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ASSESSMENT OF THE AIRFRAME SYSTEMS AFFECTING SAFETY RISKS CAUSED BY LARGE AIRCRAFT

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Abstract

Hazard is a safety condition that could cause or be a part of unsafe aircraft operation. It also has an impact on aviation safety related to aircraft systems as well as services. Safety risk is a part of so-called safety management and is the predicted probability and severity of the outcomes of a hazard. Aircraft utilized by airlines and cargo operators which have MTOM >5700 kg are defined by authors as a large aircraft and have to be treated in their systems reliability analysis separately from small aircraft. Despite the fact that both types of aircraft categories events are included in the same databases - European Coordination Centre for Aviation Incident Reporting Systems (ECCAIRS) and Aircraft Continuing Airworthiness Monitoring (ACAM), due to different predominant systems failures could not be considered in the same way.

The authors have performed processing of the data contained in available databases analysing large aircraft airframe systems faults, which were assigned to the specific ATA chapters. The most frequently occurring defects of the aircraft systems were identified.

The goal of this article is to present a method of the current reliability of large aircraft systems assessment. Based on it, the authors are proposing a way of safety risk estimation and prediction of the safety levels for the next two years.

The results of this analysis may support the decisions of supervisory authorities in the areas where security threats are most important. They can also help aircraft operators with identification of the aircraft systems, which require special attention.

Keywords: *large aircraft, failure, ATA chapter, safety level*

1. Introduction

MTOM of the contemporary commercial aircraft vary from 50 to 550 tonnes. It takes from a few dozen to several hundred passenger sand the amount of fuel in their tanks is between 20 tonnes (B737, A-320) and 250 tonnes (A380). Operated by LOT B787 aircraft can be filled up with fuel for 100 tonnes and can carry passengers in the number of 250…290. Therefore, it is extremely important to detect and eliminate the elements, which lower the flight safety.

Decades ago, it was found out that not only the exploitations time affects the wear out of the aircraft systems and their components. Other factors are atmospheric pollution (dust, sand, sea aerosol), the type of operations (short trips, frequent take-offs / landings or long intercontinental flights), and even the experience and temperament of the aircrew.

The wide spread introduction of FDR's (Flight Data Recorder) and development of the methods for the engine as well as airframe systems operational parameters data processing has made aircraft exploitation possible on - condition. Such system could be introduced backed by the experience gained from long-term airframe's fatigue tests and engines endurance tests.

Manufacturers of aircraft and engines track defects of the various systems appearing in the exploitation. They keep their own databases in order to improve these structures, especially the elements that negatively affect the durability and reliability.

According to [5] flight safety is affected by the following factors:

– the reliability of the aircraft systems and components,
– aircraft's flight performances,
– method of the support services operation (airport services, maintenance, ATM etc.),
– proper functioning of the aircrew,
– ambient conditions (weather, the presence of birds, hail, lightning).

The authors describe an analysis of the first from the above-mentioned factors, with the support of the ECCAIRS (European Coordination Centre for Aviation Incident Reporting Systems) database. It contains more than 6,000 occurrences, including about 4,000 reported events on the MTOM > 5700 kg aircraft for the period of 2008 ... 2015 [6].

During 2008-2015, the number of aircraft involved in air traffic has been changing. In order to objectify the analysis of the data coefficients relating the number of all the events or in any aviation occurrence category to the number of aircraft registered (per 1,000 aircraft) or to the number of passenger operations [8] (per 1000 operations) was introduced.

$$ZS_K = \frac{1000 * \mathrm{LZ}_K}{\mathrm{LSP}_K}, \tag{1}$$

where:
LZ_K – number of events for aircraft MTOM>5700 kg,
LSP_K– number of registered aircraft MTOM >5700 kg.

$$W1000 = \frac{LZ * 1000}{LOairport}, \tag{2}$$

where:
LZ – total number of events or in the certain airport,
$LO_{airport}$, – number of the passenger operations in certain airport.

