicating & Recording	49 - Auxiliary Power Unit (APU)	74 - Ignition
22 - Auto Flight	32 - Landing Gear	52 - Doors	75 - Engine Air
23 - Communications	33 - Lights	53 - Fuselage	76 - Engine Controls
24 - Electrical System	34 - Navigation	54 - Nacelles Pylon	77 - Engine Indicating
25 - Equip & Furnishings	35 - Oxygen	55 - Stabilizers	78 - Exhaust
26 - Fire Protection	36 - Pneumatic	56 - Windows	79 - Engine Oil
27 - Flight Controls	38 - Water & Waste	57 - Wings	80 - Engine Starting
28 - Fuel	44 - Cabin Systems	71 - Power Plants	
29 - Hydraulic	46 - Information Systems	72 - Engine	
30 - Ice & Rain Protection	47 - Inert Gas System	73 - Engine Fuel & Controls	

The Failure Report Rate will be determined as the representation below:

$$\frac{Reports}{Cycles} x100$$

After the gross comparison, we will apply some comparisons separating the aircraft into subgroups according to their parking period and age, seeking other insights for further analysis.

Another important Report Rate will be an analysis per ATA Chapter. That analysis intends to guide Engineering and Technical departments to evaluate if additional tasks or special care will be necessary for some specific system. We can observe increments in the failure report rate and understand if the referred chapters were more susceptible to parking effects. The authors may consider a 1000 cycles rate instead of the usual 100 cycles due to report numbers in each chapter.

Operational Reliability and Operational Interruption Rate

The general and established Operation Reliability equation is represented below and presents how many interruptions an airline has for each 100 revenue flights.

$$Operational\ Reliability\ (\ OR)\ =\ \frac{OI}{RFC}\ x\ 100$$

Where:
OI - Operational Interruption
RFC - Revenue Flight Cycles

This is the standard and fundamental analysis that will allow the analysis to determine if the airline faces more interruptions after the parking process.

Data analysis

One of the statistical tools used for data analysis will be the t-test. According to Field, the t-test is a parametric test based on the normal distribution; for this purpose, it is assumed that the data are measured at an interval level. Thus, two data samples are collected, and the mean of the samples is calculated. In this case, it is assumed as an experimental hypothesis that the two samples' means differ because of the differentiated manipulation imposed on each of them (and not for external reasons).

The t-test can be used for testing different groups (independent t-test) or for the same group, which will be evaluated from exposure to different experimental manipulations in a given time interval (dependent t-test, design of repeated measurements). For analysis of this study, it is assumed that the dependent t-test is the most indicated, and the equation used for it is presented below:

$$t = \frac{\overline{D} - \mu_D}{S_D\ /\ \sqrt{N}}$$

With $\overline{D}$ meaning the average difference between the two samples. With μ_D meaning the difference between the means (which, in case the null hypothesis is true, μ_D will be equal to zero). And $S_D / \sqrt{N}$ symbolizing the standard error of the differences, which is nothing more than the standard deviation of the sample distribution.

Explaining the application of the t-test for the present study

First of all, the differences between the scores found in the pre and post-pandemic situation (Overall performance and ATA performance) of each plane are added together to give the differences. Then, by dividing this difference by the number of airplanes, we have the average difference (that is, how much on average the score (of the ATA and general performance) of an airplane differed from the pre-pandemic condition to the post-returned condition). This mean difference is represented by/in the equation and indicates the data's systematic variation (representing the experimental effect).

The standard deviation of the differences between conditions represents the mean deviation of the difference in means, so the standard deviation is how much variation there is between the differences in scores, thus representing the non-systematic variation in the experiment.

If all aircraft or groups have the same rate or average, then the standard deviation will be zero, which means no non-systematic variation. In short, dividing by standard deviation means standardizing the mean difference between conditions. However, to know how the difference between the means of the samples behave, in comparison with what was expected if there was no experimental manipulation (that is, in our case, if there were no effects of the pandemic - parking process), instead of dividing the mean difference between conditions by the standard deviation of the differences, one should divide it by the standard error of the differences. This division (by standard error) informs how the two samples means compare and standardizes the mean difference between conditions.

