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Кафедра авіоніки**

ДОПУСТИТИ ДО ЗАХИСТУ

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# **ДИПЛОМНА РОБОТА**

**(ПОЯСНЮВАЛЬНА ЗАПИСКА)**

**ВИПУСНИКА ОСВІТНЬО-КВАЛІФІКАЦІЙНОГО РІВНЯ**

**“МАГІСТР”**

**Тема:** «Науково методичні та практичні засоби об’єктивного та суб’єктивного контролю повітряного судна»

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“    ” \_\_\_\_\_ 2022p.

# **GRADUATE WORK**

**(EXPLANATORY NOTE)**

**GRADUATE OF EDUCATIONAL AND QUALIFICATION LEVEL  
"MASTER"**

**Theme:** «Scientific methodological and practical means of objective and subjective control of an aircraft»

**Done by:** \_\_\_\_\_ Oleksii TURAK

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Kyiv 2022

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**TASK**

Oleksii Turak

1. **Topic of the thesis:** “Scientific methodological and practical means of objective and subjective control of an aircraft”, approved by the rector's order from «13» September 2021 №1413/ст.
2. **The term of the work:** from 05.09. 2022 to 30.11.2022.
3. **Initial data for work:** Representation of Objective and Subjective control as a communicative analysis system. Possible use during accident investigation as well as workplace analysis. Further connection and actuality while used in the Safety Management System.
4. **Contents of the explanatory note (list of issues to be developed):** List of conditional terms and abbreviations; Introduction; Chapter 1: Objective control and its implementations; Chapter 2: Subjective control and its impact on flight safety; Chapter 3: Objective and subjective control as a balanced system; Chapter 4: Safety management in airlines and maintenance organisations and its importance; Labour protection; Environmental protection; References; Conclusions.
5. **A list of mandatory graphic material:** figures, charts, graphs.

6. Planned schedule

№ п/п	Task	Deadline	Performance note
1	Validate the rationale of masters work theme		
2.	Carry out a literature review		
3	Develop the first chapter of diploma		
4.	Develop the second chapter of diploma		
5.	Develop the third chapter of diploma		
6.	Analysis and research based on real airline and maintenance organisations for the development of the fourth chapter		
7.	Labour protection		
8.	Environmental protection		
9.	Preparation of graphic material		

10.	Issuance of an explanatory note		
11.	Presentation to the department. Elimination of deficiencies, preparation of an explanatory note		

7. Consultants from individual departments

Section	Consultant (post, Name)	Date, signature	
		Issued the task	I accepted the task
Labour protection	Kateryna Ivanovna		
Environmental protection	Pavlyukh Lesya		

8. Issue date of the assignment: « \_\_\_\_ » \_\_\_\_\_ 2022.

Supervisor of the thesis \_\_\_\_\_

Yurii HRYSCHENKO

The task took to perform \_\_\_\_\_

Oleksii TURAK

## **ABSTRACT**

Explanatory notes to bachelor work 'Prevention of aviation accidents by means of subjective and objective control of the aircraft' contained XX pages, 14 figures, 2 charts, 16 references.

**Keywords:** OBJECTIVE CONTROL, TRAFFIC COLLISION AVOIDANCE SYSTEM, FLIGHT RECORDERS, SUBJECTIVE CONTROL, REASON'S MODEL, BALANCED SYSTEM.

**Object and subject of research** – dividing aircraft system and organizational systems into objective and subjective, investigating aircraft accidents as examples of different mistakes done in different areas (objective and subjective), regarding objective and subjective control as a united balanced system.

**Purpose of bachelor work** – introduce a new communicative and analysis model for aircraft accident investigation and its role in analysis of flight data.

**Research Method** – Engineering psychology theory, analysis theory, statistics theory and information theory were used to solve this goal.

**Scientific novelty** – proposed recommendations and methods to introduce a new analytical method to analyse accidents and other aviation related data.

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## LIST OF ABBREVIATIONS

AE	Aviation Equipment;
AOA	Angle of Attack;
ATS	Air Traffic Services;
BAFDA	British Airways Flight Data Analysis;
CPO	Crew Performance Optimisation;
FAA	Federal Aviation Administration;
FDA	Flight Data Analysis;
ICAO	International Civil Aircraft Organization;
MCAS	Manoeuvring Characteristics Augmentation System;
MMS	Market Monitoring System;
MOC	Material of Objective Control;
OC	Objective Control;
OCE	Objective Control Equipment;
RA	Resolution Advisory;
SOR	Standard Operating Rules;
TA	Traffic Advisory;
TCAS	Traffic Collision Avoidance System;
TOEWS	Threat and Opportunity Early Warning System;



## INTRODUCTION

**Actuality.** Safety remains and will remain a very important part of the aviation industry. Airplane remain one of the fastest and most comfortable solutions to long range travel. However not all flights end as planned. Minor incidents do occur occasionally, but the worst cases are the ones that result in loss of human lives. In addition, EASA has issued a Regulation (EU) 2021/1963 amending Regulation (EU) No 1321/2014 which in part means that PART-145 organisations are obliged to have Safety Management System. Objectivity and subjectivity are a philosophical and (from a certain stand-point) scientific components of safety itself.

Aircraft accidents are currently not one hundred percent preventable due to our human nature. People are not perfect, far from it. Accidents are not only caused by mistakes of the machinery and onboard systems (objective) but also by organizational disputes/troubles as well as human errors (subjective).

By correctly dividing aircraft as a system of objective and subjective control as well that this system has to be in a certain balance will prevent more accidents and provide a better understanding how accidents happen in the first reason, especially when used in conjunction with other already well-established models of analysis.

Objectivity is nearly impossible for humans to achieve, and the essence of human objectivity can only be grasped with the power of hindsight. Only by analysing past actions with the knowledge of today it could be said if the actions of a person were truly objective. Objectivity is achieved through other machine based or algorithm-based methods which also increase flight safety, however doing so does increase flight complexity in return.

Subjective control is culmination of human input in its entirety not only as decisions of air traffic controllers and pilots but the input of maintenance crew and even corporate management of an airline company. Subjectivity is in majority of time a negative aspect that is meant to be reduced to a minimum.

By controlling subjectivity and objectivity and keeping them in balanced system, more accidents could be prevented and if accidents and incidents do arise, they can be analysed with subjective and objective control in mind (in addition to already existing analysis models such as Reason's Swiss Cheese models and SHELL model).

**Purpose of the work** is to introduce a new communicative and analysis model for aircraft accident investigation and its role in analysis of flight data.

Following tasks should be done to achieve this purpose of the work:

1. Identify what objective control represent, what systems are considered to be part of objective control;
2. Identify what subjective control is, what does it include, what can be done to improve it;
3. To present objective and subjective control as a part of the same balanced system;

**Object of the research** are general trends in aviation accidents, incidents and catastrophes, as well as factors that led to those events.

**Subject of the research** are methods of prevention of future accidents using stricter subjective and objective control regulation.

**Research Method** – Engineering psychology theory, analysis theory, statistics theory and information theory as well as basis of the safety management were used to solve this goal.

**Scientific novelty** – proposed recommendations and methods to introduce a new analytical method to analyse accidents and other safety aviation related data.

# CHAPTER 1

## OBJECTIVE CONTROL AND ITS IMPLEMENTATIONS

### 1.1 Objective control. Concepts, tasks and types.

Objective control (OC) is a system of actions performed by the head of the state aviation authority and is focused on the comprehensive use of all technical means of information recording, its processing, analysis, summarization and use to control the completeness of work tasks, improvement of methods and quality of training of flight personnel, ensuring field safety, reliability of aviation equipment (AE), and forecasting of its technical condition, detection of deficiencies in the organization and operation of AE, air traffic organization, technical operation of ground-based communication equipment, alerting and monitoring.

Ensuring the implementation of OC in the state and civil aviation is achieved by the implementation of the following measures:

- Organizational - a set of measures including:
  - Issuance of orders by the head of the state aviation authority on the organization of OC, and appointment of OC groups and persons responsible for its management;
  - Approval of instructions with functional responsibilities of the officers in charge for maintaining constant readiness of the means of the objective control equipment (OCE);
  - Ensuring their immediate activation and implementation of OC, compliance with the regime of secrecy and protection of service information in the course of implementation of OC in the state aviation in accordance with the established procedure for the use of technical devices, registration, storage and use of material of objective control (MOC);

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- Technical - is a set of measures for the equipment of technical MOC air traffic services, as well as service jobs on the equipment of state aviation, equipment of stationary or mobile photo laboratories, classes (premises) for processing primary media MOC.

However, such a description of OC (specifically the issuance of orders by the head of the state aviation) can't be considered fully objective, as humans will have certain biases that will affect future prospects and developments in the state aviation as well as private aircraft producing companies and airlines. These ideas will be further elaborated on in the next chapter.

On the other hand, computer systems and recording devices that take up a significant part of OC, as the role they provide in on-board systems is invaluable. These systems replaced a human part in civil aviation, the flight engineer, making the flight overall more objective from a technical standpoint. Subsequently, the room for human error drastically decreased. Nonetheless, the role of the aircraft system observer has shifted mostly to the maintenance team. This, in turn, has benefited aviation safety greatly, since it is much easier and convenient for the ground staff to manage aircraft systems (which therefore adjust and monitor inflight aircraft parameters accordingly) than for an air engineer to perform the same tasks.

Small powerful integrated circuits helped immensely in development of on-board systems. They are considered the catalyst of rapid air engineer replacement not only in civil but also in military aviation. One of the most influential aircraft on-board systems which increased level of objective control is **Traffic Collision Avoidance System** (hereinafter referred to as TCAS)

## **1.2 TCAS. Principle of work, functions.**

TCAS is a system intended to reduce the risk of mid-air collision. It's main operating principle fully depends on the installation of the appropriate transponder on all commercial airliners or specifically any aircraft with take-off mass of over 5,700 kg. Installation on these

aircraft of TCAS is mandated by the International Civil Aircraft Organization (hereinafter referred to as ICAO).

Main operational principle of TCAS is dispatch of a request signal to nearby/surrounding aircraft. Surrounding aircraft's transponder respond to these request signals. Mode C transponders respond with the information about aircraft's absolute altitude, while mode S transponders reply with the information about aircraft's absolute altitude (identical of mode C's transponder) as well as with aircraft's assigned individual address. Based on this information along with the transmitting-receiving time, TCAS calculates the distance to the intruder aircraft. Taking into account the information in the response, absolute height is reassessed, which determines whether an intruder possess any threat.

If TCAS's logic circuit anticipates that nearby aircraft could cause a potential collision, TCAS's collision prevention logic determines an appropriate vertical manoeuvre in the vertical plane to reduce the risk of collision. Information about each high-risk aircraft is processed specifically for that aircraft to ensure that Resolution Advisory (hereinafter referred to as RA) are selected based on its trajectory data. An appropriate manoeuvre is one that allows for the separation from all threatening aircraft, on the assumption that the threatening aircraft will not manoeuvre in opposition to RA and that the own aircraft responds to the recommendation in accordance with RA.

If the intruder aircraft is equipped with TCAS that is capable of issuing RA, thus begins a process of coordination with the help of communication line air to air in the S mode. This process insures that RA do not contradict on any of the aircraft. There is also Traffic Advisory (hereinafter referred to as TA) which is intended to issue flight crew a warning of a potentially threatening aircraft with a longer warning period than that of an RA.

As it can be assumed, TCAS has increased objectivity of flight immensely, as in case of any potential mid-flight collision or otherwise any other conflict situation without any input from air traffic control. Even in the case of a potentially dangerous situation between TCAS and air traffic control, TCAS takes priority as there have been cases where such

miscommunication led to a mid-air collision. Fortunately, TCAS was developed further and further, thus all the accidents and incidents associated or caused by TCAS were not in vain. To better understand principle of operation of TCAS operation, basic component scheme has to be examined (figure 1.1). An aircraft with a TCAS has electronic surveillance equipment as part of the system which sends requests to S-mode transponders installed on other aircraft and receives responses from them

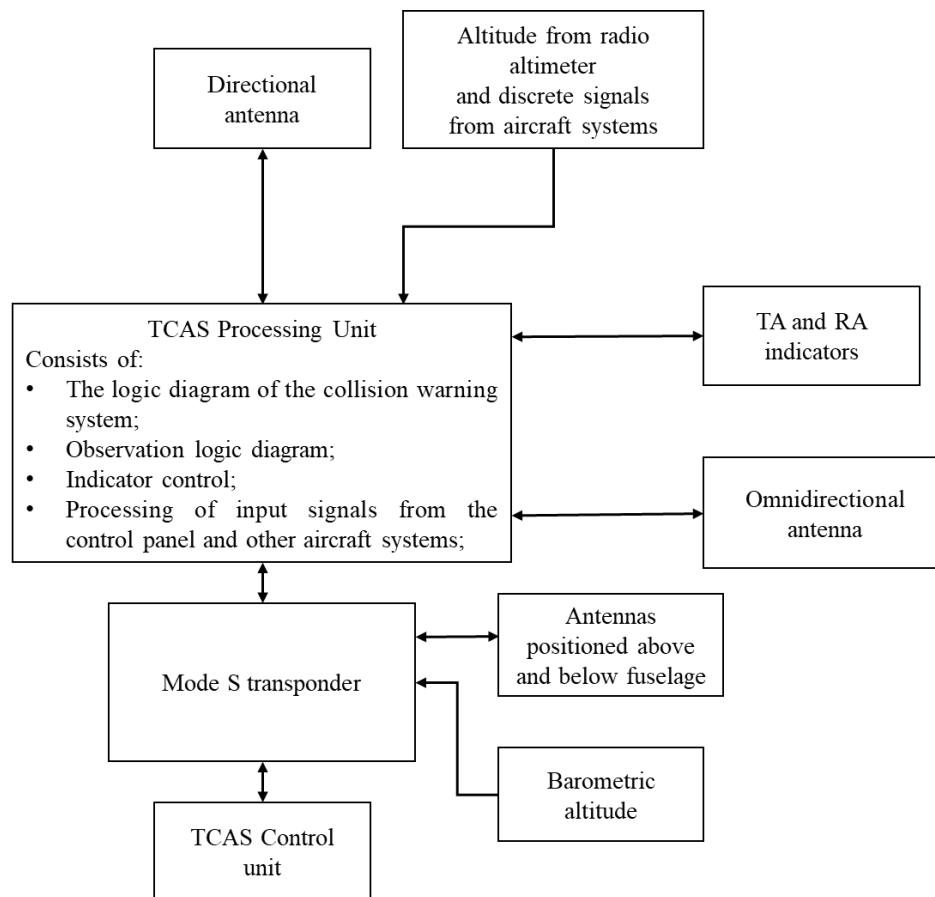


Figure 1.1 Main elements of TCAS

Basic warning functions of TCAS are divided into two types. TA and RA as briefly mentioned previously.

TA alerts the flight crew to possible recommendations for resolving the collision threat and may indicate the range, range change rate, absolute altitude, vertical speed and bearing of the offending aircraft relative to its own aircraft. TA without absolute altitude data may also be issued to aircraft equipped with Mode C or Mode S equipment which have temporarily lost the ability to automatically transmit absolute altitude. The TA issued by

TCAS is intended to assist the flight crew in observation of the movement of aircraft in the vicinity.

When the threat detection logic program in the TCAS computer determines that a conflict situation with a nearby aircraft may soon result in a dangerous approach or collision, the collision threat resolution logic program determines an appropriate manoeuvre in the vertical plane that will provide safe vertical echelon for both aircraft. The selected manoeuvre provides adequate vertical echelon within limitations imposed by the rate-of-climb characteristics and the proximity to the ground of the two aircraft.