The current method of analysing the data contained in ECCAIRS is based on comparing the number of events in the current year with a corresponding number of events in the previous year. The decrease in the number of events is considered as an indicator of safety improvement. Such a method does not reflect changes in traffic and the number of registered aircraft. The authors propose forecasting, based on observation, of the trend of several years and setting alert levels, assuming a normal distribution. These forecasts should be verified annually by comparing them with the actual number of events.

To determine the alert levels the method of Shewhart Control Charts could be used which allows for an observation of process variability, as well as identifying the reasons that cause this increase in volatility [3]. 2σ limits on both sides of the line of mean values were assigned as the maximum predicted levels also denoted in figures as AL (alert levels).

In order to assess airframe systems, which affect safety risks, a method proposed by ICAO's "Safety Management Manual" [7] was widely used by the Authors. It has to be mentioned that the size and the complexity of aviation activities in Poland were taken into account.

In the 2008 ... 2015 approx. 110 ... 140 aircraft with MTOM> 5700 kg were operated in Poland (number of helicopters accounted for approx. 1/10 of the number of aircraft). Annually approx. 330 ... 690 events in this class of aircraft were reported and recorded in the ECCAIRS database (see. Fig. 1).

Events caused by failures of the airframe systems represent almost 26% of the total ICAO's aviation occurrence categories [1]. They were reported between 2008 and 2015 on MTOM > 5700 kg aircraft (see Fig. 2).

A big number of the occurences which have significant influence on flight safetyalso draws attention. Bird strikes (BIRD) and blinding by a laser beam (LASER) are external causes of dangerous situations. On the other hand, there are events related to air proximity issues (MAC – MIDAIR COLLISIONS) like: Traffic Collisions Avoidance System (TCAS)/Airborne Collision Avoidance System (ACAS) alerts, loss of separation as well as near collisions or collisions between aircraft in flight [1].

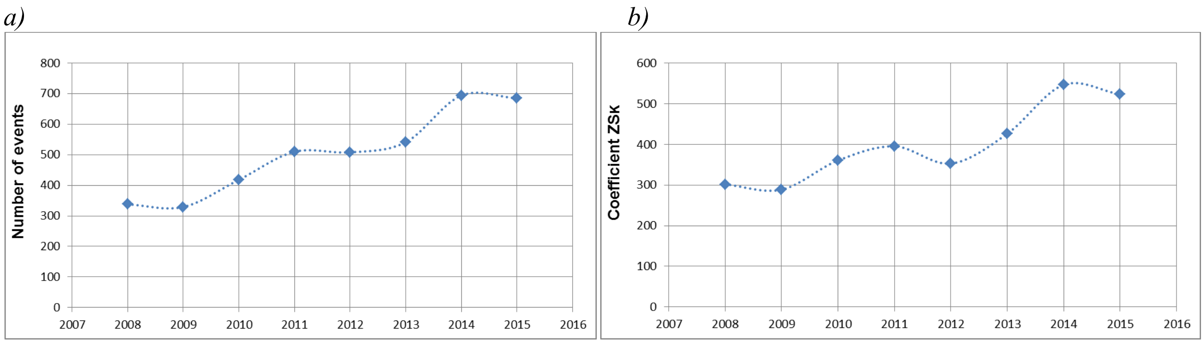

Fig.1. The number of reported events a) for aircraft with MTOM> 5700 kg (data from the database ECCAIRS) and the change of the ZS_K b) in the years 2008-2015