Chapter IV

Outcomes

In this chapter, the authors intend to explain all the fleet classifications made for the various attempts at performance analysis proposed to us in this capstone. With a clear understanding of the criteria, the reader will be able to read and interpret the results obtained in all the different statistical analysis waves carried out.

Aircraft Table Information and Classification

The first wave of analysis will compare the aircraft's performance that passed through the parking process regarding reports rate and operational reliability. We will work with 53 Airbus A320 family aircraft and compare the average performance pre and post of this fleet to observe a difference in the performance and mainly if the difference is statistically significant using the t-test method.

In the second round of analysis, the group intended to evaluate and compare the effects of parking in the same parameters, but with the fleet segregated into three different main groups:

- Group 1: Parking period no longer or equal to 60 days (average of 43 days);
- Group 2: Parking period between 61 and 95 days (average of 81 days);
- Group 3: Parking period longer than 95 days (average of 113 days);

In all groups, we can observe that some aircraft performed at least one flight test or non-revenue flight during this period, or even in some cases, the plane needed to be used in operation for a few days. The second wave of analysis will break and compare each group into two subgroups depending on whether the aircraft flew or not while it was parked. Table 03 illustrates the complete table of aircraft and categories and the sample of aircrafts parked and its average days in preservation.

Table 03: Aircraft Overview by Parking Time Groups

Final Group	Aircraft Quantity	Days Parked (Average)
< 60 DAYS_No Flight	11	45
< 60 DAYS_Flight	5	41
60 to 95 DAYS_No Flight	7	81
60 to 95 DAYS_Flight	10	81
> 95 DAYS_No Flight	10	113
> 95 DAYS_Flight	10	113

Reports Rate per aircraft

A. Report Rate Table per aircraft (Pre and Post Parking)

The authors calculated individual rates pre and post parking with the specific rate and reports of each aircraft. It was possible to observe a rate range from 6,72 fault reports to 94,51 fault reports every 100 cycles. The complete report rate table is attached in Appendix 02 of this capstone. For the data treatment, the aircraft named on Appendix 01 as #A28 will be considered an outlier due to an abnormal Post Parking result. They will not be considered in the future analysis to guarantee a closer, realistic, and accurate statistical analysis.

B. Report Rate Average (Pre and Post Parking)

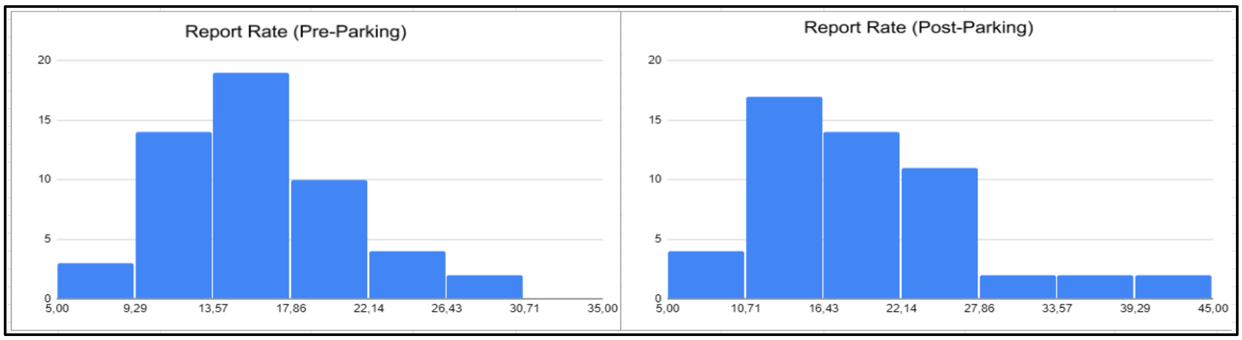
The first evaluation consisted of comparing both report rate averages (Pre and Post parking) to understand if the Post Parking performance was worse than in the Pre parking 2020 period. The pre parking resulted in 16 faults every 100 cycles, and the post parking presented 19,7 faults at the same flight frequency.