The RAs issued to the pilot may be divided into two categories: corrective recommendations which instruct the pilot to deviate from the current flight path (For instance "CLIMB" when the aircraft is in horizontal flight); and precautionary advisories which instruct the pilot to maintain or not to use certain vertical speeds (For instance "DON'T CLIMB" when the aircraft is in horizontal flight). The general function scheme performed by TCAS are shown in the figure below. For clarity, in the figure 1.2 the "assessment of own aircraft position" and "tracking of intruder aircraft" are shown once under the "observation" function.

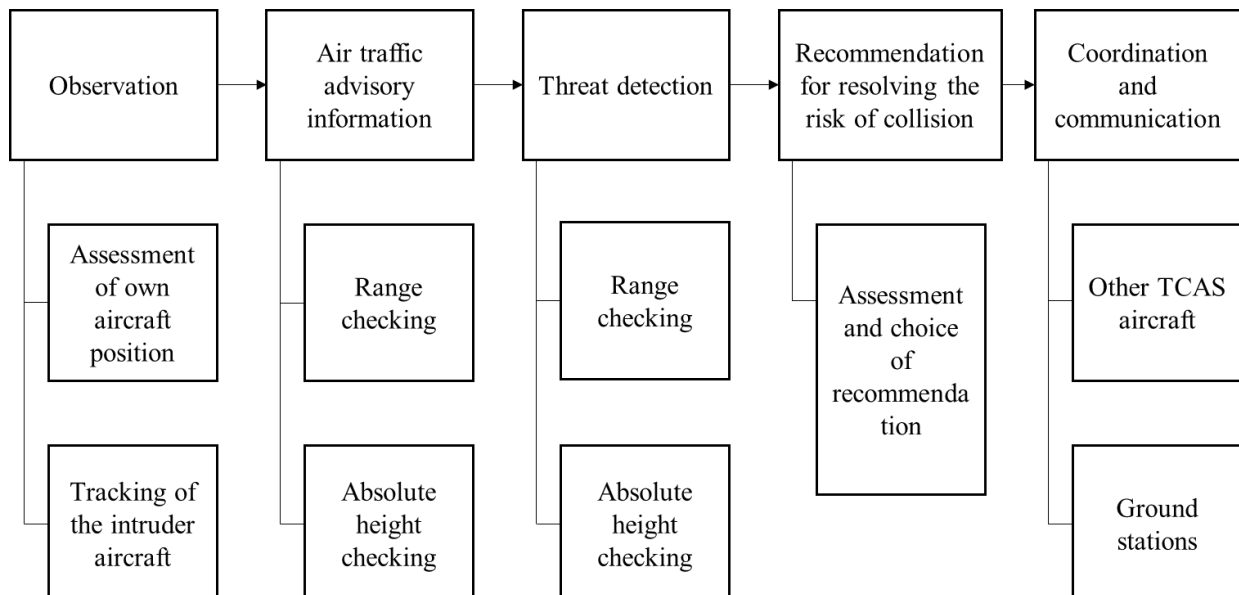


Figure 1.2 Functions of TCAS

To better understand at which ranges RA and TA operate, visual representation of airspace which surrounds each TCAS equipped aircraft can be made. TCAS protected airspace size depends on:

- Altitude;
- Speed;
- Heading;

Observation function provided information is used in conjunction with data from aircraft's own pressure altitude to establish their own altitude, vertical speed of each aircraft in range. This data is used in logic diagram of the collision warning system to determine whether TA or RA is required (figure 1.3).

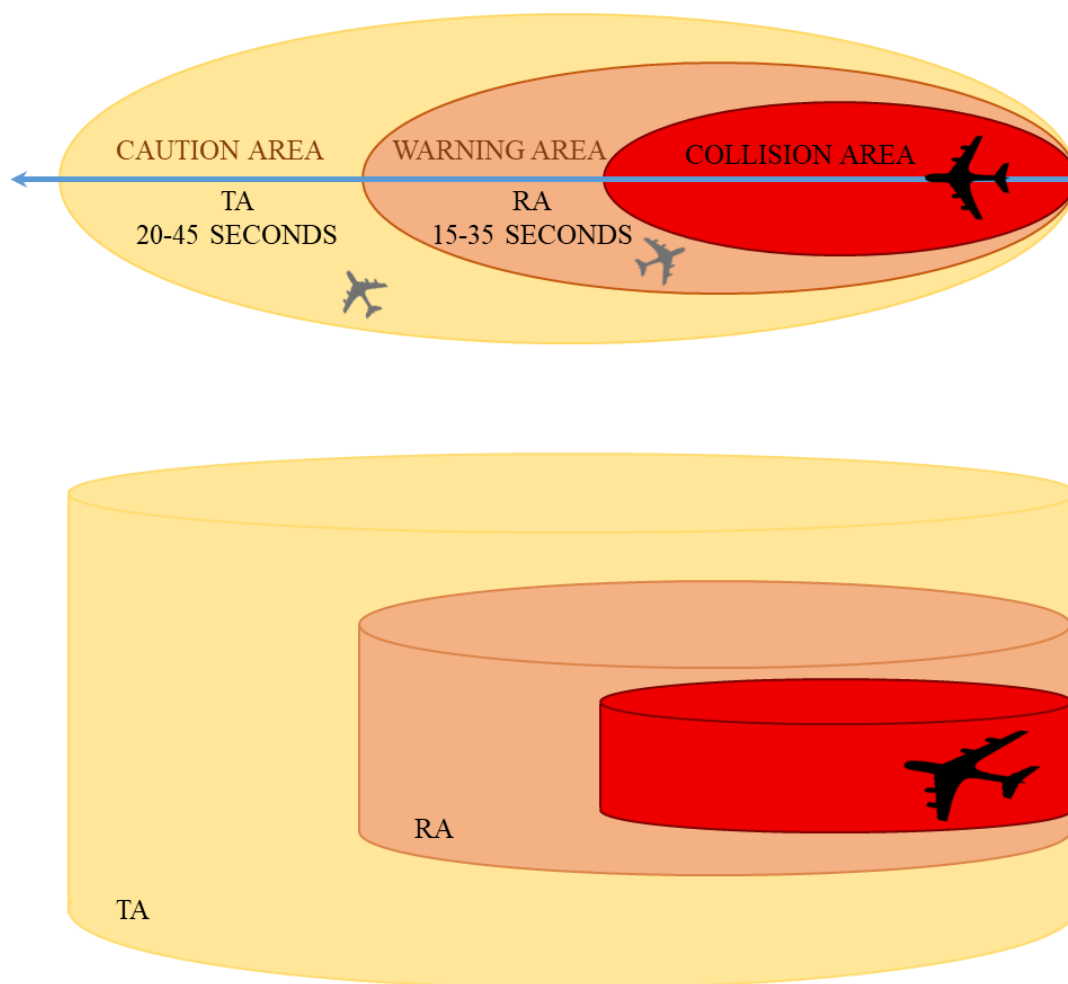


Figure 1.3 TCAS Protection volume/Area (Not to scale)

Generally, if an intruder aircraft is detected within the warning area, one of the possible conflict situations may play out.



- Aircraft are moving in parallel one after another;
- Aircraft are moving towards one another in the same flight path;
- Aircraft are moving on the flight paths that intersect.

In case of any of the situations above, one of the following commands will be given to the aircraft by the TCAS (figure 1.4):

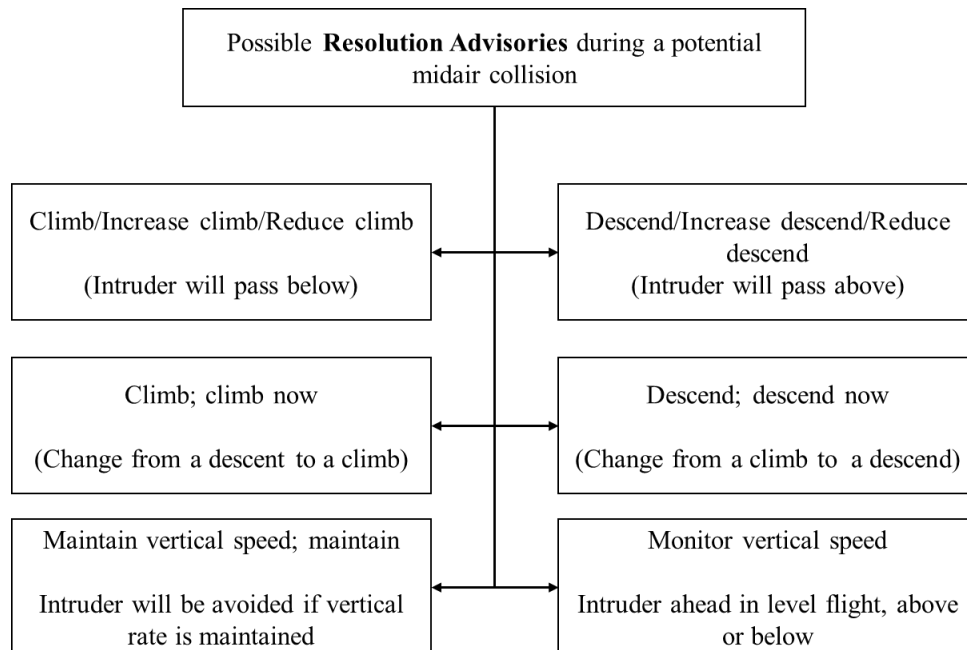


Figure 1.4 Possible resolutions for solving dangerous situation with intruder aircraft

As it can be seen yet again, TCAS makes it much easier to avoid mid-air collisions, given the fact the TCAS RA commands take priority over air traffic control. Air traffic controller's job is very stressful and responsible as it is and TCAS eases the unnecessary weight of controller's job. If intruder comes in range of TCAS's warning area or RA zone, time frame for action is very small. It is not hard to imagine that without the help of TCAS and with the rising amount of air traffic air traffic controllers would be under much more stress and the flights themselves would become more subjective. It is projected that the amount of aircraft fleets in the world will increase from 26000 to 48000 between 2019 and 2039. Despite the fact that 2020 has been a challenging year for aviation, there is no sign that the amount of commercial aircraft will not increase.

With such a steady development of aviation and steady decrease in airway volume over the years. OC systems will prove themselves to be very useful, as relying on subjective choices of pilots and air traffic controllers may prove itself to be very unwise choice.

OC has also one more use case, that is more commonly explored. OC is more commonly referred to recording devices which main application is to record all the actions of the pilots and on board systems, for future aircraft accident prevention. “Post-Factum” control systems are not a new idea as flight recorder systems known by their misnomer black boxes (when they are, in fact, painted in very bright colours to aid in recovery after accidents)

### **1.3 Flight recorders, principle of work, data analysis.**

A flight recorder is the final device of a recording system, mainly used in aviation to record basic flight parameters, internal indicators of the functioning of aircraft systems, crew conversations, etc. Information from the recorders is routinely used to monitor the crew's actions and the performance of aircraft after each flight and, in special cases, in the investigation of flight accidents. The objective control system itself consists of a large group of sensors (internal and external), information processing units and a separate recording device (data logger)

The flight recorder is part of the aircraft's objective control system which collects information on the state of the material (fuel pressure at engine inlet, pressure in hydraulic systems, engine speed, gas temperature behind the turbine, etc.), crew actions (degree of control deviation, retraction and release of take-off and landing gear, pressing the flight button), navigation (flight speed and altitude, course, passage of drive beacons) and other data.

Usually, two flight recorders are installed on an aircraft: a voice recorder, recording crew conversations, and a parametric recorder, recording flight parameters. In addition, many modern airliners have two sets of recorders: an operational recorder (which does not have

a protective housing and is designed to monitor the operation of systems and crew after flight) and an emergency recorder (in a robust sealed housing). Information may be recorded on optical (photographic film) or magnetic (metal wire or magnetic tape) media; recently, flash memory has been widely used.

The operation recorder (also known as quick access recorder) is unprotected and is used in the day-to-day operation of the aircraft. Ground personnel read the operation recorders of the objective control system after each flight. The information read out is decoded and analysed to determine whether the crew has performed any unacceptable actions or evolutions during the flight - whether the maximum roll or pitch allowed by the manufacturer has been exceeded; whether landing overload has been exceeded, whether the prescribed operating time for afterburner or take-off modes has been exceeded, etc. This data also enables monitoring of the aircraft's service life and timely performance of maintenance works, thus reducing the failure rate and increasing the reliability of aircraft and flight safety.

Unlike operational recorders, emergency recorders are well protected: the current TSO-C124 (Technical Standard Order) standard requires them to maintain data after 30 minutes in full fire, at a depth of 6,000 m for one month, and subject to shock loads of 3,400 g for 6 ms and static overloads of more than 2 tonnes for 5 minutes. Previous generations of recorders with magnetic carriers could withstand shock overloads of 1,000 g and retain information when fully engulfed by fire for 15 minutes.

Radio beacons and hydro acoustic "pings", which automatically activate in the event of an accident (the latter make it easier to find the recorders under water), are incorporated in the recorders to facilitate their retrieval

Often in the media emergency flight recorders are called "black boxes". As mentioned before, however, the bodies of such recorders are usually in the shape of a balloon or cylinder, as the shells of this shape resist external pressure better, and are painted bright

orange or red to make them easier to locate among the wreckage at the scene of an aircraft accident.

Using data from flight recorders, it is possible to establish a Flight Data Analysis (FDA) Program.

It is used to prevent deviations and irregularities from the established flight rules, in order to improve flight safety. FDA Program has the following goals:

**The determination of safe operating parameters for aircraft is a systematically repeated process monitored through the FDA system and is intended to determine Safety Performance Indicators.** The "desirable" level of Safety Performance Indicators should be determined on the basis of average safety performance, which reflects the flight data statistics of the same type of aircraft for at least one year. It is advisable at the outset of FDA implementation to download the previous year's flight data into the system in order to obtain a comprehensive database for the calculation of desirable and cautionary levels of Safety Parameter Indicator in accordance with the provisions of ICAO Doc. 9859.

**Identification of actual and potential risks inherent in processes specific to aircraft type, aerodrome, air traffic controller technology, etc., highlighting anything related to deviations from standards or unusual in terms of aircraft operation, or leading to a violation of flight safety.** First of all, FDA is used as part of the Safety Management System to identify risk areas and deviations from Crew Operating Technology, as well as to determine the limits of deviations that occur without affecting the safe operation of the aircraft. This helps to define safe operation criteria against which changes in flight safety status can be detected and measured.

**Assessment of risks caused by single events or general trends, either frequently recurring events or having a potential hazard with the identification of unacceptable trends if they continue for a significant period of time.** Virtually any increase in the relative intensity of flight events at certain flight phases, aerodromes, etc. identified by the

system should be analysed and evaluated in order to both implement possible improvement measures and make recommendations if necessary.

**Develop measures to prevent negative trends related to flight safety and monitor the effectiveness of measures aimed at improving flight safety.** Once an unacceptable flight safety risk has been identified, whether it currently exists or is determined to be a negative trend, it is appropriate to use both planned risk-reduction measures and emergency measures (figure 1.5). These measures must be applied in such a way that the risk cannot transform and manifest itself elsewhere in the production system.