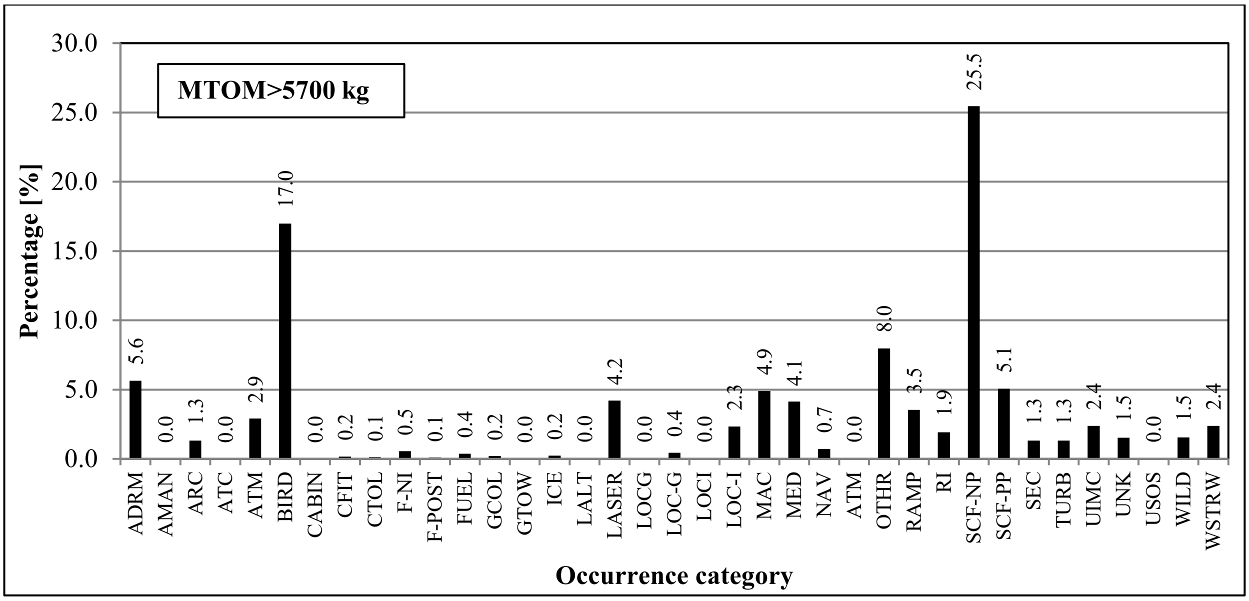

Fig. 2. Reported in percents of the total number of events per ICAO's aviation occurrence categories in Poland for MTOM >5700kg aircraftin the years 2008-2015

Figure 3 shows in percents aircraft maneuvers "share" during which reported SCF-NP events happened.

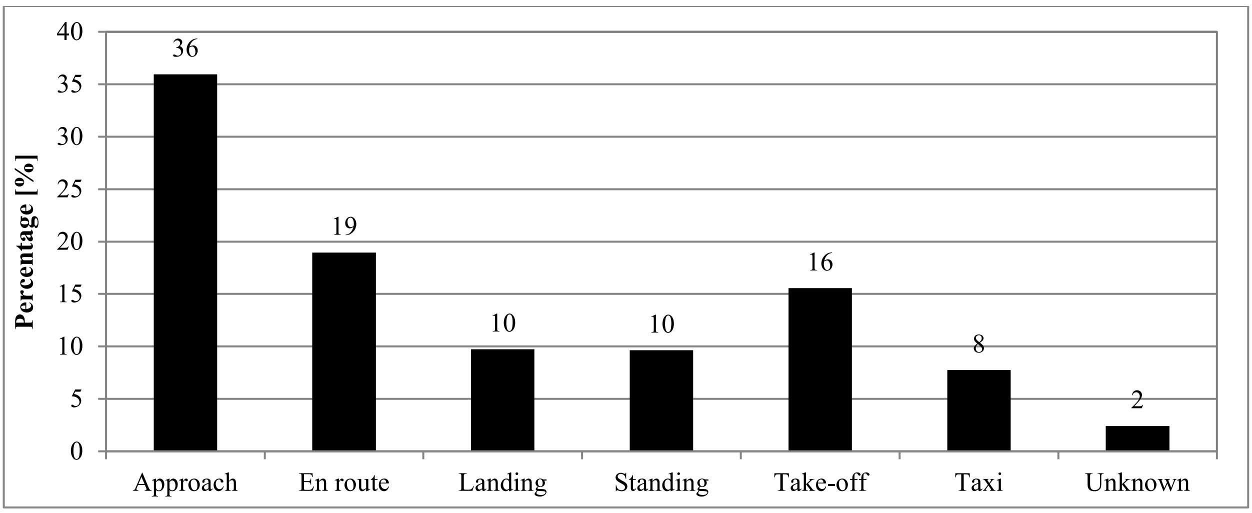

Fig. 3. The share in percents of particular maneuver of aircraft when airframe SCF-NP aviation occurrence events have taken place in the 2008 – 2015 on MTOM >5700 kg