Description	Pre Parking	Post Parking
Average	16,0	19,7

C. Rate Distribution Histogram Graph (Pre and Post)

As a finding of the statistical analysis, it was possible to observe a similarity in both distributions' shape on figure 06, symmetry in terms of shape. In this case, the two-tailed t-test is indicated and can confirm if the mean difference is statistically significant.

Figure 06: Histogram Graph - normal distribution for the Pre and Post Parking performance



D. Two-tailed t-test result for Average Report Rate

With the results above, considering the Null Hypothesis of an insignificant difference between Pre Parking and Post Parking report fault rate average, we can reject the Null Hypothesis and statistically affirm that the Post Parking rate is considerably worse than the Pre Parking fault rate.

Description	Pre Parking	Post Parking	
Average	16,0	19,7	
Variance	23,8	67,6	
Observations	52	52	
Average Difference Hyphotesis	0		
df	83		
Stat t	-2,79231		*value obtained*
p (T<=t) Two-Tailed	0,00649		*proof value (p<0,05)*
Critical t Two-Tailed	1,98896		*Stat t outside the acceptance zone (> 1.98 and <than -1.98)*

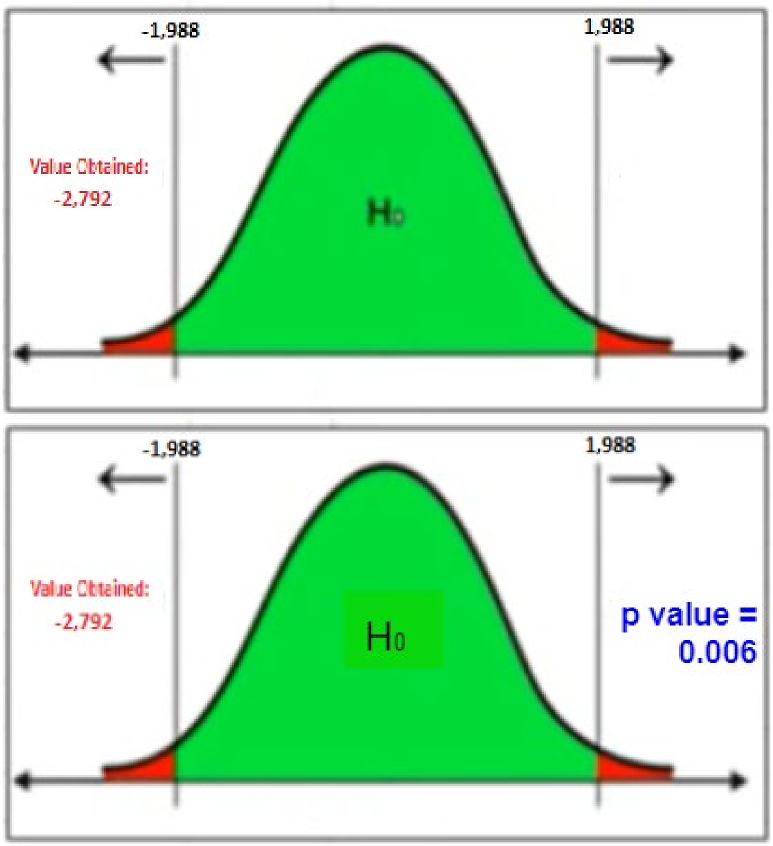


Figure 07 - Representation of a Two tailed t-test graphic with acceptance zone (green) and reject zone (red) based on stat t values and critical t values.

E. Two-tailed t-test result for Average Report Rate according to Aircraft Model

The authors evaluated the performance of each fleet model separately. They observed that the difference observed was statistically significant in fleets A319 and A320, but, considering that both fleets represented 92% of the whole group, the insight was pretty much similar to the overall result. It was not considered relevant information for this capstone purpose.