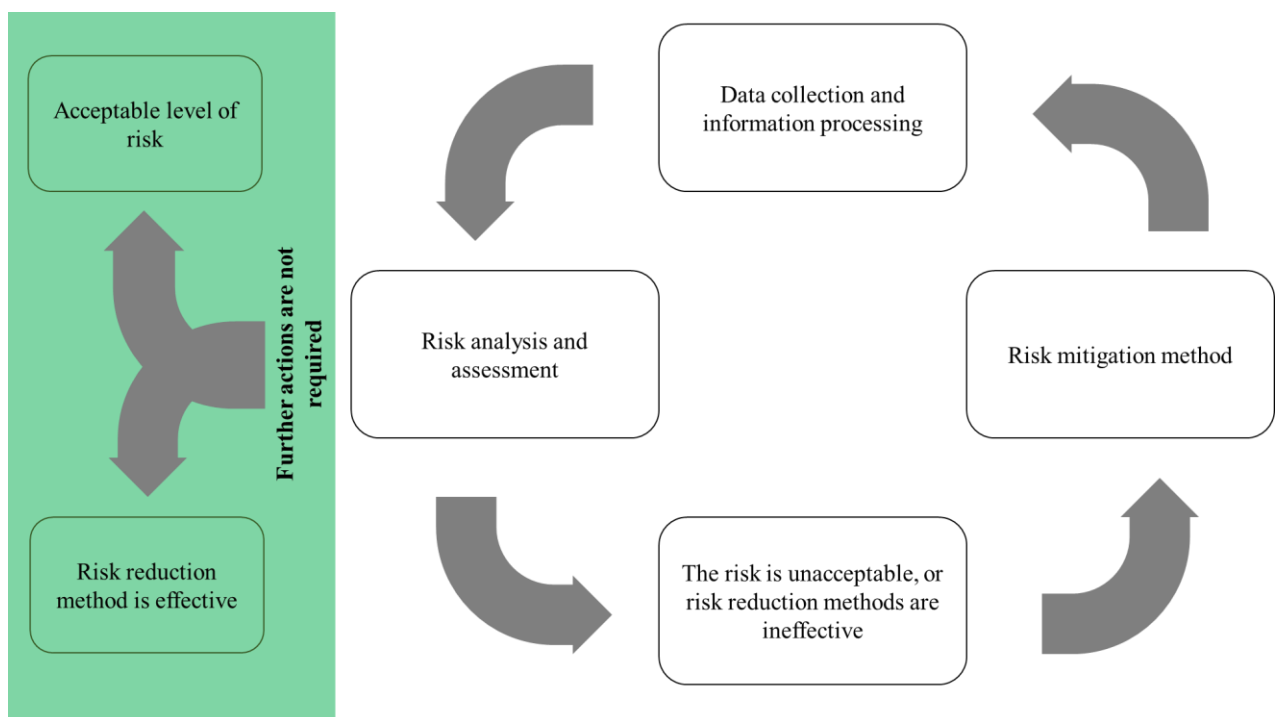


Figure 1.5 Risk reduction scheme

**Optimisation of training processes.** In case of negative trends in flight data monitoring results for an aircraft type or a specific crew, recommendations or corrective actions with optimised training processes should be considered. Typically, negative trends can be detected within 2-3 months of operation with a well-established FDA Programme; however, if a new indicator or indicator is introduced into the system, unusual trends for these indicators can only be identified after data analysis and average values satisfactory for flight safety are obtained. Measures to assign additional training to a specific crew

member should be considered only if the flight safety risk or trend becomes unacceptable, in which case a crew member identification procedure can be performed.

**A comparative analysis of the flight data of the flight of interest to the aircraft type average for incident investigations, which is necessary to facilitate analysis of the events surrounding the incident.** This comparison technique can most often be used for an incident that occurred at a time when no hazardous risks and trends were identified. In this case, an error has been made in the aircraft type FDA, so additional control parameters must be introduced into the FDA Programme to identify unacceptable trends in flight operations in a timely manner.

**The use of the FDA Programme database for the engine performance monitoring programme aims at reliable engine analysis, as manual analysis of engine performance parameters has the disadvantages of lower accuracy and lower reliability, as well as a later delivery time of the information.** Events of exceeding engine operating limits, detected by the FDA Programme, are a good tool for monitoring critical engine performance parameters. When an engine overshoot or deterioration trend is detected, FDA informs the Engine Performance Monitoring department, which performs an in-depth analysis of the resulting parameters to determine the technical condition of the engine.

**Risk management using real, rather than assumed, results of analysis of flight performance data.** Completeness of data is achieved by creating flight events in the FDA Programme to track the Flight Safety Indicator and, provided that more than 80% of the total number of flights performed has been analysed. Fulfilment of the above-mentioned conditions makes it possible to collect the necessary data for flight safety risk management purposes.

**Provision of data for flight economics analysis, which is a secondary function of the FDA Programme to collect fuel consumption data and Aircraft Performance**

**Control.** Fuel Consumption and Flight Performance Control report is generated by the system monthly for each aircraft, this report follows the format of Emissions Trading Scheme software. The Flight Characteristics Control report helps to determine actual flight characteristics of each aircraft in comparison to the manufacturer's specification, while the fuel report allows for various analyses of fuel statistics and thereby indicating measures for fuel consumption reduction.

**Taking measures to limit the number of generated false flight events in the system to less than 0.1%.** Most of the false flight events in FDA Software are the consequence of flight data file corruption during recording by flight data recorder and flight data transfer equipment, also false flight events may be generated by the system, when the value of the set or calculated parameter in the formula generating a specific flight event was determined incorrectly. In order to analyse and detect a large number of false events a lot of additional time is required, which increases the workload of the FDA Department, so timely repair of recording and processing equipment, corrections to the formulas by which flight events are generated in the system, may help to reduce the number of false events to an acceptable level.

**Analyse at least 90% of the total number of flights performed for aircraft equipped with wireless transmission equipment and at least 80% for all others (For instance, per airline).** The greater the number of flights decrypted, the more reliable the data obtained from the analysis of those flights. Flight data decoding norms are set based on the actual capabilities of the equipment providing transmission, collection and processing of information, as well as for obtaining a more reliable and complete FDA.

General FDA in practice can consist of an aircraft mounted Airborne Digital Flight Parameter Recorder, a ground based FDA program, (such as British Airways Flight Data Analysis; BAFDA) and as a reserve system Aerobytes (figure 1.6) may be used. The ground-based program converts the digital parameters into an appropriate format suitable for analysis, graphing and visualizing the resulting data to facilitate the evaluation of flight

events. The analysed flight parameters help to determine whether the aircraft's operational limits have been exceeded and whether deviations from the Crew Operating Procedure have occurred. Parameters monitored in flight events are values that reflect the requirements of applicable regulations and are entered into the program to facilitate the process of identification and assessment of risks threatening flight safety. Limit values for flight event detection are continuously reviewed and updated, in accordance with the regulations currently in force.

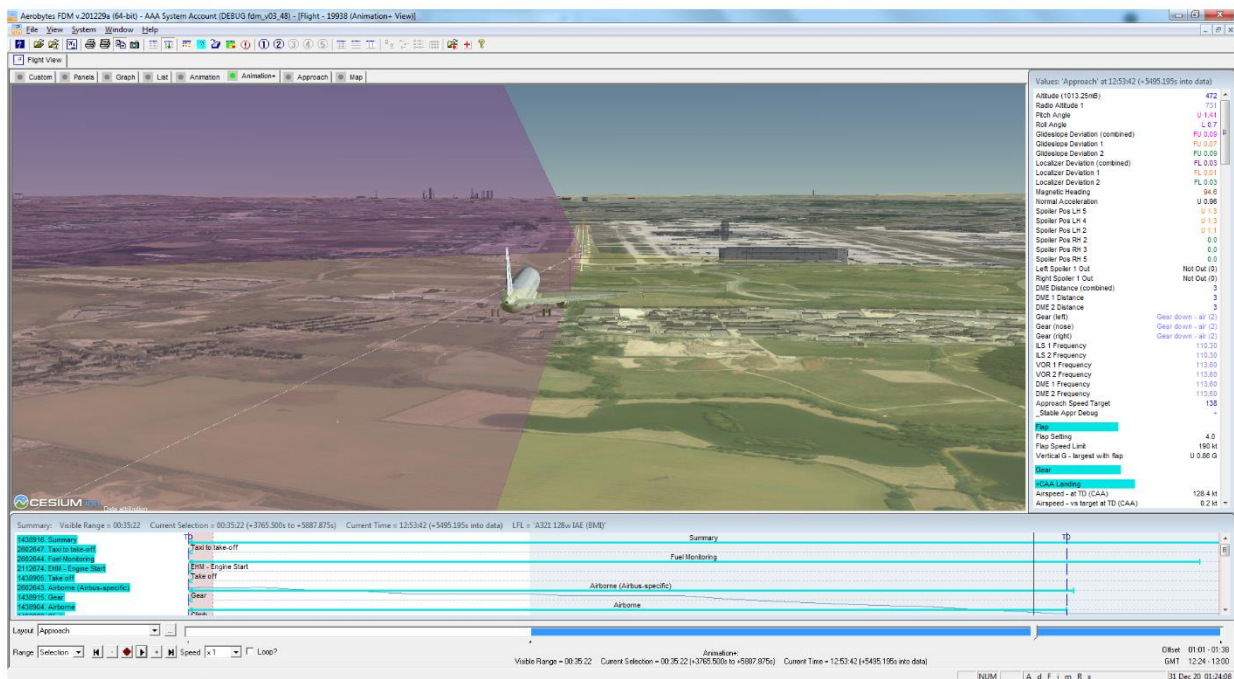


Figure 1.6 An example of Aerobytes Flight Data Analysis interface  
(Image courtesy of <https://www.aerobytes.co.uk/>)

The following equipment is used for effective FDA:

- The On-Board Digital Flight Parameter Recorder is a device installed on board an aircraft to read and record a large number of different types of flight parameters and one-off commands.
- Quick Access Recorders and the Wireless Ground Link Quick Access Recorder are the means for transmitting data recorded on board an aircraft to a ground server.
- BAFDA is a ground based computer system (software) for transcribing and analysing flight parameters (data), identifying deviations from normal values, producing statistical



reports to facilitate the interpretation of the analysed data, etc. Also, this software provides the possibility to reproduce all available flight parameters by means of their visualization, both for its analysis and for the purpose of debriefing with the crew.

### **On-board equipment:**

The On-Board Digital Flight Parameter Recorder is a device installed on board an aircraft and designed to record flight parameters obtained from the Flight Data Acquisition Unit, which also transmits the flight data either to an electronic unit installed in an easily accessible location from which the recorded flight parameters are taken, or to a device for wireless transmission of recorded flight parameters.

Quick Access Recorders or Wireless Ground Link Quick Access Recorder have no anti-shock protection and are installed on aircraft if necessary, such units' record flight parameters either on removable inexpensive media or transmit the recorded parameters to a ground server using wireless means of communication.

### **Ground-based computer system for flight parameter analysis:**

- Flight parameter files are downloaded from the aircraft recorder to the ground computer system server, then the server automatically transmits the data to BAFDA and Aerobytes for processing with analytical software, where this confidential information is stored and protected from unauthorized access at all times.

- BAFDA software facilitates the daily analysis of flight parameters for the purpose of identifying abnormalities that may require immediate action to prevent them.

- BAFDA software checks downloaded data for anomalies. Logical formulas are commonly used to identify deviations, made up of a large number of absolute values and calculated parameters that are derived from various sources such as aircraft performance curves, Crew Operating Technology, engine performance, aerodrome flight patterns and approach features. Some of the simplest logic formulas are created to control deviations from normal values, such as instrument readings in the red zone or operational limits. The

values entered into the logical formulas for controlling deviations from normal values are determined by the Flight Operations and Corporate Safety Compliance Departments.

- Normal flight parameters and all abnormalities are displayed in various formats on the computer screen. The interpreted flight parameters can be presented by the software in a variety of forms such as colored symbols, curves and straight lines, as a series of numerical values, cockpit instrument animations, aircraft flight animations, including the use of programs such as Google Earth.

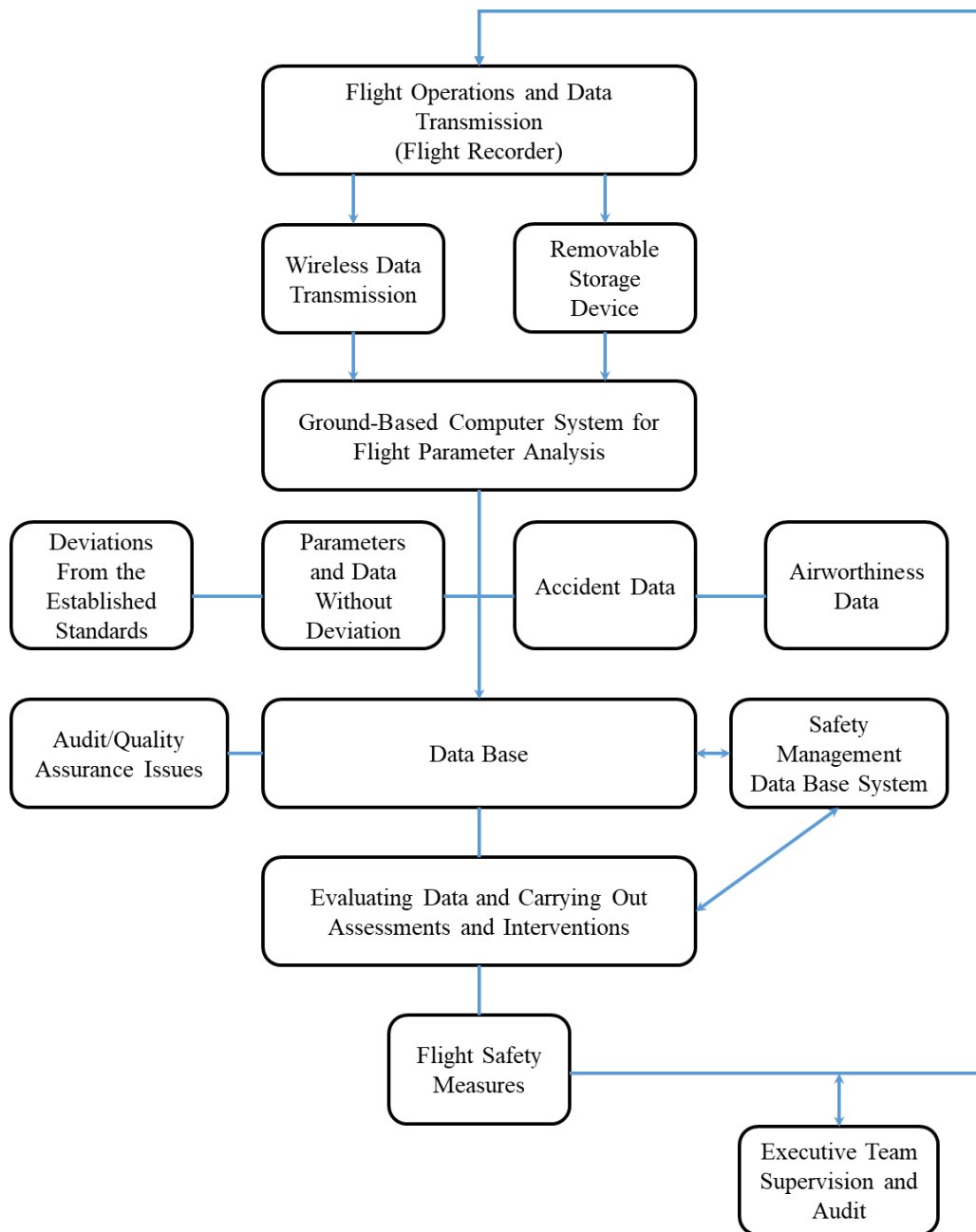


Figure 1.7 An example of Flight Data information exchange within an airline company.

One of the main methods to analyse and receive useful information from Flight Data is the detection of deviations, such as deviations from the operational limits of the aircraft flight operations manual or Crew Operating Technology. The list of mandatory flight events and parameters for monitoring is defined with consideration of obtaining such data that are of the greatest interest to the Flight Operations Department and the Corporate Safety Compliance Department. Flight events associated with abnormalities represent factual information, which may be supplemented by information from the crew and engineering staff.

