# CALCULATION OF ALERT LEVELS FOR RELIABILITY

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**ABSTRACT**

Safety in Aviation is a forecast of failure. That's why many situations occuring during the whole exploatation are noticed and analysed. Analyse is devided in to many factors and, as every statistic use as many data as possible. To get any conclusions one have to compare results of analyses with established alert levels. Those alert levels are a picture of wider experience. The paper describes how to make such a picture. After one simulates when some component will failed, one can replace the component by new one before failure.

## INTRODUCTION

Reliability engineering and maintenance are the source of safety. They are one of the most important aims in modern aviation. The modern reliability engineering is also the way of seeing safety as exploitation costs reduction. Following good written reliability programs airplanes earning money as long as possible, as often as possible. They are not spending time waiting for parts, which were unexpectedly broken, they are reaching destinations on time. The customers are glad because of accuracy and reliability. How to reach this aim?

## PROBLEM FORMULATION

Safety in Aviation is a forecast of failure. That's why many situations occuring during the whole exploatation are noticed and analysed. Analyse is devided in to many factors and, as every statistic use as many data as possible. As many data as possible it means that operators shuold share to each other with thay problems, failers, mistakes and all ashamed accidents which can be usefull for reliability statistics. That's why all participants have to make some Proprietary Information Agreement to protect Shared Data from Misuse. Misuse it means for instance marketing, competitors activity analysys and so on.

To get any conclusions one have to compare results of analyses with established alert levels. Those alert levels are a picture of wider experience, experience of a big amound of same type aircrafts.

The Reliability Report is required by aviation authorities from every operator. For European countries authority is the EASA (European Aviation Safety Agency) and for USA it is the FAA (Federal Aviation Agency). Reports in most cases reach authorities every month, for every aircraft, from every operator. Reports differ between each other depending on type of aircraft, number of aircrafts operated in company, number of hours flown, tape of missions and so on. What form and kind of data will appear in report is written in Reliability Programs accepted by aviation authorities and created by operators, but in every report there are such data as hours flown by each aircraft, number of landings, number of defects and accidents, schedule interruptions, delays, cancellations, air turnbacks, and diversions and reporting

## GROUPING AIRCRAFT SYSTEMS

All of reported defects have to be divided using ATA code. The Ata code is the System (two digids), subsystem (four digids) or Component (8 digids) Code Table DEVELOPED by The Air Transport Association of America (ATA), and called Specification 100 code. Now it is used By FAA and accepted by EASA. Such

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fragmentation is useful when you want to know what part of the airplane, what system or what component most common makes problems, where you have to look more often. The main system is as follows:
21 Air conditioning
22 Auto Flight
23 Communications
24 Electrical Power
25 Equipment Furnishing
26 Fire Protection
27 Flight Controls
28 Fuel
29 Hydraulic Power
30 Ice & Rain
31 Indicating & Record
32 Landing Gear
33 Lights
34 Navigation
35 Oxygen
36 Pneumatic
37 Vacuum
38 Water / Waste
45 Central Maintenance
49 Auxiliary Power
51 Structures
52 Doors
53 Fuselage
54 Nacelles / Pylons
55 Stabilizers
56 Windows
57 Wings
71 Power plant
73 Engine Fuel Control
74 Ignition
76 Engine Controls
78 Exhaust
79 Oil
80 Starting
As it can be seen there are only some chosen chapters, and in every chapter there are also subchapters. The system is independent on aircraft type so if some operator frequently have to change parts in its different type of aircraft's, so with different Part Numbers it is simple to check if, for instance there is permanent problem with landing gear system. Then one can ask if it is a maintenance problem or exploitation or conditions problem. But this question is to answer using system other then ATA 100. A mean for all aircrafts, operators and conditions on all over the world is, that on the first place are:

1. ATA 32 - Landing Gear;
2. ATA 34 - Navigation;
3. ATA 24 - Electrical Power;
4. ATA 27 - Flight Controls.

It does not mean that those are the main reasons of crashes, but dalays, flight cancelations or just aims for line maintenance.

**RALIABILITY FACTORS**

The reliability factors can be divided in 3 groups.The first group contains factors describing whole aircraft and people who are somehow connected with the aircraft, pilots, management, and maintenance. In this group one can find such factors as:

- PRR (*Pilot's Reports Rate*) Factor

This factor shows how many defects or problems were reported/found by pilots. Some of defects appeared during the flight but there is also group of cases, where the problems were found by pilots because they were not found by mechanics. The parameter is given as cases for 1000 flights.

- PRMR (*Pilot's Reports/Maintenance Report* ) Factor

This factor show how many defects or problems were reported/found by pilots in compare to defects found by maintenance departments.

- DR (*Dispatch Reliability*) Factor

This factor analyses technical reason influence on dispatch delays/cancelations compare to all delays/cancelations.

- SR (*Shop Rate*) Factor

Factor shows amount of time when aircraft spend on unplanned maintenance every 100 flight hours.

- TF (*Technical Functionality*) Factor

The TF Factor is number of hours flown with accepted defects and flight limitations (Flight with Minimum Equipment List Regulation, and Hold Item List Document usage) for every 100 flight hours.

- TI (*Technical Incidents*) Factor

This factor is calculated for 1000 flights. The deference is because of calculated case. It is a serious defect with influence on flight safety, which should be report in separate report to authorities.

The second group contains factors, which more precisely describe aircraft and its components. Every of factor below is calculated separately for each ATA 100 chapter or, in case of number of defects/removals/shop time even subchapters. In this group one can find following factors:

- <u>RR ( *Removals Rate*)</u> Factor

The RR factor show number of removals of exact component from an aircraft, independently of reason for this removal for every 1000 cycles or working hours.