F. Two-tailed t-test result for Average Report Rate according to Aging Groups

Group 1 (6 to 10yo)	Pre Parking	Post Parking	
Average	13,8	14,6	
Variance	18,9	26,9	
Observations	18	18	
Average Difference Hyphotesis	0		
df	34		
Stat t	-0,502	*value obtained*	
p (T<=t) Two-Tailed	0,619	*proof value (p>0,05)*	
Critical t Two-Tailed	2,032	*Stat t value inside the acceptance zone (< 1,69 and > -1,69)*	

Group 2 (11 to 15yo)	Pre Parking	Post Parking
Average	16,4	23,0
Variance	17,4	69,9
Observations	18	18
Average Difference Hyphotesis	0	
df	25	
Stat t	-2,997	*value obtained*
p (T<=t) Two-Tailed	0,006	*proof value (p<0,05)*
Critical t Two-Tailed	2,060	*Stat t outside the acceptance zone (> 1.98 and <than -1.98)*

Group 3 (16 to 20yo)	Pre Parking	Post Parking
Average	18,1	21,8
Variance	29,6	71,4
Observations	16	16
Average Difference Hyphotesis	0	
df	26	
Stat t	-1,476	*value obtained*
p (T<=t) Two-Tailed	0,152	*proof value (p>0,05)*
Critical t Two-Tailed	2,056	*Stat t value inside the acceptance zone (< 2,056 and > -2,056)*

At the second round of analysis, it is observed that the intermediate group, with aircrafts age between 11 to 15 years of usage, was the only affected by the parking period, and that can lead us to conclude that aircraft of this age require airlines to take higher care levels or take different actions from the rest of the fleet when they return to operations. This analysis is important to demystify any tendency to consider an older fleet to need special management to return to operations.

G. Two-tailed t-test result for Report Rate per Parking Period Groups

Another finding of this capstone is to understand the hypothetical impact of parking period length on technical performance. In other words, if aircraft that stayed more than others presented a worse report rate. The effect of any intermediate flight in the parking period was considered as well.

It was applied to the t-test for all means according to parking groups. The result was that even worsening was observed, the parking period and the intermediate flight are not relevant for a fleet performance modification.

Group	# Acft	Pre Parking Rate	Post Parking Rate	t test result
< 60 days without flight	11	15,4	16,5	*Difference is statistically insignificant*
< 60 days with flight	5	15,5	18,3	*Difference is statistically insignificant*
60 to 95 days without flight	6	13,9	21,7	*Difference is statistically insignificant*
60 to 95 with flight	10	16,8	19,5	*Difference is statistically insignificant*
> 95 without flight	10	15,3	20,8	*Difference is statistically insignificant*
> 95 with flight	10	17,5	20,6	*Difference is statistically insignificant*

Even though the t-test did not confirm the importance of the difference, it is important to highlight the performance of the aircraft parked between 60 and 95 days groups, and mainly the effect of an intermediate flight in the results of those two groups. The 60 and 95 days without flight group had the best pre parking average rate of all the groups and the worst post parking performance.

On the other hand, the 60 and 95 days with the flight group presented the second-worst pre parking average rate and the third-best post parking performance across all groups. The authors understand that the intermediate flight was irrelevant for the post parking performance in the other groups.

H. Aircraft System Performance Comparison

In a deep dive of aircraft systems, some good insights can support the Engineering and Maintenance departments to take care of the aircraft systems.

Some chapters are essential in terms of report quantity and present a relevant decrease in performance; it is the case of Pneumatic System, Auto Flight System, Navigation System, among others.

On the other hand, the parking period represented a moment to recover or improve the quality cabin equipment and furnishings and communication and IFE systems. The two biggest report rates and both presented a better report rate after the parking period.

The complete table with all systems rates pre and post parking per 1000 cycles is attached in Appendix 03 of this capstone.

Operational Reliability Comparison

Regarding performance from the point of view of Operational Reliability, the authors' hypothesis was confirmed in this case since technical performance may not be the protagonist of this rate.

It is strongly recommended that airlines always have at least one more parameter of performance analysis because reliability, although very important and a parameter recognized worldwide, can be mitigated or aggravated according to the company's structural condition from the point of view of network and fleet.