Once the parameters from the flight recorders have been processed, the system stores data from all flights, not just those relating to significant events. The stored data allows the selection of the necessary parameters to describe the performance of each flight and the comparative analysis of a large number of changing operational criteria. Emerging negative trends must be controlled before the risk associated with a deviation reaches a value above an acceptable level.

For all flights, the programme undertakes a comparative analysis to determine normal operating practices, which can be accumulated by storing various types of, including exemplary information from each flight

The statistics are a set of quantitative data collected for analysis. Thus, it is sufficient to have the number of flights flown by each aircraft and the information on flight events in them to obtain the number of events per flight unit, as well as information on trends.

If FDA detects flight events in the course of routine analysis, they must be examined and checked in more detail to confirm their authenticity or fictitiousness. In this case, the main flight parameters are examined more thoroughly, e.g. engine operation, speed, roll, pitch, etc., and the variation of these parameters during the different phases of the flight. Such parameters can be compared with parameters of other flights performed without deviations, which do not need to be checked. After detailed examination and comparison of parameters and, if necessary, consultation with pilots and engineers, it can be concluded that the event in question is valid.

Once the data check has been completed and the deviations from normal operation have been determined with reference to environmental conditions, aircraft technical condition, etc., the event must be validated in the system, rated by hazard, marked with a keyword and secured against change. FDA software accumulates confirmed flight events in a database (flight event module) to build different graphs and identify trends in different variants that contribute to an in-depth and comprehensive analysis.

FDA reviews and summaries are prepared monthly on a regular basis, but investigation of individual significant flight events must be timely and action taken without delay. All data is analysed to identify specific exceedances of operational thresholds and the occurrence of undesirable trends, which are communicated to Flight Operations and Training management. Flight crews are informed of specific exceedances of performance thresholds and significant deviations on a daily basis by telephone or e-mail by an authorised person. Notifications from FDA to the Flight Operations Department are sent by e-mail.

In case piloting technique deficiencies are detected, the confidentiality of crew information must be maintained. Information about irregularities is communicated to specific flight crews through an authorised person - FDA Manager. When interacting with the crew, the FDA Manager clarifies the circumstances, obtains information from the crew and gives advice and recommendations for appropriate actions, such as additional flight crew training, changes to manuals and instructions, as well as changes to airport services' technological instructions.

All flight events in the database are archived. This database is used for the purpose of sorting the information, confirming it and presenting it in a way that is most understandable to the command and control staff. Only after a certain period of time does the accumulated information give a picture of emerging trends and risks that might not otherwise be detected.

The experience gained from the FDA Manager process is used by the airline in its safety improvement activities. Any information obtained through FDA must be used with caution, bearing in mind that consent must be obtained from all crew members to identify

the flight event before it can be used for additional training or safety improvement activities. Flight Data Analysts should also exercise caution in carrying out preventive measures, bearing in mind that crews should fly in accordance with Crew Operating Technology rather than attempt to meet the criteria set out in FDA as this may adversely affect flight safety.

FDA personnel need to program the correct parameter thresholds to detect abnormalities, providing for tolerances to ensure that minor abnormalities, false events are not detected, while ensuring the appropriate minimum range for Crew Operating Technology, but without encouraging the crew to focus on the FDA parameters to avoid abnormalities.

As in any closed-loop process, where preventive measures need to be monitored, they need to be evaluated for effectiveness. Feedback from crews is essential for identifying and solving flight safety problems, which may include roughly the following issues:

- Does the implementation and effectiveness of preventive measures meet safety requirements?
- Has the risk level been reduced, or inadvertently moved to another area of flight operations?
- Any new problems have arisen in flight operations as a result of the implementation of preventive measures?

All successes and failures of a programme should be recorded, comparing planned objectives with achieved results. This will provide a solid database for the FDA Programme audit and a foundation for future development of the programme.

## CONCLUSIONS TO CHAPTER 1

As aviation continues to improve and develop so will increase the size of airline's fleet. This, in-turn, will also increase the number of pilots and ground staff that has to be objectively supervised or supported. Thus, objective control is introduced.

OC is not a new term, as it is used in some countries around the world but mostly in military aviation but it doesn't have the same meaning everywhere as it is not an international term. In some countries OC mostly refers to flight recorder systems and FDA systems, which is a correct term but has rather limiting definition. By introducing OC as an international term it can be further researched as the need for replacing as much human input and replacing it with hard objective data is invaluable.

FDA is not a new aviation investigation subdivision, as first flight recorders have been installed on aircraft all the way back during World War II. However, as the computer systems have developed during the years so did the tools for analysing flight data. Computer analysis is much more superior to that of humans and can be further developed as Artificial intelligence gets wider use.

Furthermore, post-factum objective control is not the only way to increase flight safety, as other on-board systems can be easily identified as objective. TCAS, for instance, greatly reduces human interaction during potential mid-flight collision scenarios by eliminating the need for air traffic controllers to dispatch orders to two or potentially more aircraft. By excluding human factor and input from already time sensitive situation as well as giving simple to follow commands to pilots, objective control is greatly increased.

## CHAPTER 2

### SUBJECTIVE CONTROL AND ITS IMPACT ON FLIGHT SAFETY

#### 2.1 Subjective control. Definition and significance.

In psychology Subjective Control (SC) is not entirely defined as one definition. However, most of the definitions are very similar in their implication. For instance, the level of SC is a technique designed to diagnose internality - externality, i.e. the extent to which a person is prepared to take responsibility for what happens to and around him or her. In aviation it is possible to define subjective and objective control/system in a simpler way, as objective systems are the ones that omit expending critical decisions to the hands of human input. As mentioned in the previous chapter, systems similar to TCAS are great examples of objective control. TCAS not only gives easy understandable commands for pilots to follow but also replaces human component in form of air traffic controller. From this we can define SC as human actions that influence the safety of the flight, for example pilots, crew members, maintenance staff, design engineers, air traffic controllers and even corporate directors of airlines.

SC can be also defined as human factor but only to a certain extent, as human factor is a very widely used term. Human factor describes the possibility for human beings to make erroneous or illogical decisions in specific situations. Every human being is characterised by limitations or errors. It is not always the case that a person's psychological and psychophysiological characteristics correspond to the level of complexity of the tasks or problems to be solved. Errors, referred to as human factors, are usually unintentional: a person performs erroneous actions, believing them to be correct or best suited.

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Зав. каф.						

Human factors often play an important role in aviation as from 1950s to 2010s, pilot error resulted in 49% of all fatal accidents. While that statistic could seem high, however considering all of the tasks that pilots are responsible for it is understandable; pilots need to fly through dangerous weather, counter mechanical issues and execute safe take-offs and landings. Many aviation accidents are caused when pilots misread flight equipment, misjudge weather or fail to properly address mechanical errors. Pilot error is treated as the number one reason why planes crash.

However, pilots are not the only ones who are responsible for aviation accidents, as there are other frequently reported causes most of which carry SC. For example:

- Crew member mistakes;
- Aircraft maintenance negligence;
- Airline corporate negligence;
- Aircraft design and manufacturing defects;
- Air traffic controller negligence;

Crew member mistakes, similar to pilot's, can result in human injuries or in some cases death. These mistakes may not result in any crashes but crew members that fail to correctly perform on-board duties, such as properly storing luggage. An example of a similar mistake that led to an accident is China Eastern Airlines Flight 583. During the flight above the Pacific Ocean near the Aleutian Islands one of the crew members accidentally deployed the slats. This has forced the plane to suddenly pitch down causing all the unbuckled passengers to hit the ceiling which caused serious neck injuries. Flight 583 was carrying 255 occupants, out of who 60 were hospitalized and in the end 2 people died.

Aircraft maintenance negligence along with airline corporate negligence are an unfortunate trend in modern aviation as airlines are constantly cutting corners to keep aircraft in air as long as possible while pressuring pilots and crew to make unsafe landings



or to fly with the minimum amount of fuel. An example of aircraft maintenance negligence is aircraft accident Alaska Airlines Flight 261. An Alaska Airlines McDonnell Douglas MD-83 was on a scheduled flight AS261 from Puerto Vallarta to San Francisco to Seattle, but crashed into the water 4.5 kilometres off the coast of Anacapa Island, California, when approaching San Francisco. All 88 people on board - 83 passengers and 5 crew members - died. The final report of the investigation was published on 30 December 2002. According to the report, the crash was caused by insufficient lubricant in the screw mechanism that changes the angle of the stabiliser, which led to increased wear on the bronze nut of this mechanism, its breakage and, consequently, withdrawal of the stabiliser and loss of control. The last lubrication change before the crash was made in September 1999. The investigation also found that Alaska Airlines had increased the interval between scheduled inspections of its airliners. This greatly increased the likelihood that wear and tear would go undetected.

When the aircraft design is not fully competent, design engineers should be held liable for their mistakes. A study by Boeing concluded that approximately 20% percent of all airplane accidents were due to machine(equipment) failures. Other statistics reach a similar conclusion. As out of all commercial fatal accidents from 1950s to 2010s about 23% were caused by a mechanical failure (engine failure, equipment failure, structural failure, design flaw) (table 2.1-2.2).

CAUSE OF FATAL ACCIDENTS BY DECADE								
DECADE/ CAUSE	1950s	1960s	1970s	1980s	1990s	2000s	2010s	ALL
Pilot Error	50%	53%	49%	42%	49%	50%	57%	49%
Mechanical	26%	27%	19%	22%	22%	23%	21%	23%
Weather	15%	7%	10%	14%	7%	8%	10%	10%
Sabotage	4%	4%	9%	12%	8%	9%	8%	8%
Other	5%	9%	13%	10%	14%	10%	4%	10%

RAW DATA								
DECADE/ CAUSE	1950s	1960s	1970s	1980s	1990s	2000s	2010s	ALL
Pilot Error	82	119	112	67	77	48	28	533
Mechanical	43	62	45	36	35	22	10	253
Weather	25	15	22	22	10	8	5	107
Sabotage	6	9	20	20	13	9	4	81
Other	9	21	31	16	22	10	2	111
	165	226	230	161	157	97	49	1,085

Chart 2.1-2.2 Fatal accident data throughout the decades provided by

<http://www.planecrashinfo.com/>

Air traffic controller negligence is also very important. As the amount of aircraft in the sky will only increase with time so will the responsibility of air traffic controllers. A moment of lost attention could lead to a potential tragedy. There are plenty of examples where air traffic controllers were a big part of the accident. For example, on February 1, 1991 USAir Flight 1493, Boeing 737-300 collided with a turboprop SkyWest Airlines during landing procedure at Los Angeles International Airport. Investigation by the National Transportation Safety Board concluded that possible cause of the accident was lack of redundancy at the control tower which made local controller lose situational awareness. To make situation worse, local controller who is in part responsible for the accident had made 4 mistakes (or deficiencies) while passing last performance review. Two out of four mistakes were lack of situational awareness and aircraft misidentification.

All of the previously mentioned mistakes are a result of direct human input be it human factor or deliberate corner cutting instruction by an airline company. However, even the most fatal error during flight, human, machine or other is usually not the main reason of the accident. As aviation is filled with redundancy systems and procedures that ensure safe flight during a small pilot error for instance. Most of the accidents, especially the most tragic ones, happen when multiple things go out of the ordinary at the same time. This method of accident deconstruction is commonly known as Swiss cheese theory and was developed by James Reason in 1990.

## 2.2 James Reason's Swiss Cheese model.

James Reason suggested a witty metaphor for the succession of errors leading to disaster: "Each hole in the cheese slice is an individual error. There are many such 'holes' in any system at each level, and they are in different places and have varying degrees of potential destructiveness. However, the next level-slice, which does not have a problem in the same place, protects the whole system from an incident". This metaphor is well known to specialists in risk management.

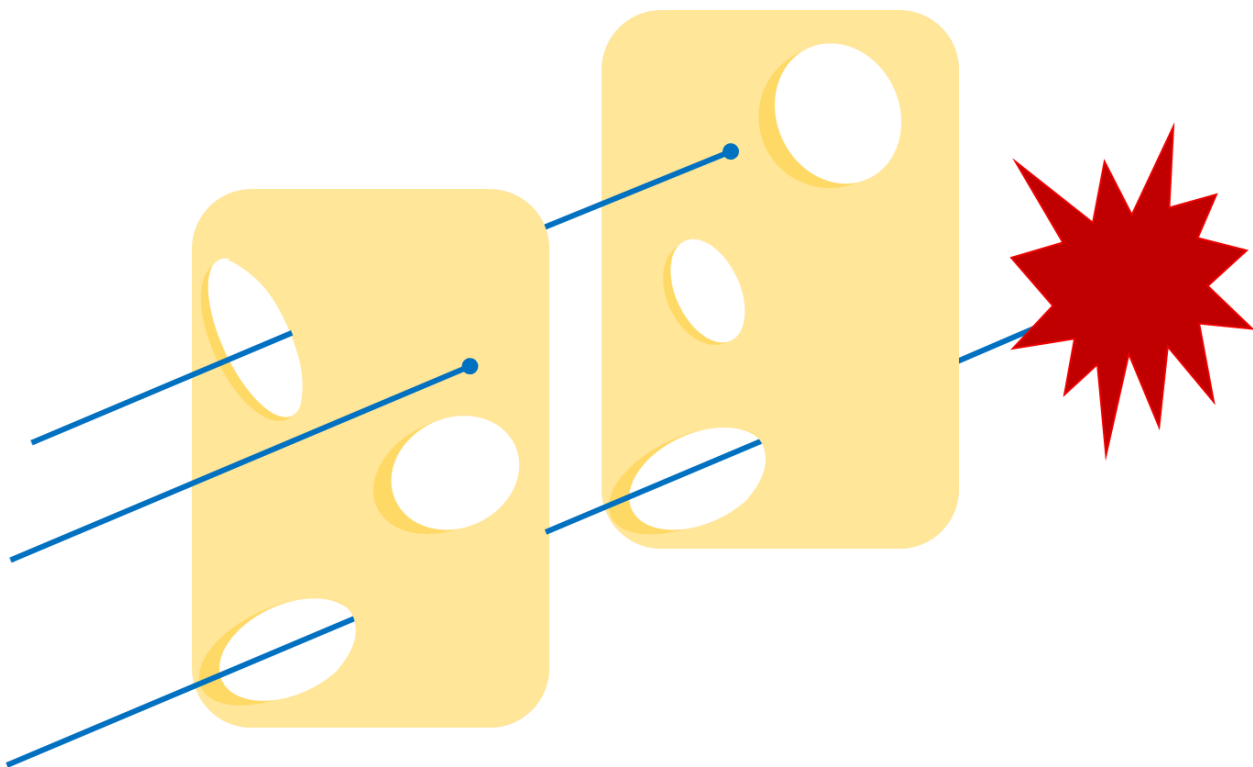


Figure 2.1 Reason's Swiss Cheese model

Reason's model is widely used in aviation as well as aviation accident investigation as it not only makes understanding aircraft accidents better but also can help prevent future accidents of similar nature from occurring. The main idea of Reason's model is to explain that most accidents happen due to a series of mistakes or failures happening that figuratively penetrate each layer of defence leading up to the accident.

The Swiss Cheese model assumes that complex systems such as aviation are extremely well protected from multiple layers, internal single failures rarely have serious consequences in an aviation system. A breach in a safety protection system is a delayed consequence of decisions made at the higher levels of the system, which do not become apparent until their impact or destructive potential is triggered by a specific set of operational circumstances. Under such specific circumstances, human errors or active failures at the operational level act as triggers of latent conditions that contribute to the failure of the inherent safety features of the system. In the Reason's model, all incidents involve a combination of active and latent conditions.