Further examination requires considering the fact that during approach there are the biggest number of reported airframe's systems events. That increases the degree of nonconfidence levelwhen flight safety is being evaluated.

2. Airframe systems

The airframe systems are the biggest contributor to the total number of reported events (see Fig. 2). Fig. 4 shows which of them has the biggest influence on that number.

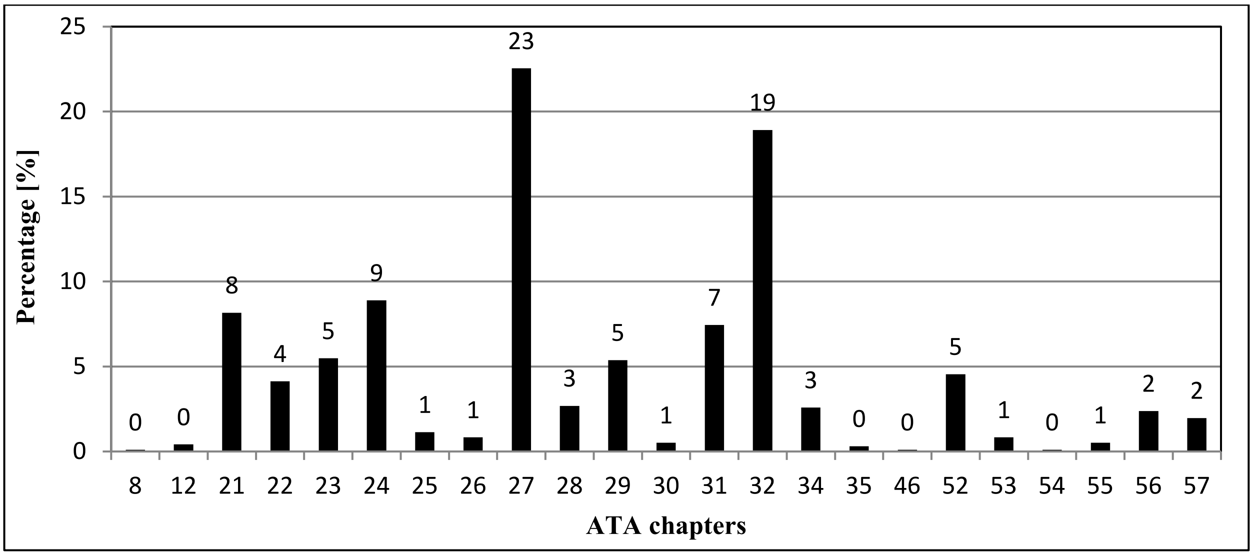

Fig. 4. Share of each airframe system (ATA-100 chapter) for SCF-NP category events in percents for MTOM > 5700 kg aircraft

Considerations concerning the impact of each airframe system on flight safety are presented in chapter 3. Fig. 5 shows example results of the statistical calculations which were performed in order to establish the expected levels of events for subsequent years caused by flight controls system (ATA chapter 27).There were 4 significant incidents, 192 incidents and 19 occurences mainly caused by flaps and slots defects. Fig. 6 presents in percent during which aircraft maneuver failures of flight controls system occurred.