On the comparison, operational reliability pre versus post parking, even with a technical worsening already confirmed in the reporting rate analysis, the Airline fleet A320 reliability had improved. By exclusion, the main factor for that was the aircraft availability due to low flight frequencies and the aircraft and engine parts cannibalization to attend the airline operations, thus providing the noted improvement. The airline can quickly recover during the scenario of pandemics, when a technical fault happens, due to the number of opportunities to steal parts from parked aircrafts or due to aircraft fleet backup easily returnable to service.

Table 04 illustrates the results of pre and post parking operational reliability. It is possible to see that there was no relevant change in the reliability rate.

Table 04: Pre and Post parking operational reliability

A320F	**Pre Parking Operational Reliability**	**Post Parking Operational Reliability**
Interruptions	368	100
Cycles	27.829	9.268
Operational Reliability	**98,7%**	**98,9%**

Chapter V

Conclusions and Recommendations

This chapter will seek to summarize all the conclusions obtained at this capstone in the analysis carried out, as well as to present some insights and provocations so that the topic continues to be evaluated and studied by everyone who may be interested in performance monitoring, continuous improvement, reliability, and so, all topics with great relevance and essential to the aircraft performance operation.

Conclusions

The analysis carried out and presented at this capstone demonstrates the pandemic period caused by COVID19 resulted in a massive parking process in the airline fleets around the world, which caused an impact on the technical condition of the aircraft and, consequently, required, or will require, a close reliability monitoring and recovery plan to return the aircrafts to airworthy condition, mitigating the impacts according to the priorities of each operator and consequently each region.

The capstone research question was: What is the effect of parking and storage on aircraft performance and reliability? With the research findings, considering the Null Hypothesis an insignificant difference between pre and post parking fault rate average, it was rejected the null hypothesis and statistically it is affirmed that the post parking rate is worse than the pre parking fault rate.

In addition, the outcomes found at section four, quantitatively presented at the appendix 2 and 3, that brings in details the worsening found at the aircrafts fault rates, which mainly affects cockpit results. Therefore, it is recommended to focus on the maintenance planning teams, and a good maintainability strategy by the airline, aiming to minimize the effect of this worsening on the post-flight operational performance of the aircrafts.

Due to a high volume of aircraft in preservation during the noted pandemics, maintenance tasks and intervals are constantly revised by the OEM. Manufacturers also encourage airlines to propose alternative methods and intervals for some specific tasks. Proposed actions may be approved under Technical Adaptations and can be followed by the airline with OEM agreement.

Usually, approved Technical Adaptations allows airlines to accomplish specific tasks in higher intervals than maintenance manuals, and as a consequence, they may contribute directly to system reliability after service return.

It is strongly believed that airlines will also need to have continuous surveillance of the maintenance program and a quick response to attack critical systems with worsening post-parking performance and manage inventory levels and positioning backups, given the expected gradual increase in operations.

Recommendations

Considering all the research and energy invested in this capstone project, it was pleasant to know that at the end, it was possible to draw out some interesting insights regarding the performance of aircraft and their systems after the parking period. Those insights could lead engineering and technical area of airlines across the globe to develop and implement a more dedicated and optimized approach in terms of preventive tasks, surveillance and prepare themselves to handle with a more challenging scenario, and also let the board aware of what expect for the near future of the companies.

It is strongly recommended the airlines to prepare themselves to experience, in general, a fleet performance around 20% worse than pre parking period, and that can mean, review backup aircrafts quantity, supply chain capacity, turnaround time, maintenance slots, maintenance staff manpower, general maintenance program and fleet preventive tasks needs, and so.

They also recommend special attention on the mid-age fleet (11 to 15 years old fleet), which presented the most significant worsening of all groups' performance. For future research, an important deep dive and question that could be covered are finding the reasons why this fleet presented a worse performance than an older fleet, for example.

Another important recommendation that is the result of this research is to take special attention and surveillance in the following systems: Navigation, Auto Flight, Pneumatic. We can affirm that those top systems were the most affected and can prioritize future action plans. Some examples of actions that could be implemented by the engineering department would be the insertion of additional maintenance tasks to the mandatory ones that already exist. These additional maintenance tasks would require the performance of preventive tests, premature replacement of components to act preventively, and prevent a failure in a component or system from affecting the aircraft's performance and, consequently, generating a negative effect on airlines' operation.