- <u>FR (*Failure Rate*)</u> Factor

The FR factor shows number of removals of exact component from an aircraft, because of failure for every 1000 cycles or working hours

- <u>MTBR (*Mean Time Between Removals*)</u> Factor

The MTBR factor, as the name says show average time between removals of exact component from an aircraft for every 1000 cycles or working hours.

- <u>MTBF (*Mean Time Between Failure*)</u> Factor

The MTBR factor, as the name says show average time between removals of exact component from an aircraft, because of failure for every 1000 cycles or working hours

- <u>MTBUR (*Mean Time Between Unscheduled Removals*)</u> Factor

The MTBR factor, as the name says show average time between unplanned removals of exact component from an aircraft for every 1000 cycles or working hours.

The third group of factors is the group of factors combined with power plants. Those very important aircrafts components have separate factors.

- <u>IFSD (*In-Flight Shut Down Rate*)</u> Factor

Factor describing number of In flight shut down of engines or other serious problems with engines during flight. Because the case is not very common the factor is calculated for 1000 flight hours.

- <u>URR (*Unscheduled Removals Rate*)</u> Factor

This factor is unscheduled engines removals from an aircraft rate. The factor differs from previous one, because removal can be made also after defect find on ground. The factor is calculated for 1000 flight hours.

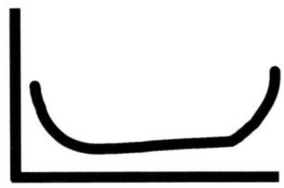
- <u>SVR (*Shop Visit Rate*)</u> Factor

This is a parameter showing number of engine repairs in a shop for 1000 flight hours.

**AGE RELIABILITY PATTERNS**

Analyzing changes of the parameters during life of components one can found that some components aging in different way than others. This is only sometimes obvious, usually which component is accurate to which curve one knows after looking in to statistics. The typical curves can be divided in two groups. In first group one can find components with limited age, or, where setting age limit is reasonable, the second, much more common, where not. The first group examples are:

1. The Bathtube Curve:



Infant mortality, followed first by a constants or gradually increasing failure probability and then by a pronounced “Wear Out” region.
An age limit may be desirable, provided a large number of units survive to the age at which out begins. Such curve is respond to 4 % of components only.

2. Constant or gradually increasing failure probability, followed by a pronounced wear out region. Such curve is respond to 2 % of components only.

3. Gradually increasing failure probability. No change in characteristic in age, but setting limit is reasonable. Such curve is respond to 5 % of components only.

Those 3 types are together 11% of all components, and only this amound require setting time limits in maintenance programs.
Secound group are the cases where setting such limit is not reasonable:

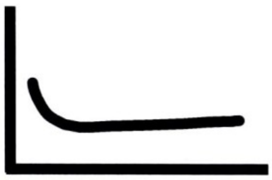
1. Low failure probability when the item is new or just out of the shop, followed by a quick increase to a constant level.

Such curve is respond to 7 % of components only.

2. Flate rate. Constant failure probability during years/ flight hours/ cycles.

Such curve is respond to 14 % of components.

3. Infant mortality, followed by a constant or very slow increasing failure probability. This is valid for 68% of all components and is typical to electronic equipment.



The second group is 89% of all cases.

**ALERT LEVELS CALCULATIONS**

There are several methods of calculation alert levels, all of them are well known as statistical error calculation. Main or most common are:

1. MEAN + 3 SD
2. MEAN + STANDARD DEVIATION OF MEAN OF MEANS + 3 SD
3. MEAN x 1,3
4. MEAN + 2 SD
5. Weibull Method

As the errors are used for foresight they have to be racalculeted after getting new data. It depending on operator how often alert levels have to be recalculated. Most common case is every month, but some companies recalculated alert levels every three months or even every half a year, depending of flight hours does the fleet fly every month.

**CONCLUSIONS**

Lot of the presented factors is similar and the choice which is more useful for an operator or airlines depends on operator its self and authorities which have to accept the Reliability Program. Factors can also be created especially for operators needs or problems they think are more common. But the most important thing is to analyze the changes of calculated factors during time, after each probe and compare it to reliability levels predicted by previous years of flying on analyzed aircraft and results for rest aircraft the same type which are flying all over the world, whole manufactured fleet. The simulation is as proper as large is the number of cases the statistics data used for this simulation is based on.

**REFERENCES**


1. Jerzy Lewitowicz *Podstawy Eksploatacji Statków Powietrznych – Statek Powietrzny i Elementy Teorii*, Wydawnictwo Instytutu Technicznego Wojsk Lotniczych, Warszawa 2001

2. Jerzy Lewitowicz, Kamila Kustroń *Podstawy Eksploatacji Statków Powietrznych – Własności i Właściwości Eksploatacyjne Statku Powietrznego,* Wydawnictwo Instytutu Technicznego Wojsk Lotniczych, Warszawa 2003

3. Jerzy Lewitowicz *Podstawy Eksploatacji Statków Powietrznych – Systemy Eksploatacji Statków Powietrznych*, Wydawnictwo Instytutu Technicznego Wojsk Lotniczych, Warszawa 2006

4. Reliability Programs of deferent Airlines and Aircraft Operators.

5. Appendix 1 (part M) to implementing Rules EC 2042/2003 dated November 20/2003

6. Civil Aviation Authorieties, Safety Regulation Group – CAP562 Civil Aircraft Airworthiness Information and Procedures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