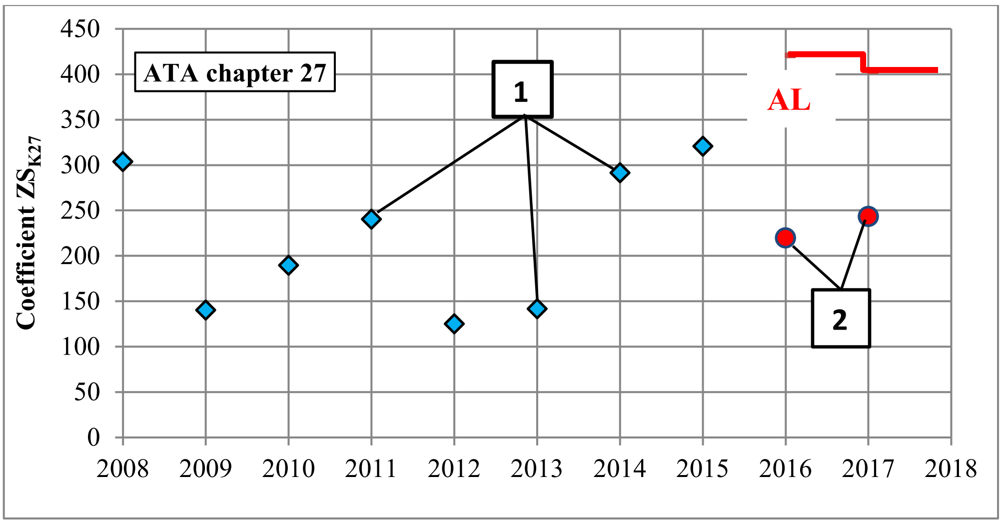

Fig. 5. Annual and forecasted value of ZS_{K27} coefficient for ATA chapter 27 – flight controls:1 – current year coefficient value, 2– forecasted mean, AL – calculated predicted alert level

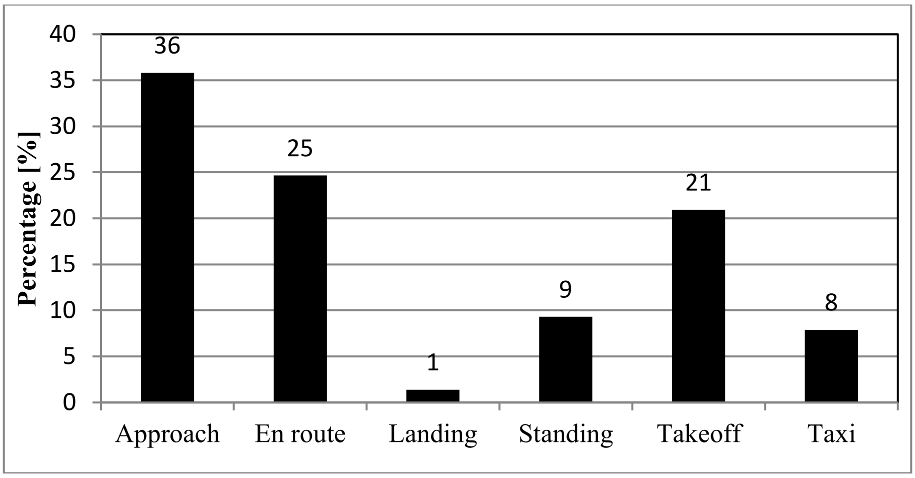

Fig. 6. The share in percents of particular maneuver of aircraft when airframe related events in ATA-100 chapter 27 occurred in 2008-2015

3. Safety risk

Proper safety management lies not only in an identification of essential safety parameters and prediction of their level, but also requires an estimation of safety risk connected with selected safety indicators.

In order to assess safety risk, it is necessary to estimate the probability that the consequences of hazard will come to effect during aircraft operations. In literature five point probability table is frequently used [7]. Such table has been adopted by the authors. The table includes five categories, which describe the probability related to an unsafe event.

Tab. 1. Safety risk probability [7]

Likelihood	Meaning	Value
Frequent	Likely to occur many times (has occurred frequently)	**5**
Occasional	Likely to occur sometimes(has occurred inferequently)	**4**
Remote	Unlikely to occur, but possible (has occurred rarely)	**3**
Improbable	Very unlikely to occur (not known to have occurred)	**2**
Extremely Improbable	Almost inconceivable that the event will occur	**1**

Figure 4 shows "share" of the certain ATA chapter in percent in the total volume of the SCF-NP reported events. It was assumed that the most frequently occurred events – ATA chapters 27 and 32 have probability level 5.