The authors also recommended turning on the warning signal to systems Engine Fuel and Control System and Engine Oil System, even that they were not so representative in terms of report quantity. However, both systems are still very important for the safety of the operations and presented a very significant increase in reports volumetry, basically already reaching the same number of reports than in the pre-pandemic period, even having flown 60% less than before. The studied airline company will probably face important problems and tend to experience operational events with the root cause of these systems shortly if nothing specific to these systems is done on a preventive basis.

The authors also alert the airlines to consider a robust cash plan and a supply chain plan to re-configure the aircrafts to service and stock of spare parts, considering the high cannibalization of parked aircraft.

For future research, it is recommended two additional studies:

1) Extract even more of the aircraft systems, evaluate subsystems, and increase the correlation between failures and aircraft model or parking length.
2) The fleet that was in storage condition did not return to service by the conclusion of this project, so the authors understand that another research will be needed to understand the impact of this different process on fleet performance.

Key Lessons Learned

The pandemics will impact the aircraft's performance that was parked for long periods, that did not return to operate until the data of the capstone publication, or already impacted the aircrafts that returned to service at the worldwide airlines fleet, by the findings of this capstone.

On the other hand, with this capstone's findings, it was possible to identify the most impacted systems, which can drive focus from the airlines reliability and engineering department focusing with special inspections and predictive maintenance actions post-parking, but before return to service for the first flight.

In addition to the points mentioned, It was also possible to identify significant differences in the mid-aged fleet parked; in other words, the aircraft from 11 to 15 years of operation presented a higher fault rate, which gives another important insight to the airline's reliability department.

Finally, here the group brings an alert to the airlines when operations return to a level closer to the pre-pandemic in terms of flights and, consequently, in terms of operational interruptions and the ability to mitigate the effects of this increase in technical failures once the backup fleet and possibilities for recovery from flight delays will be reduced.

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Appendix

Appendix 01 - Aircraft complete table

Aircraft code	Parking Period Start	Parking Period End	Total (days)	Group Parking Period	Interm. Flight?	Age	Age Group
#A1	March 20, 2020	June 30, 2020	102	> 95 DAYS	Y	6	6 to 10
#A2	March 24, 2020	July 7, 2020	105	> 95 DAYS	Y	6	6 to 10
#A3	July 10, 2020	August 8, 2020	29	< 60 DAYS	Y	7	6 to 10
#A4	March 25, 2020	May 25, 2020	61	60 TO 95 DAYS	N	7	6 to 10
#A5	March 24, 2020	June 8, 2020	76	60 TO 95 DAYS	Y	7	6 to 10
#A6	March 22, 2020	June 12, 2020	82	60 TO 95 DAYS	N	7	6 to 10
#A7	March 25, 2020	July 17, 2020	114	> 95 DAYS	N	7	6 to 10
#A8	March 27, 2020	May 18, 2020	52	< 60 DAYS	N	8	6 to 10
#A9	June 10, 2020	August 5, 2020	56	< 60 DAYS	Y	8	6 to 10
#A10	April 28, 2020	July 14, 2020	77	60 TO 95 DAYS	Y	8	6 to 10
#A11	April 1, 2020	June 22, 2020	82	60 TO 95 DAYS	Y	8	6 to 10
#A12	April 20, 2020	May 15, 2020	25	< 60 DAYS	N	9	6 to 10
#A13	March 24, 2020	April 28, 2020	35	< 60 DAYS	N	9	6 to 10
#A14	April 10, 2020	June 3, 2020	54	< 60 DAYS	N	9	6 to 10
#A15	March 1, 2020	May 6, 2020	66	60 TO 95 DAYS	N	9	6 to 10
#A16	March 23, 2020	July 1, 2020	100	> 95 DAYS	N	9	6 to 10
#A17	April 3, 2020	August 7, 2020	126	> 95 DAYS	N	9	6 to 10
#A18	March 23, 2020	April 24, 2020	32	< 60 DAYS	N	10	6 to 10
#A19	March 25, 2020	April 27, 2020	33	< 60 DAYS	N	11	11 to 15
#A20	June 17, 2020	July 29, 2020	42	< 60 DAYS	Y	11	11 to 15
#A21	April 9, 2020	July 29, 2020	111	> 95 DAYS	Y	11	11 to 15
#A22	April 1, 2020	August 15, 2020	136	> 95 DAYS	N	11	11 to 15
#A23	April 13, 2020	June 11, 2020	59	< 60 DAYS	N	12	11 to 15