Active conditions are acts or omissions, including errors and violations, that have a direct negative impact. They are generally considered (retrospectively) to be dangerous actions. Active failures are usually associated with the direct performers (pilots, air traffic controllers, aviation mechanical engineers, etc.) and can lead to severe consequences.

Latent conditions are conditions that existed in the aviation system long before the accidents occurred. Latent conditions may not manifest themselves for long periods of time. Initially they are not perceived as dangerous, but this becomes apparent once the system's defences have been breached. Such conditions are usually created by people who are quite distant in time and space from the event itself. Hidden conditions in an aviation system include circumstances created by a lack of safety culture; in addition, they can also be caused by poor equipment or procedures; conflicting organisational objectives;

deficiencies in organisational systems; and poor management decisions. A forward-looking approach to incidents due to organisational causes seeks to identify and mitigate these hidden conditions on a system-wide basis, rather than through localised measures to minimise active failures by individuals.

The underlying concept of organisational causal incidents in the Reason’s model can best be understood by applying a modular approach consisting of five building blocks (figure 2.3). The top building block is represented by organisational processes. These are activities that any organisation directly controls within a reasonable amount of time. Typical examples are providing guidance, planning, information sharing, resource allocation, supervision, etc. There is no doubt that the two fundamental organisational processes in terms of flight safety are resource allocation and information exchange. Failures or deficiencies in these organisational processes create disruption on two fronts.

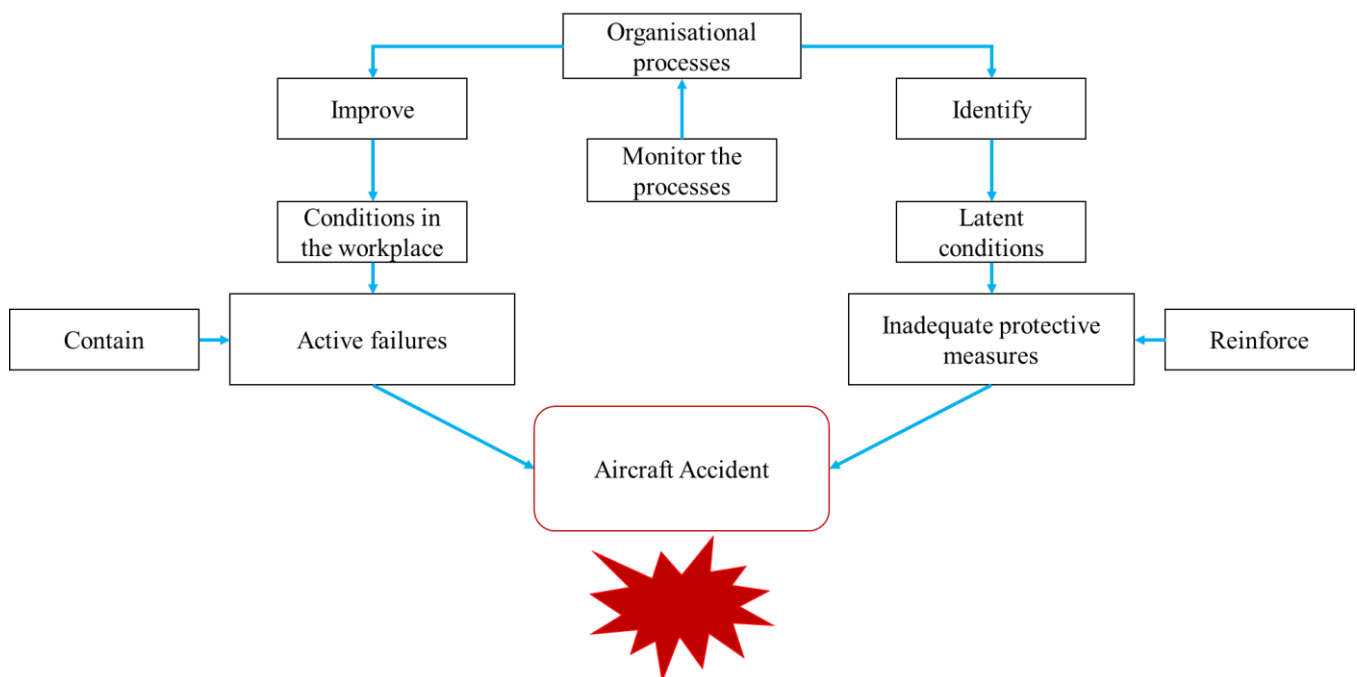


Figure 2.2 Modular representation of Reason’s model

One direction is the path of latent conditions. Examples of latent conditions can include: deficiencies in equipment design, inadequate/incorrect standard operating procedures and lapses in staff training. In general, latent conditions can be divided into two large groups.

One group is inadequate identification and management of safety hazards, with the result that safety risks associated with hazards are not brought under control, but wander freely through the system and are eventually brought into an active state by operational factors.

The second group is known as deviation normalisation, a concept which, in simple terms, indicates the operational context in which the exception becomes the rule. In this case, the inadequacy of allocated resources is taken to an extreme. As a consequence of the lack of resources, the operational staff, who are directly responsible for the actual implementation of production activities, have only to resort to various tricks to successfully carry out such activities, resulting in constant breaches of rules and procedures.

Swiss Cheese model had a few versions but all of them bear a similar idea in mind (the iconic Swiss Cheese metaphor appeared as a result of one of the later models). Reason's model has gone under a bit of criticism when it was first introduced, however it was not enough to completely omit accident investigators and flight data analysts from using the model. As the criticism provided was not associated with any of the three primary uses:

- As a Conceptual Framework;
- As a Means of Communication;
- As a Basis for Analysis;

As the points of criticism were accusing Reason's model of failing at what it was not made for. Since aircraft accidents vary in complexity a lot there is always a desire to have a universal model that could be used for investigation. Swiss Cheese model looks promising at the first glance, but it can't be used for every case as it has its own pros and cons. However, it still remains one of the primary models for accident investigation and prevention (if it is applicable adequately).

### 2.3 SHELL model.

Aviation has multiple areas where human subjective nature can show its negative influences. SC should try to help visualize cases where human input was the direct result of an accident or an incident. SHELL is a great model for visualizing work as a system with multiple layers or parts that are connected between each other (figure 2.4).

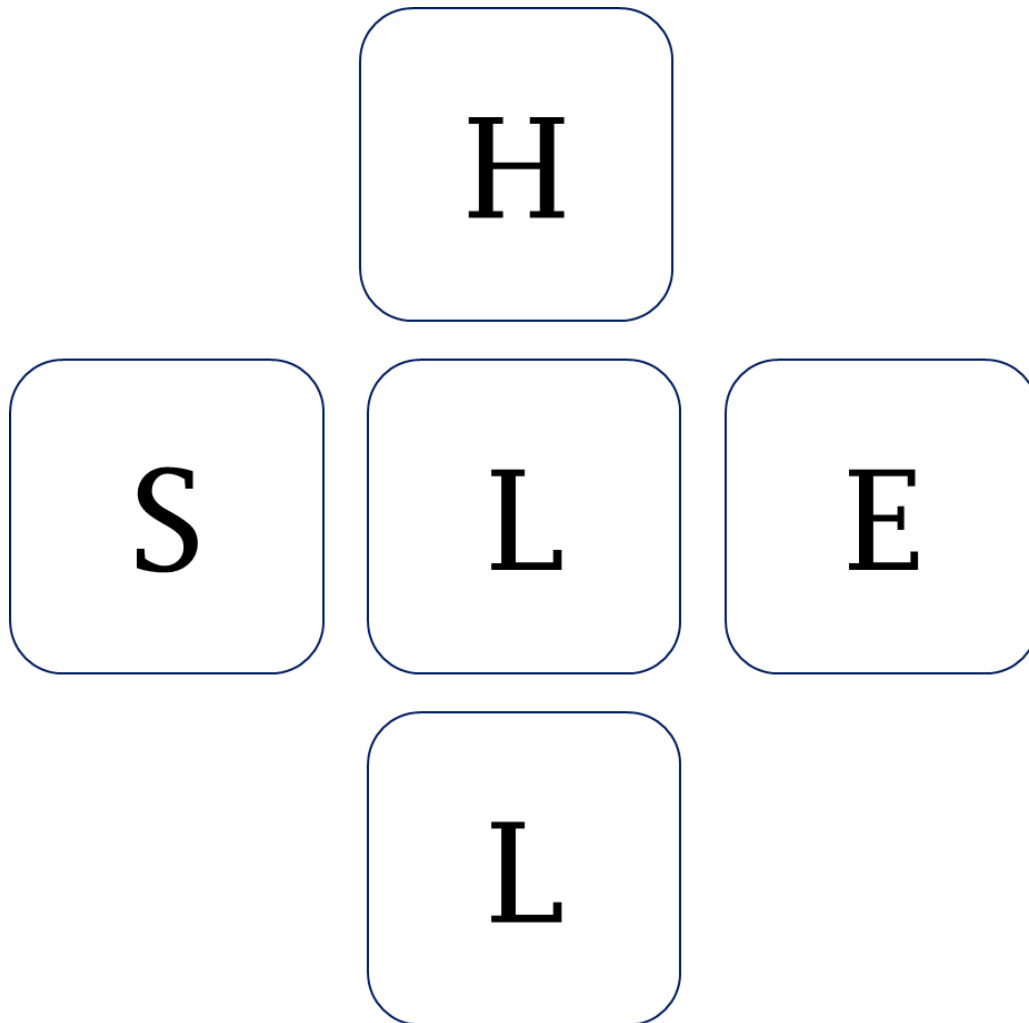


Figure 2.3 Visual representation of the SHELL model.

SHELL itself is an acronym that stands for:

- **S** – Software;
- **H** – Hardware;

- **E** – Environment;
- **L** – Liveware;

At the heart of the SHELL model are people at the forefront of operations. Although people have an amazing ability to adapt, nevertheless their performance is subject to significant fluctuations. People cannot be standardised to the same extent as equipment, so the boundaries of this unit are not as simple and straightforward. People do not interact perfectly with the various components of the environment in which they work and as a result are susceptible to subjective opinions formed. To avoid tensions that could negatively impact human actions, it is necessary to understand the implications of interface inconsistencies between the various SHELL units and the central "Liveware" unit. In order to avoid stresses in the system, other components of the system must be carefully matched to people. The SHELL model is particularly useful to visualise the interface between the various components of an aviation system:

- **Liveware-to-Hardware (L-H)**. When referring to human action, the interface between humans and the physical attributes of equipment, machines and devices is most often considered. The interface between humans and machinery is usually considered in the context of human action in aviation activities, and humans have a natural tendency to adapt to inconsistencies in the L-H interface. That said, however, this tendency can mask serious shortcomings that may only become apparent after an incident.
- **Liveware-to-Software (L-S)**. The L-S interface represents the relationship of the individual to the support systems available in the workplace, for example: regulations, manuals, control charts, publications, standard operating rules (SORs) and software. This interface includes aspects such as recent work experience, accuracy, size and presentation, terminology, clarity and symbolism.
- **Liveware-to-Liveware (L-L)**. The L-L interface represents the relationship of the individual to others in the workplace. As flight crews, air traffic controllers, aircraft maintenance engineers and other operational personnel work in teams, it is important to recognise that information exchange and relationship skills, as well as



team dynamics, have an impact on their performance. With the advent of the concept of Crew Performance Optimisation (CPO) and its extension to air traffic services (ATS) and maintenance, the emphasis has been on operational error management across multiple segments of aviation operations. Employee-management relations and all aspects of the corporate culture are also within the scope of this interface.

- Liveware-to-Environment (L-E). This type of interface covers the relationship between the individual and the indoor and outdoor environments. The internal working environment includes physical parameters such as temperature, lighting, noise, vibration and air quality. The external environment includes aspects such as weather factors, aviation infrastructure and terrain. The interface also covers the relationship between the internal environment in which human activities take place and the external environment. Psychological and physiological factors, including illness, fatigue, financial turmoil, team relationships and career issues, can be caused by subject-environment (L-E) interactions or have external secondary sources at their core. Working conditions in aviation lead to disruptions in normal biological rhythms and habitual sleep patterns. In addition, aspects of the environment can also include organisational issues affecting decision-making and creating additional pressures, providing the basis for seeking 'workarounds' or small deviations from standard operating rules.

According to the SHELL model, divergence between Liveware and the other four components contributes to human error. Thus, interactions along the lines listed above must be assessed and accounted for in all sectors of the aviation system.

SHELL model can help break down maintenance roots of mistakes as during maintenance, human error usually manifests itself in an unintentionally caused malfunction of the aircraft (physical degradation or failure), the cause of which can be attributed to the action or inaction of the technicians maintaining it. The word 'explained' is used because human error in maintenance can be of two main types. In the first, it results in a specific fault in

the aircraft that did not exist prior to the maintenance operation. Any maintenance operation carries the potential for human error that could lead to an unintentional malfunction of the aircraft. Examples are the incorrect installation of replacement units, a safety plug left in the assembly of a hydraulic line under repair, or the breakage of an air duct because it was used as an access step for a maintenance operation (among other examples, these illustrate the lack of pairing of L-H elements in the SHELL model). The second kind of error results in failure to detect an undesirable or unsafe condition when performing routine or non-routine maintenance, the purpose of which is precisely to detect such a condition. Examples of such errors are: a crack in a power unit not noticed during visual inspection or the removal of a faulty electronic unit '1 instead of a defective one due to an incorrectly identified cause of the fault. Errors of this kind can also be caused by hidden faults, such as insufficient training, lack of allocated resources or tools required for maintenance, lack of time, etc. They can also be caused by poor - ergonomically speaking - tool design (L-H coordination flaw), incomplete documentation or manuals (L-S coordination flaw), etc.

SHELL and Swiss Cheese model can also help breakdown cases of maintenance or corporate mismanagement or negligence. For instance, previously mentioned Douglas MD-83 flight, which had an accident due to unlubricated stabiliser screw, show a latent condition results of which are shown only with time. If the airline company decided to omit themselves from cutting corners by increasing the time between each lubrication, such an accident could have been avoided. Unfortunately, airlines and aircraft producing companies will continue to cut corners as the nature of aviation business is very monopolistic and “cut-throat”. Companies are trying to be profitable businesses first and foremost as a consequence they try to save-up as much money as possible. Be it by keeping aircraft up and running longer with lesser maintenance check-ups, bribing the aircraft certification giver or by rushing the whole aircraft development process. These cases occur all the time, the problem is that we can only analyse them after an accident or incident occurred as the longer the company keeps on getting away with extreme cost

cutting schemes, the more likely is it that they will become the norm within that company. (L-L coordination flaw). Another problem arises when after an accident has occurred The blame is often put up on one person (or perhaps a group) and the root of the problem is labelled as a human factor error. While it is tempting to push the blame into one person while calling it a human mistake or especially human factor, it is almost fully incorrect to do so. Both from the point of human factor as form of ergonomics and physiological study as well as from the standpoint of Reason's model and the SHELL model. This can be proven further with an example, an investigative analysis of Boeing 737-8 MAX accidents that occurred from 2018 to 2019.

#### **2.4 Boeing 737-8 MAX accidents. Analysis and study.**

The consequences of the two crashes of the Boeing 737-8 MAX for the world's largest aircraft manufacturer have been severe and surprisingly unpredictable. On 29 October 2018, an Indonesian Lion Air airliner crashed shortly after take-off and on 10 March 2019, an Ethiopian Airlines plane crashed under similar circumstances. The accidents claimed the lives of 336 people total. This, as well as the subsequent complete shutdown (or grounding) of the entire global 737 8 MAX fleet - approximately 380 aircraft - just five days later, was the highlight of the global aviation industry in recent years. According to investigation reports, the crash was partially caused by Boeing's newly introduced Manoeuvring Characteristics Augmentation System (MCAS): it automatically steers the nose down, even when the autopilot is turned off, if the aircraft's nose gets too high. Boeing did not prepare a new pilot training programme for Max, so they were not aware of the new system. On both fatal flights, the angle-of-attack sensor mistakenly reported that the nose was too high, MCAS activated itself and directed the aircraft downwards - before the pilots realised what was happening and switched the system off.