Next, 34, 21 and 31 level 4, 23, 29, 52 and 22 level 3, 28, 34, 56, and 57 level 2 and the remaining level 1.

The next step is a safety risk severity assessment, which is a potential harm that might occur as a consequence of the identified hazard. Tab. 2 from [7] has been utilized in order to evaluate safety risk as a consequence of a potential event caused by any airframe system.

Based on the two tables above safety risk assessment could be performed. Usually it is performed utilizing Tab. 3 Safety risk assessment matrix [7], which is a combination of severity/probability.

Tab. 2. Safety risk severity [7]

Severity	Meaning	Value
Catastrophic	– Equipment destroyed – Multiple deaths	**A**
Hazardous	– A large reduction in safety margins, physical distress or workload such that the operators cannot be relied upon to perform their tasks accurately or completely – Serious injury – Major equipment damage	**B**
Major	– A significant reduction in safety margins, a reduction in the ability of the operators to cope with adverse operating conditions as a result of an increase in workload, or as a result of conditions impairing their efficiency – Serious incident – Injury to persons	**C**
Minor	– Nuisance – Operating limitations – Use of emergency procedures – Minor incident	**D**
Negligible	– Little consequences	**E**

Tab. 3. Safety risk assessment matrix [7]

Risk probability		Risk severity				
		Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent	5	**5A**	**5B**	**5C**	**5D**	**5E**
Occasional	4	**4A**	**4B**	**4C**	**4D**	**4E**
Remote	3	**3A**	**3B**	**3C**	**3D**	**3E**
Improbable	2	**2A**	**2B**	**2C**	**2D**	**2E**
Extremely improbable	1	**1A**	**1B**	**1C**	**1D**	**1E**

Certain index has been assigned to every ATA chapter. In this way any aviation authority can develop or order program implementation of safety risk mitigation, in our case on Country level.

Events caused by particular airframe system were assigned as it is shown in Tab. 4.

Every item presented in the red field is unacceptable. In our case immediate actions have to be taken on the country level in order to mitigate safety risk connected with the landing gear system. Airframe systems marked in yellow are acceptable based on risk (moderate risk) mitigation. However, a schedule for performance of safety assessment has to be prepared in order to find ways to bring down safety risk to low.

Tab. 4. Safety risk assessment matrix for airframe systems

ATA chapter		
No	**Contents**	**Index**
27	Flight controls	**5D**
32	Landing gear	**5C**
34	Navigation	**4D**
21	Air conditioning	**4E**
31	Indicating/ recording system	**4E**
23	Communication	**3D**
29	Hydraulic power	**3C**
52	Doors	**3D**
22	Auto flight	**3D**
28	Fuel	**2E**
56	Windows	**2D**
57	Wings	**2D**
8	Leveling and weighing	**1E**
12	Servicing – routine maintenance	**1D**
25	Equipment/ furnishings	**1E**
26	Fire protection	**1D**
30	Ice and rain protection	**1D**
35	Oxygen	**1E**
46	Information systems	**1E**
53	Fuselage	**1E**
54	Nacelles/ pylons	**1E**
55	Stabilizers	**1E**

4. Conclusions

Several airframe's systems falls into moderate risk level however, it is necessary to observe potential changes of their coefficient ZS_K value thoroughly in order to react in the timely manner in case of the increasing trend.

Same method as presented in the article has to be adopted to powerplant's systems as well as to each ICAO's aviation occurrence categories and aircraft maneuvers.

It is advisable to establish, for example, at Polish Civil Aviation Authority team of experts in order to continuously monitoring changes of the essential for aviation safety parameters and with responsibility of the safety risk management.

The use of the Gaussian distribution is doubtful in the case of the parameters large fluctuations.

Acknowledgement

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