#A24	April 10, 2020	June 8, 2020	59	< 60 DAYS	N	12	11 to 15
#A25	April 12, 2020	June 19, 2020	68	60 TO 95 DAYS	Y	12	11 to 15
#A26	April 27, 2020	July 17, 2020	81	60 TO 95 DAYS	N	12	11 to 15
#A27	April 3, 2020	July 1, 2020	89	60 TO 95 DAYS	Y	12	11 to 15
#A28	March 7, 2020	June 9, 2020	94	60 TO 95 DAYS	N	12	11 to 15
#A29	April 14, 2020	July 21, 2020	98	> 95 DAYS	N	12	11 to 15
#A30	March 23, 2020	July 1, 2020	100	> 95 DAYS	N	12	11 to 15
#A31	March 24, 2020	July 2, 2020	100	> 95 DAYS	N	12	11 to 15
#A32	April 24, 2020	June 16, 2020	53	< 60 DAYS	Y	13	11 to 15
#A33	March 30, 2020	May 24, 2020	55	< 60 DAYS	N	13	11 to 15
#A34	March 28, 2020	June 9, 2020	73	60 TO 95 DAYS	Y	13	11 to 15
#A35	March 1, 2020	May 14, 2020	74	60 TO 95 DAYS	Y	13	11 to 15
#A36	March 26, 2020	June 26, 2020	92	60 TO 95 DAYS	Y	13	11 to 15
#A37	April 2, 2020	July 27, 2020	116	> 95 DAYS	Y	13	11 to 15
#A38	March 29, 2020	June 29, 2020	92	60 TO 95 DAYS	N	17	16 to 20
#A39	March 24, 2020	June 24, 2020	92	60 TO 95 DAYS	Y	17	16 to 20
#A40	March 23, 2020	June 27, 2020	96	> 95 DAYS	Y	17	16 to 20
#A41	April 12, 2020	July 18, 2020	97	> 95 DAYS	Y	17	16 to 20
#A42	March 23, 2020	July 26, 2020	125	> 95 DAYS	Y	17	16 to 20
#A43	March 25, 2020	July 30, 2020	127	> 95 DAYS	N	17	16 to 20
#A44	March 24, 2020	August 13, 2020	142	> 95 DAYS	Y	17	16 to 20
#A45	July 6, 2020	August 2, 2020	27	< 60 DAYS	Y	18	16 to 20
#A46	April 10, 2020	May 15, 2020	35	< 60 DAYS	N	18	16 to 20
#A47	March 22, 2020	May 15, 2020	54	< 60 DAYS	N	18	16 to 20
#A48	April 13, 2020	July 7, 2020	85	60 TO 95 DAYS	Y	18	16 to 20
#A49	March 28, 2020	June 28, 2020	92	60 TO 95 DAYS	N	18	16 to 20
#A50	March 17, 2020	July 1, 2020	106	> 95 DAYS	N	18	16 to 20
#A51	March 23, 2020	July 28, 2020	127	> 95 DAYS	Y	18	16 to 20
#A52	March 23, 2020	July 10, 2020	109	> 95 DAYS	Y	19	16 to 20
#A53	March 1, 2020	July 3, 2020	124	> 95 DAYS	N	19	16 to 20