However, MCAS cannot be the only thing to blame. As the Swiss Cheese model implies failure of a single defence layer usually doesn't cause an accident. In this scenario 2

defensive layers are already broken. Lack of pilot training as well as an MCAS failure. Subsequent investigation and questions should be pointed towards the cause. Why were the pilots not aware of the MCAS? Why was MCAS so aggressive in its commands and functions?

Investigation of Indonesian Lion Air accident conducted by National Transportation Safety Committee (NTSC) concluded on 25 October 2019 and it outlined what it considers to be the main Contributing Factors. In total 9 contributing factors were highlighted. These factors are represented solely on their chronological characteristics and do not represent or display the level of contribution each of them provide.

1. When Boeing 737-8 MAX was in the design and certification phase, assumptions were made regarding the flight crew's response and response time to on-board malfunctions which were incorrect despite the fact that they were consistent with the industry guidelines of today.
2. With the incorrect assumptions about the flight crew response during malfunction and the incomplete review of all the flight effects that follow from this, it was believed that using a single sensor for MCAS to be convenient.
3. Relying on a single Angle of Attack (AOA) sensor makes MCAS susceptible to inaccurate data coming from that sensor.
4. The lack of counselling provided about MCAS or detailed information about the application of trim in the flight manual as well as during flight crew training, made it problematic for flight crews to deal with a rampant MCAS.
5. The AOA DISAGREE signal was not set up and enabled correctly during the development of Boeing 737-8 MAX. Subsequently, AOA DISAGREE alert did not pop-up with the inadequate AOA sensor, thus could not be documented by the flight crew and therefore maintenance cannot identify the inaccurate AOA sensor.
6. The AOA sensor installed on the accident aircraft had been mis-calibrated as a result of an earlier repair. This mistake has not been noticed during the repair.
7. It could not be determined during the investigation if the installation test and procedure were conducted properly. The mis-calibration was not noticed.

8. Lack of documentation within the aircraft flight and maintenance log regarding the continuous stick shaker and use of the Runaway Stabilizer NNC meant that data wasn't obtainable to the maintenance crew in Jakarta nor was it obtainable to the accident crew, creating it harder for everyone to perform the correct actions.
9. Continuous MCAS reactivations, multiple alerts going off at the same time as well as confusion caused by numerous air traffic controller distractions proved themselves to be too much to be handled efficiently.

From these 9 points it becomes apparent that Reason's Swiss Cheese model fits perfectly, especially since the main points are laid out in a chronological order. It is no fully apparent if this was done intentionally or just that the Swiss Cheese model applies here well. Furthermore, SHELL model also could be used to further improve understanding of the accident.

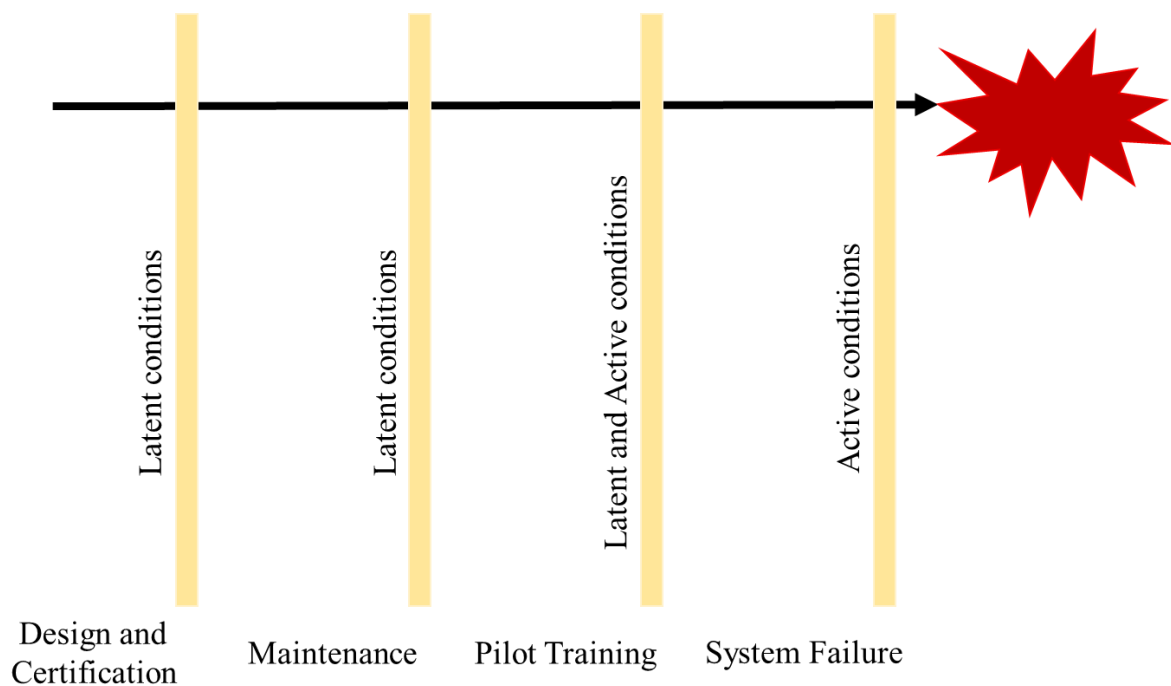


Figure 2.4 Reason's Swiss Cheese model being applied to Lion Air accident

If the Lion Air accident was the only one for the Boeing 737-8 MAX it wouldn't be that out of the realm of random error. However, as less than a full calendar year later another accident occurred on the same new "fresh out the oven" airplane. This caused quite a stir in a world of aviation.

Ethiopian Airlines Boeing 737-8 MAX crashed six minutes after take-off on 10 March 2019. Full report has not been published yet, however interim report published almost a year later (on 9 March) stated that the Ethiopian Airlines aircraft had defective on-board software.

The researchers noted that just before both crashes, the aircraft had performed erratic manoeuvres that took them into a dive. The MCAS "made it vulnerable to unwanted activation," the report said. Specifically, the system was activated automatically, guided by signals from only one angle-of-attack sensor - this one analyses the angle of the aircraft in relation to the oncoming airflow.

When the pilots, following the procedures recommended by the manufacturer, tried to regain control of the aircraft, they failed. The aircraft was descending at 900 kilometres per hour. The commission's report said Boeing's training on the 737 Max aircraft was "found to be inadequate" in the similar manner as in the Lion Air accident.

In an interview with The New York Times, current Boeing CEO David Calhoun suggested that the pilots' actions were a key factor in the 737 MAX crash, saying that pilots in Indonesia and Ethiopia "do not have the practical experience that their American counterparts have," but declined to answer a direct question about whether American pilots could have handled the MCAS malfunction.

To make matters worse, the fact that these 2 accidents happened in such a quick succession, made Boeing 737-8 MAX have an accident rate of 4 accidents per million flights. As between the release of the March 2017 (first public flight of Boeing 737-8 MAX) and March 2019 (Ethiopian Airlines accident) 737 had operated 500,000 flights with 2 accidents under its belt.

Considering the severity of the situation aviation regulators (such as the U.S. Federal Aviation Administration or simply FAA) decided to ground the aircraft. In addition, U.S. Congress and numerous other U.S. agencies had investigated the certification given to MAX by FAA. Among the agencies that were part of the investigation were: Federal

Bureau of Investigation, Transportation Department, National Transportation Safety Board.

It has emerged that the FAA has greatly broadened the authority of Boeing Corporation engineers over Boeing's safety testing and certification of the Boeing 737 MAX 8, effectively allowing Boeing to certify its product itself, which calls into question the objectivity of these tests. Appearing at a Senate hearing, Acting FAA Administrator Daniel C. Elwell said FAA aviation safety engineers and test pilots worked 110,000 hours during the 737 MAX certification, and they conducted or supported 297 test flights.

Amid the prohibition scandal, there have been news reports that Boeing has ignored repeated requests from the unions to create the necessary simulator to train pilots. As a result, some pilots were forced to learn the new model by training on an iPad tablet. According to the New York Times, the US Attorney General's Office is also investigating the possibility that Boeing pilot Mark Forkner, who was testing the new 737 MAX, deliberately misled the FAA about new software for the aircraft of this model.

In addition, multiple engineers that were involved in the design and manufacturing phase of the Boeing 737-8 MAX has stated that from the very beginning they were forced to cut many corners, however the validity of such statements is hard to prove.

From the accidents that took place in addition to the overall level of negligence that took place at Boeing, it can be seen that there were other elements that played a part in the development and construction of 737-8 MAX. One of those elements was most definitely Airbus, Boeing's main competitor.

Stating that Airbus is Boeing's competitor would actually be an overstatement, due to the fact that both of these tech giants are sharing a monopoly, or in a simpler term, have a duopoly. As the barrier of entry is so high in aviation, it is incredibly difficult for new companies to enter the scene. That is why this duopoly might continue on indefinitely. Airbus had an uphill battle to fight when it first came into market in 1972 with A300, first wide-body twin-engine aircraft. In the recent years Airbus has managed to keep up with

American Boeing. And this has led to the year of 2012. Airbus announced the development of their next generation of aircraft A320neo. 2 years later in 2014 Boeing announces 737-8 MAX. This 2-year gap is somewhat crucial in the accidents that occurred in 2018 and 2019. As due to a head start, Airbus has managed to successfully deliver their flagship aircraft prior to their competitor. This could be considered as the first layer of defense broken according to Reason's model. As every consequent condition could be considered a result of inability to react/predict action of the competitor.

## **2.5 Market monitoring.**

When in 2010 Airbus first claimed that new Airbus 320neo was in the works, Boeing executive told that it posed no threat. This implies that Boeing severely under estimated Airbus, as seen by Boeing's 737-8 MAX there were problems during development. In addition, Airbus has managed to have a better, more profitable 2020. As 2020 has been a challenging year for aviation due to COVID-19, this implies that Airbus had a more solid grasp on market monitoring. This shows the importance of market analysis, as it can indirectly influence aircraft safety.

Market monitoring is a continuous and methodical process of collecting, analysing and disseminating information about the external business environment. The "business environment" should be understood in its broadest sense, including all relevant actors: consumers, competitors, distributors, suppliers, technology developers and suppliers, as well as regulators and the macroeconomic environment.

### **Key challenges of market monitoring**

Many companies feel that their own market monitoring systems are not sufficiently developed. Common problems noted include the following:

- Overabundance of information
- Irrelevance of received information



- Inability to draw conclusions on the basis of the information received
- Lack of concise and clear information
- Lagging of information
- Outdated market trends reflected in the information and insufficient reflection of future trends
- Isolation of market monitoring from other company processes
- Difficult to access format of information
- Difficulty of access to information.

Fortunately, all these problems can be solved with the help of publicly available methods and knowledge.

One of the main reasons for low effectiveness of market monitoring is incomplete understanding of the link between market monitoring and strategic management. The information generated by monitoring needs to be clearly separated into information that is used in implementing strategy and information that helps the company formulate strategy. There are many other critical factors that need to be taken into account, but understanding this distinction is the first step to ensuring effective monitoring.

### **Market monitoring and strategic management**

In today's business world, most large companies have their own market monitoring systems that allow them to gather information on competitors, customers and other market players. The usefulness of such systems is generally not in doubt, but their specific benefits are often difficult to articulate. To understand how to maximise the utility of market monitoring, we should start by analysing the relationship between it and strategic management.

The strategic management process is clearly divided into two stages: strategy formulation and strategy implementation. At the formulation stage, strategic planning, self-assessment and analysis of strategic alternatives take place, on the basis of which decisions regarding

the mission and goals of the company are made. This is done by the top management of the company.

At the strategy implementation stage, managerial and organisational resources are mobilised and used to achieve the set goals.

Market monitoring system (MMS) is the process of tracking the competitive environment in order to provide useful data to the decision makers of the company. Thus, MMS is a means of implementing the company's strategy, as it is the strategy that defines the part of the competitive environment that is to be monitored. In addition, the relevance of the information provided to decision-makers is also determined according to the themes and priorities set out in the strategy. The MMS is supposed to be able to recognise threats and opportunities for the strategically prioritised areas.

The strategy is implemented through the day-to-day activities of the company's divisions. The sales department seeks to create revenue, and the MMS can give it direction. Marketing seeks to increase the company's market share and MMS informs it of competitors' behaviour. The purchasing department seeks resources at minimum cost and the MMS assists it by monitoring suppliers and market prices. These are all aspects of strategy implementation.

The Threat and Opportunity Early Warning System (TOEWS) is a process of scanning the wider environment than the area outlined in the current strategy. The process is designed to identify opportunities beyond the current strategic priority areas and to respond to even subtle signals with a high degree of uncertainty. In this respect, TOEWS differs significantly from MMS. The output of the TOEWS is used to identify new strategic alternatives, helping the company to formulate new strategies. For this purpose, TOEWSs can produce even ambiguous, dubious signals that run counter to the current strategic paradigm, which would be unacceptable for MMS because such outputs are unclear and unprofitable. Information from TOEWSs is mainly used by strategic planners or senior management.

The ability to identify opportunities in advance, say, when a new consumption trend emerges, the legal framework changes, new global challenges rise or new technologies emerge, is important in itself. However, being able to do so before competitors, means being able to capture more market share, generate more revenue, enhance brand image or decrease losses in case of a global crisis.

Without a predictive monitoring system, a company only learns about market events after they have occurred (figure 2.5). As a result, it can only take action on the effects of an event that has already occurred and after competitors have already taken their own action. This often results in sub-optimal resource allocation, low profits and a market share below potential.

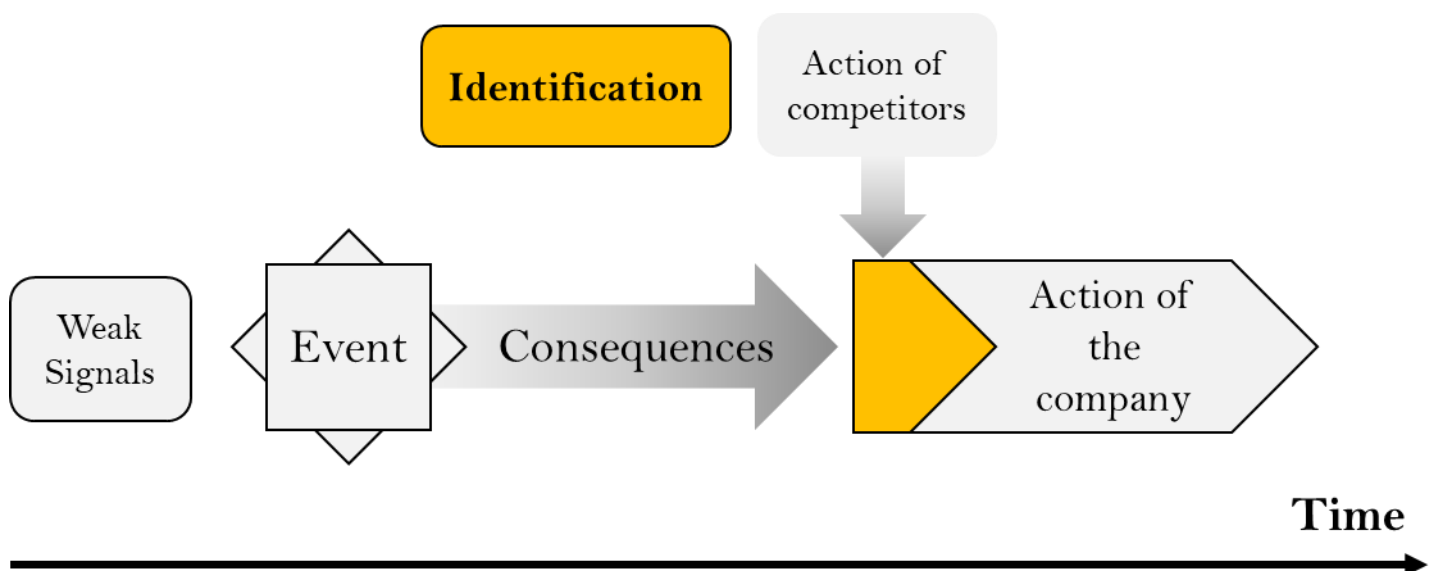


Figure 2.5 Scheme of late company market reaction due to a lack of market monitoring and strategic management system

With a predictive market monitoring system in place, a company can anticipate an event, take appropriate action and allocate resources ahead of both the event itself and its competitors (figure 2.6). In this way, the company gains a head start over its competitors, a larger market shares and higher profits.

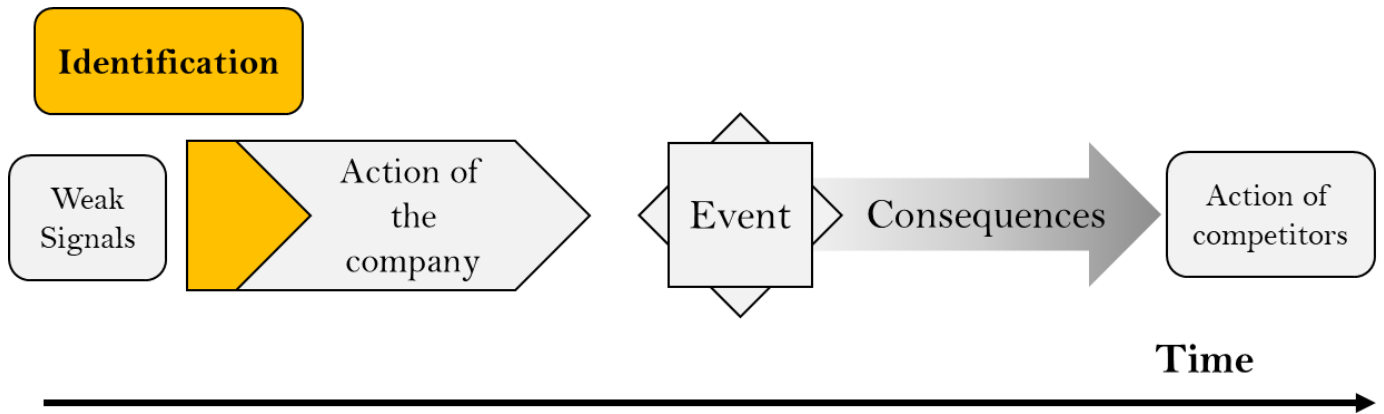


Figure 2.6 Early reaction towards weak signals puts the company ahead of the competitors.

## CONCLUSIONS TO CHAPTER 2

SC plays an important role in aviation of today. As throughout the years the overall number of mechanically related accident has decreased dramatically and most of the accidents nowadays are caused by a combination of human inputs (Pilot error, Human factor, direct negligence). By introducing SC as a form of investigative/communication term accidents and incidents could be analysed with more scope. In addition, SC helps divert human errors to organizational errors.

Since the level of redundancy in aviation is very high, human error/factor alone is usually not enough to cause an accident. By utilizing SC as terminology in analysis in conjunction with other models, greater level of accident analysis can be achieved. As SC is not limited by specific designations and names, since it combines human input overall first, to further divide it into different categories afterward.

## CHAPTER 3

### OBJECTIVE AND SUBJECTIVE CONTROL AS A BALANCED SYSTEM

Currently, most aviation accidents occur due to human input of some sort. These were discussed in the previous chapter, but this doesn't mean that we should solely blame people as the main reason accidents happen. The interaction between human and machine within the aircraft should be considered as a full integral unit. Human-machine system interaction plays an important role and it is one of the main components of engineering psychology.

Engineering psychology is a scientific discipline that studies objective regularities of human-machine information interaction processes in order to use them in human-machine system design, construction and operation practice. The processes of information interaction between man and technology are the subject of engineering psychology.

Since ancient times, when creating tools and means of labour, certain properties and abilities of a person were taken into account. In the beginning, intuitively, and later with the involvement of scientific data, the task of adapting technology to humans was solved. However, different properties of human beings have been consistently subject to analysis.

In the early days, the focus was on the human body and the dynamics of working movements. Biomechanical and anthropometric data was used to develop recommendations relating only to the shape and size of the human body and the tools that it uses. Then the physiological properties of the person at work were investigated. Recommendations arising from the data of the physiology of work, not only relate to the design of the workplace, but also to the regime of the working day, the organization of working movements, to combat fatigue. Attempts have been made to assess different types of work in terms of the demands they place on the human body.

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Engineering psychology emerged at the intersection of technical and psychological sciences. Therefore, it is characterised by features of both disciplines.

As a psychological science, engineering psychology studies human mental and psychophysiological processes and properties, figuring out what requirements to individual technical devices and the Human-Machine System as a whole are derived from the specifics of human activity, i.e. it addresses the problem of adapting technology and working conditions to humans.

As a technical science, engineering psychology studies the principles of construction of complex systems, control stations and consoles, machine cabs, and technological processes to clarify the requirements for psychological, psychophysiological and other properties of human operators.

The scientific and technological revolution has led to significant changes in the conditions, means and nature of working activity. In modern manufacturing, transportation, communication systems, construction and agriculture automatic machines and computer technology are increasingly used; many production processes are being automated.

Thanks to the technical upgrading of production, the functions and role of the human being are changing considerably. Many tasks, which were formerly the prerogative of man, are now being performed by machines. However advanced technology may be, labour is and remains a human asset, and machines, however sophisticated, are mere tools of labour. By using machines as tools, man realises the goals he has consciously set for himself.

Consequently, as technology develops and becomes more complex, the importance of the human factor in production increases. The need to study this factor and take it into account in the development of new techniques and technological processes, in the organisation of production and operation of equipment is becoming increasingly evident. The efficiency and reliability of the operation of the created machinery depend on the successful solution of this problem,

The functioning of technical devices and the activity of man, who uses these devices in the process of labour, must be considered in interrelation. This viewpoint has led to the formation of the concept of the Human-Machine System. The Human-Machine System refers to a system comprising a human operator (a group of operators) and the machine through which labour activities are carried out. The Human-Machine System refers to a set of technical means used by a human operator during an activity. The Human-Machine System is the object of engineering psychology.

Human-Machine System is a particular case of control systems in which the functioning of the machine and human activities are linked by a single control loop. When organising the relationship between man and machine in the Human-Machine System, the main role belongs not so much to anatomical and physiological but rather to psychological properties of man: perception, memory, thinking, attention, etc. The psychological properties of a human being largely determine his or her informational interaction with the machine.

A system in general systems theory refers to a set of interrelated and interacting elements designed to solve a single problem. Systems can be classified according to various characteristics. One of them is the degree of human involvement in the system. From this point of view, a distinction is made between automatic, automated and non-automatic systems. An automated system works without human intervention. In a non-automatic system, the work is done by a person without the use of technical devices. An automated system involves both a human being and technical devices. Therefore, this system is a Human-Machine system.

In practice, a wide variety of Human-Machine Systems are used. The basis for their classification can be the following four groups of features: the purpose of the system, the characteristics of the human link, type and structure of the machine link, the type of interaction between components of the system.

The purpose of the system has a decisive influence on many of its characteristics, and is therefore a primary characteristic. According to the purpose it is possible to allocate the following classes of systems:



- controlling, in which the main task of the human is to control the machine (or complex);
- servicing, in which a human being monitors the state of a machine system, looks for faults, makes adjustments, settings, repairs etc.;
- training, i.e. developing specific skills (technical training aids, simulators, etc.);
- informational, which ensure search, accumulation or acquisition of information necessary for a person (radar, television, documentary systems, radio and wire communication systems, etc.);
- research ones, used for analysis of some phenomena and search of new information and new tasks (simulating apparatuses, mock-ups, research instruments and installations).

The peculiarity of controlling and servicing systems consists in the fact that the machine component of the system is the object of purposeful influence. In training and informational Human-Machine Systems the direction of influence is opposite - on human. In research systems, the influences have both directions.

Two classes of Human-Machine Systems can be distinguished according to the characteristic of the "human link":

- Monosystems comprising one person and one or more technical devices;
- Polysystems consisting of a certain group of people and one or a set of technical devices interacting with it.

In turn, polysystems can be divided into "parity" and hierarchical (multilevel) ones. In the first case, the interaction of people with machine components does not establish any subordination and priority of individual group members. Examples of such polysystems are the human collective-life support system (e.g., a life support system on a spacecraft or submarine). Another example would be a large-screen information display system designed for use by a collective of operators.

In contrast, hierarchical Human-Machine Systems establish either an organizational or priority hierarchy of human interaction with technical devices. For example, in an air

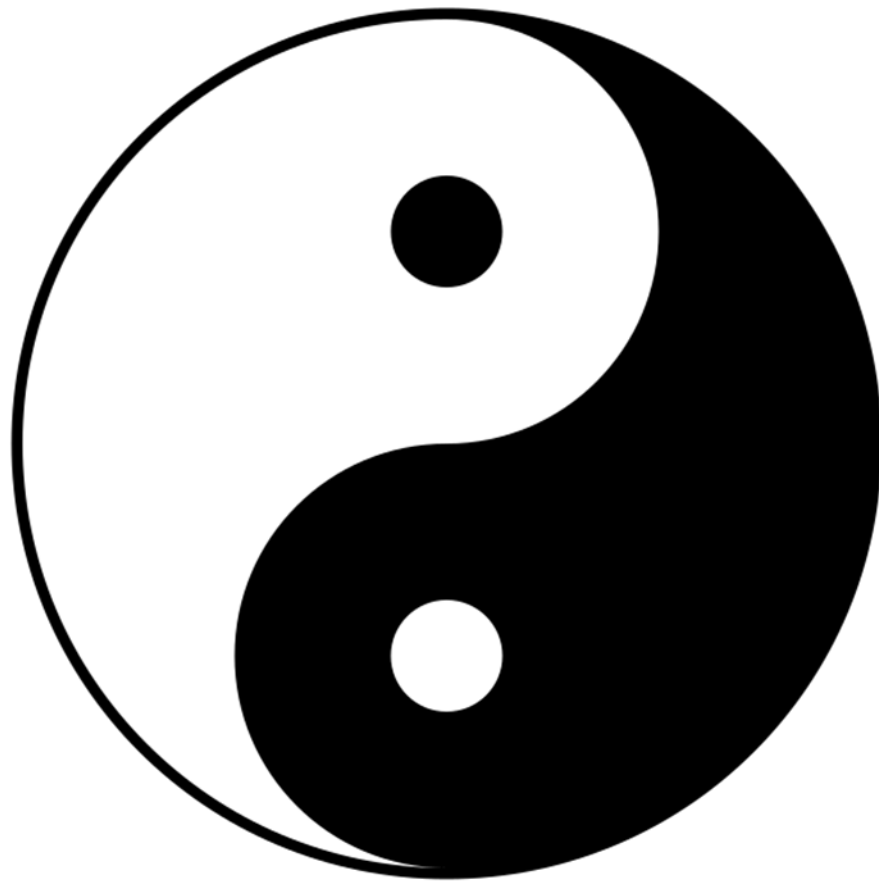
traffic control system, the air traffic controller forms the top level of control. The next level is the aircraft commanders, whose actions are directed by the dispatcher. The third level is the rest of the crew, working under the direction of the aircraft commander.

According to the type and structure of the machine component, instrumental Human-Machine Systems can be distinguished, which include instruments and devices as technical devices. A distinctive feature of these systems is usually the requirement for high accuracy of human operations.

Another type of Human-Machine System is the simplest Human-Machine System, which includes a stationary and non-stationary technical device (various kinds of energy converters) and a human being using this device. Here, the human requirements vary considerably depending on the type of device, its intended use and the conditions of use. However, their main feature is the comparative simplicity of human functions.

Human-Machine System as concept is implemented in aviation industry. Whether in the cockpit during flight or in the maintenance hangar on the ground, well established Human-Machine System will decrease the possibility of an accident and increase Objective Control and general objectivity of the flight.

During accident investigation it is very easy to blame either the subjective or objective side of the aircraft. For instance, 50% percent of all fatal accidents are caused by some sort of pilot error and only 20% are caused by machine failure (as mentioned previously). However, Objective and Subjective control should not be looked at as separate systems but as a balanced Human-Machine System (figure 3.1).



■ Subjective Control

□ Objective Control

Figure 3.1 Allegorical representation of a balanced Objective and Subjective control systems

Yin and Yang are only used as a demonstration of balance between systems in allegorical sense. However, this representation does present itself rather sufficiently. This could be proven with a simple example.

In a “normal” flight where most of external conditions are the ones that could be omitted, the aircraft of choice is well maintained and the onboard crew is not in a particularly bad mood. During such a flight, Objective Control is at a very high level as the pilots’ input

are kept to a minimum. Pilots just have to take-off/land smoothly, turn-on the appropriate automatic control systems after take-off, observe the parameters of the aircraft and follow the commands and recommendations of the air traffic controller. During such a flight most of the actions are done as a result of autopilot or other automated control systems.

Furthermore, the amount of human input and decision making is kept to a minimum. Such a situation can represent an upper half of figure 3.1. On the other hand, in case of an emergency situation or other in-flight abnormality pilots and air traffic controllers would be responsible for most of the decision making. However, due to general flight system redundancy, during most of these situations there would be one or two systems designed to aid the pilot. This situation represents the lower half of figure 3.1.

Nowadays, it is impossible to have fully objective flight as some quantity of human input is always going to be required, to either operate, maintain, design aircraft. To regulate the level of subjective control on the ground, different safety regulations are introduced by FAA and Eurocontrol, however as it was seen with Boeing 737-8 MAX, not all of these regulations are often followed.

It would also seem that the easiest way to reduce in-flight subjectivity, is to introduce more objective automated systems that either reduce pilot's stress and/or aid in dangerous or unsafe situations. This is currently a common practice, as throughout the years more and more automatic systems are introduced in aircraft. However, adding more automation to an already complex system, may in reality, lead to more accidents. According to Congressional Research Service, constant increase in complexity and automation of aircraft flight control systems makes it harder to address aircraft certification and pilot training. As in the last decades, aircraft automation and complexity had led to pilot confusion which had been cited in number of accidents and incidents, including Boeing 737-8 MAX mentioned before.

Modern jet airliners rely on numerous automated features to assist and alert pilots as well as to prevent aircraft from getting into precarious and potentially dangerous situations. In many cases, pilots' lack of understanding or familiarity with the design and operation of these automated features has led to inappropriate use of automation or inappropriate

responses when cockpit automation has gone awry. In other cases, latent flaws and unintended consequences of highly complex automated flight control systems designs have been implicated in commercial airplane accidents. The complexity of these automated systems has also raised questions about the manner in which new aircraft flight control system designs are evaluated and certified.

Therefore, this means that whenever a new complex aircraft system is implemented it has to be studied by pilots extensively. As lack of proper training will result in pilot confusion whenever a crucial unknown by the pilots' system goes down.

## CONCLUSIONS TO CHAPTER 3

It is important to understand, that aviation of today requires not only modern and safe in-flight systems, but also well trained pilots. As the aviation does increase in safety with each year, so does the complexity of it. And pilots have to be knowledgeable of automatic systems control what exactly.