Appendix 02 - Aircraft individual report rate per 100 cycles

Acft	Report Rate (Pre)	Report Rate (Post)	Acft	Report Rate (Pre)	Report Rate (Post)
#A1	15,34	11,93	#A28*	21,27*	94,51*
#A2	18,16	26,80	#A29	17,28	17,72
#A3	11,64	15,67	#A30	17,34	30,77
#A4	7,69	16,58	#A31	9,64	12,20
#A5	7,87	10,55	#A32	11,51	26,32
#A6	17,52	23,76	#A33	17,97	30,08
#A7	14,47	13,68	#A34	14,55	23,56
#A8	16,21	11,28	#A35	13,07	26,85
#A9	12,50	6,72	#A36	20,29	27,39
#A10	23,17	8,04	#A37	18,57	14,06
#A11	21,03	19,23	#A38	20,32	44,23
#A12	11,80	12,72	#A39	16,40	21,30
#A13	10,93	12,75	#A40	30,05	21,67
#A14	14,89	16,18	#A41	17,49	13,30
#A15	10,31	14,59	#A42	11,30	21,57
#A16	15,60	11,76	#A43	14,29	19,86
#A17	9,02	20,00	#A44	20,57	36,71
#A18	10,86	11,19	#A45	26,45	24,55
#A19	13,58	11,03	#A46	11,91	17,86
#A20	11,28	23,13	#A47	16,13	16,67
#A21	18,28	23,70	#A48	20,07	24,62
#A22	13,33	41,84	#A49	13,79	9,28
#A23	25,30	21,67	#A50	21,76	18,08
#A24	17,66	14,17	#A51	10,57	16,25
#A25	23,98	21,09	#A52	15,81	23,40
#A26	16,92	35,00	#A53	22,16	19,05
#A27	15,19	13,95			

Rate per Aircraft Table. The aircraft #A28 is considered an outlier due to an abnormal Post Parking result and it was not considered int the analysis.

Appendix 03 - Report Rate per ATA Chapter

Ata Chapter	Description	Pre Parking Reports	Post Parking Report	Pre Rate	Post Rate	Diff
25	Equip & Furnishings	589	166	21,16	17,91	-15,37%
23	Communications	333	107	11,97	11,55	-3,52%
21	Air Conditioning	296	100	10,64	10,79	1,44%
36	Pneumatic	195	97	7,01	10,47	49,36%
22	Auto Flight	183	95	6,58	10,25	55,88%
34	Navigation	183	92	6,58	9,93	50,96%
27	Flight Controls	263	91	9,45	9,82	3,90%
32	Landing Gear	281	76	10,1	8,2	-18,79%
33	Lights	218	74	7,83	7,98	1,93%
28	Fuel	137	54	4,92	5,83	18,35%
52	Doors	213	52	7,65	5,61	-26,69%
31	Indicating & Recording	85	49	3,05	5,29	73,10%
46	Information Systems	86	45	3,09	4,86	57,12%
24	Electrical System	130	35	4,67	3,78	-19,16%
30	Ice & Rain Protection	88	33	3,16	3,56	12,60%
35	Oxygen	68	27	2,44	2,91	19,22%
73	Engine Fuel & Controls	28	25	1,01	2,7	168,10%
29	Hydraulic	41	22	1,47	2,37	61,12%
49	Auxiliary Power Unit (APU)	62	22	2,23	2,37	6,55%
26	Fire Protection	66	20	2,37	2,16	-9,01%
38	Water & Waste	35	15	1,26	1,62	28,69%
79	Engine Oil	19	13	0,68	1,4	105,45%
77	Engine Indicating	33	13	1,19	1,4	18,29%
47	Inert Gas System	19	10	0,68	1,08	58,04%
74	Ignition	19	7	0,68	0,76	10,63%
71	Power Plants	15	6	0,54	0,65	20,11%
80	Engine Starting	8	5	0,29	0,54	87,67%
56	Windows	13	5	0,47	0,54	15,49%
53	Fuselage	18	5	0,65	0,54	-16,59%
78	Exhaust	21	4	0,75	0,43	-42,81%
72	Engine	11	2	0,4	0,22	-45,41%
75	Engine Air	1	1	0,04	0,11	200,27%
44	Cabin Systems	2	1	0,07	0,11	50,13%
55	Stabilizers	2	1	0,07	0,11	50,13%
54	Nacelles Pylon	12	1	0,43	0,11	-74,98%
57	Wings	55	1	1,98	0,11	-94,54%

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