In addition, modern aircraft (especially airplanes) may heavily depend on automatic control systems implemented. Some of which, such as fly-by-wire, may even block pilot's input which it regards as dangerous. All of these features increase the overall safety of the flight, but, on the other hand, are not entirely useful without the proper human input. As Objective and Subjective control are a part of the same balanced system they have to be both in tune with each other. Understanding and realizing that, will bring higher level aircraft ergonomics understanding and increase overall flight safety.

## CHAPTER 4

### SAFETY MANAGEMENT IN AIRLINES AND MAINTENANCE ORGANISATIONS AND ITS IMPORTANCE

#### 4.1 Safety Management System. Scope, definition.

The ideas and concepts of previously mentioned objectivity and subjectivity are well represented in Safety Management System (SMS). SMS is a system that defines and provides for the management of flight safety, which encompasses the organizational structure, responsibilities, procedures, processes and regulations designed to implement the aviation safety policy for air traffic services, ensure a desired or acceptable level of safety and provide for the monitoring of safety.

Safety is defined as a state in which the risks associated with aviation activities are maintained at an acceptable level, which requires the establishment of risk management methods calculated in a safety management system (SMS). The ICAO recommendations propose only a risk matrix as a risk assessment tool, which has known limitations. In practice, each airline and/or maintenance organization solves this problem independently. The proposed methodology is defined as a combination of methods for the synthesis of industry and general scientific developments and practical experience in the form of the implementation of the following principles for the construction of a SMS:

- 1) distinguishing three safety management circuits based on three ICAO hazard identification methods (Fig. 4.1);
- 2) dividing system state management tools (and risks) into two types: reaction to events and risk assessment of adverse events in SMS;

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- 3) maximizing the use of real data on airline operations, formalizing these data and applying simple software tools;
- 4) quantitative assessment of the significance of risks using conditional units when taking into account the system's properties to counteract hazards;
- 5) approach to risk management in an aviation enterprise as a task of situational management due to the characteristic properties of the management object:
- the uniqueness of the object, i.e. risks of each aviation enterprise have its own characteristics;
  - some complexity of formalizing the purpose of existence - the well-known dilemma of Production – Protection
  - inability to choose the best option: the quality of a decision cannot be assessed if the alternatives have not been tested;
  - dynamism: The system must be adaptive, i.e. change must be managed;
  - incompleteness of description: not all assumptions in the risk assessment are formulated.

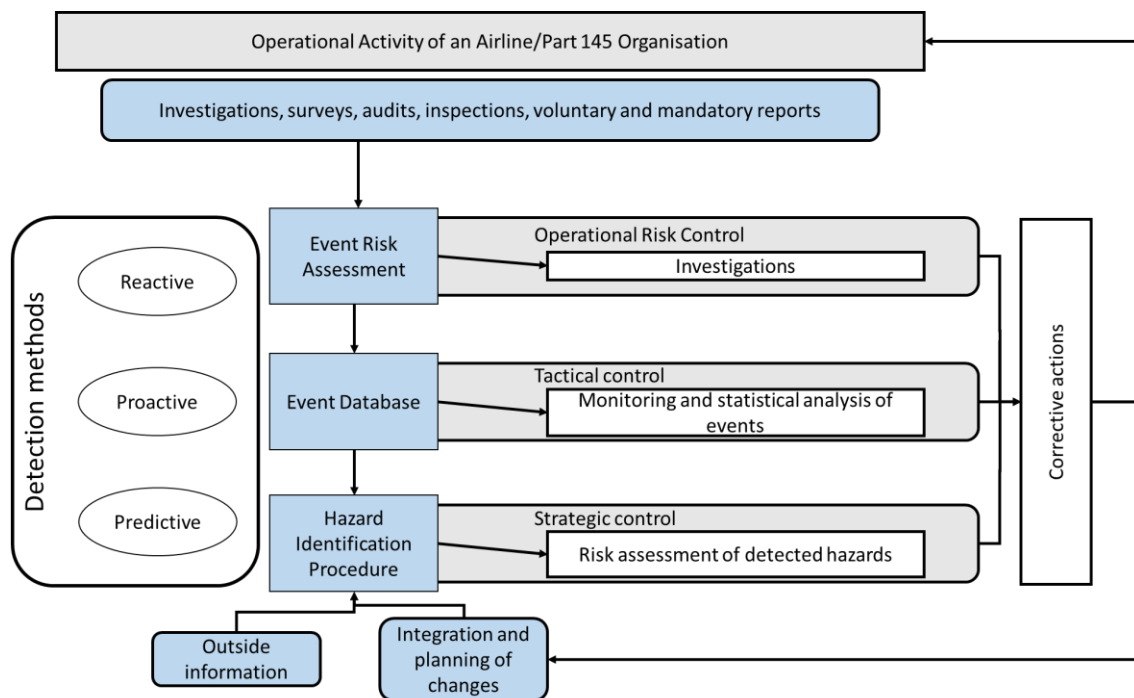


Figure 4.1 Three loops of risk management.



Given these features, we can only talk about the feasibility of solutions, not their optimality. This approach makes it possible to use both classical probabilistic methods and methods of fuzzy and soft estimation, which complement each other, to solve the problem at hand.

The process of bringing the safety risks of the consequence(s) of hazards under organizational control starts by assessing the probability that the consequence(s) of the hazard materialize during operations aimed at delivery of services. This is known as assessing the safety risk probability.

Safety risk probability is defined as the likelihood that an unsafe event or condition might occur. The definition of the likelihood of a probability can be aided by questions such as:

- Is there a history of similar occurrences to the one under consideration, or is this an isolated occurrence?
- What other equipment or components of the same type might have similar defects?
- How many personnel are following, or are subject to, the procedures in question?
- What percentage of the time is the suspect equipment or the questionable procedure in use?
- To what extent are there organizational, management or regulatory implications that might reflect larger threats to public safety?

Any or all of the factors underlying these example questions may be valid, underlining the importance of considering multi-causality. In assessing the likelihood of the probability that an unsafe event or condition might occur, all potentially valid perspectives must be evaluated. In assessing the likelihood of the probability that an unsafe event or condition might occur, reference to historical data contained in the database of the organization is paramount in order to make informed decisions.

Based on the considerations emerging from the replies to questions such as those listed above, the likelihood of the probability that an unsafe event or condition might occur can be established, and its significance assessed using a safety risk probability table (Fig. 4.2).

<b>Likelihood</b>	<b>Meaning</b>	<b>Value</b>
Frequent	Likely to occur many times (has occurred frequently)	5
Occasional	Likely to occur sometimes (has occurred infrequently)	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 4.2 Safety Risk Probability Table

Once the safety risk of an unsafe event or condition has been assessed in terms of probability, the second step in the process of bringing the safety risks of the consequence(s) of hazards under organizational control is the assessment of the severity of the consequence(s) of the hazard if its damaging potential materializes during operations aimed at delivery of services. This is known as assessing the safety risk severity.

Safety risk severity is defined as the possible consequences of an unsafe event or condition, taking as reference the worst foreseeable situation. The assessment of the severity of the consequence(s) of the hazard if its damaging potential materializes during operations can be assisted by questions such as:

- How many lives may be lost? (Employees, passengers, bystanders and the general public)
- What is the likely extent of property or financial damage? (Direct property loss to the operator, damage to aviation infrastructure, third party collateral damage, financial impact and economic impact for the State).
- What is the likelihood of environmental impact? (Spill of fuel or other hazardous product, and physical disruption of natural habitat).
- What are the likely political implications and/or media interest?

Based on the considerations emerging from the replies to questions such as those listed in paragraph above, the severity of the possible consequences of an unsafe event or condition, taking as reference the worst foreseeable situation, can be assessed using a safety risk severity table.

Severity	Meaning	Value
Catastrophic	<ul style="list-style-type: none"> <li>- Equipment destroyed;</li> <li>- Multiple deaths.</li> </ul>	A
Hazardous	<ul style="list-style-type: none"> <li>- A large reduction in safety margins physical distress or a workload such that the operators cannot be relied upon to perform their tasks accurately or completely;</li> <li>- Serious injury;</li> <li>- Major equipment damage.</li> </ul>	B
Major	<ul style="list-style-type: none"> <li>- A significant reduction in safety margins, a reduction in the ability of the operators to cope with adverse operating conditions as a result of increase in workload, or as a result of conditions impairing their efficiency;</li> <li>- Serious incident;</li> <li>- Injury to persons.</li> </ul>	C
Minor	<ul style="list-style-type: none"> <li>- Nuisance;</li> <li>- Operating limitations;</li> <li>- Use of emergency procedures;</li> <li>- Minor incident.</li> </ul>	D
Negligible	<ul style="list-style-type: none"> <li>- Little consequences.</li> </ul>	E

Figure 4.3 Safety risk severity table

Safety risk severity table (Fig. 4.3) contains five categories, which characterizes severity level of hazard or condition, the meaning of each category and assign each category a corresponding value.

Once the safety risk of the consequence(s) an unsafe event or condition has been assessed in terms of probability and severity, the third step in the process of bringing the safety risks of the consequence(s) of the unsafe event or condition under organizational control is the assessment of the tolerability of the consequence(s) of the hazard. This is known as assessing safety risk tolerability. This is a two-step process. First, it is necessary to obtain an overall assessment of the safety risk. This is achieved by combining the safety risk

probability and safety risk severity tables into a safety risk assessment matrix, an example of which is presented in Fig. 4.4

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

Figure 4.4 Safety risk assessment matrix

Control and mitigation are terms that can be used interchangeably. Both are meant to designate measures to address the hazard and bring under organizational control the safety risk probability and severity of the consequences of the hazard.

If safety risk was assessed as “unacceptable under the existing circumstances”, then resources must be allocated to slide it down the triangle, into the tolerable region, where safety risks are ALARP. If this cannot be achieved, then the operation aimed at delivery of the service(s) that exposes the organization to the consequences of the hazard(s) in question must be cancelled.

Hazards are potential safety vulnerabilities inherent to the aviation system. Such vulnerabilities manifest themselves as an array of consequences. In safety management process are assessed the safety risks of the consequences of hazards, by assigning each safety risk an index. Each hazard can generate one or many consequences, and each consequence can be assessed one or many safety risks. The first step in the safety risk mitigation/control process is, therefore, hazard/consequence identification and safety risk assessment.

There are three generic strategies for safety risk control / mitigation:

- 1) Avoidance.

The operation or activity is cancelled because safety risks exceed the benefits of continuing the operation or activity.

2) Reduction.

The frequency of the operation or activity is reduced, or action is taken to reduce the magnitude of the consequences of the risks.

3) Segregation of risk.

Action is taken to isolate the effects of the consequences of the hazard or build-in redundancy to protect against it.

In evaluating specific alternatives for safety risk mitigation, it must be kept in mind that not all have the same potential for reducing safety risks. The effectiveness of each specific alternative needs to be evaluated before a decision can be taken. It is important that the full range of possible control measures be considered and that trade-offs between measures be considered to find an optimal solution. Each proposed safety risk mitigation option examined from perspectives of effectiveness.

To summarise, safety risk control / mitigation strategies are mostly based on the deployment of additional safety defences, or in the reinforcement of existing ones.

Defences and it is recalled that defences in the aviation system can be grouped under three general categories:

- a) technology;
- b) training;
- c) regulations;

#### **4.2 Risk Assessment with the help of event trees.**

The three levels of risk management (Figure 4.1) - operational, tactical and strategic (reactive, proactive, predictive) - are interpreted as module structures for risk assessment on three forecast horizons:

- 1) upcoming flight risk - operational forecast, or operational risk;

2) average flight risk as a characteristic of an airline for 1-6 months within the medium-term forecast - medium-term risk;

3) long-term risk (a year or more) taking into account planned changes in operations - long-term risk;

The methodologies for calculating these risks differ only in terms of the input data. The assessment is based on the modelling of aviation event trees - logical schemes reflecting possible scenarios for the development of an aviation event from manifestations through intermediate events and safety barriers to events of a certain type. Such schemes are modelled using a combination of Fault Tree Analysis (FTA) and Event Tree Analysis (ETA) methods for the main scenarios. The input data used are Flight Data Monitoring (FDM) results, reliability data, event statistics, meteorological information, inspection and audit results, etc. In the project a large volume of expert assessments were carried out using methods from, for example, the estimation of transfer coefficients of causal relationships of event trees (conditional probabilities). According to the ETA-FTA methodology, it is initially necessary to identify the hazardous End Effects for the study object. Given the complexity, it is proposed to perform calculations for each type of CA. An international list of aviation event categories is given below. However, these existing lists are designed for the organization of AS databases but not for the tasks of forecasting these events. For risk prediction, certainty in the consequences of the final event is necessary. In order to solve this problem, a classifier of AS developed based on the ICAO international classifier, presented in Fig.4.5, is proposed.

<b>№</b>	<b>Code</b>	<b>Description</b>
1	ARN	ABNORMAL RUNWAY CONTACT
2	BIRD	BIRD
3	CFIT	CONTROLLED FLIGHT INTO OR TOWARD TERRAIN
4	FIRE	FIRE
5	GCOL	GROUND COLLISION
6	LOC-1	LOSS OF CONTROL – INFLIGHT

7	MAC	AIRPROX/ ACAS ALERT/ LOSS OF SEPARATION/ NEAR MIDAIR COLLISIONS/ MIDAIR COLLISIONS
8	RE	RUNWAY EXCURSION
9	SEC	SECURITY RELATED
10	CTOL	COLLISION WITH OBSTACLES DURING TAKE-OFF AND LANDING
11	DECOM	DECOMPRESSION
12	ADES-1	AIRFRAME DESTRUCTION – INFLIGHT

Figure 4.5 Event Classifier

Event types according to the FTA methodology are the top (head) events. The next step in the ETA-FTA methodology is to compile a list of hazards determining the development of specific types of Aircraft. Substantial information support can be obtained from the analysis of statistical data on Aircraft. In doing so, a bottom-up ETA method is implemented - from the hazards to the Aircraft types. The statistical analysis procedure should be combined with studies of Aircraft types according to the FTA principle - from the top event through intermediate events and safety barriers to hazards. Hazards should be presented in a way that provides input data for calculating their severity as a probability of triggering event. Hazards characteristics can be: numerical values, random parameters of stochastic nature with known and unknown probability distributions, parameters of non-numerical nature that can be calculated solely on the basis of expert judgement.

In each case, one has to be creative, seeking to use those data that allow one to calculate the desired probability of an intermediate event with the greatest certainty. For example, for one of the types of "Rolling Out of Runway on Landing", a significant "landing zone overrun" is considered as an intermediate event. This event is a manifestation of several "Crew" events, among them flying over the runway threshold at an altitude significantly higher than recommended, long leveling, significant Vapp overspeed, etc. However, in order to predict a "significant overflight" event in an upcoming flight, it is advisable to use a probability distribution of the "overflight" value from the data for a particular pilot. Of course, the characteristics of the aerodromes, in particular the available landing distance,

must also be considered. Such an approach can greatly simplify the structure and procedure of the 'tree' (Fig. 4.6).

A distinction must be made between 'manifestation of Hazards' and 'cause of Hazards'. For example, Crew Hazards can be: exceeding the recommended descent rate, creating a roll that is more than acceptable on landing, etc. In other words, a Hazard manifestation is an event which has unambiguously definable consequences for a specific type of Aircraft. Hazards can be caused by: occupational training; human psycho-physiological characteristics, etc. However, it is not possible to clearly identify which consequences in the development of a given type of Aircraft event will result from, for example, a person's psychophysiological characteristics. Causal analysis and their assessment are necessary to predict the impact of these hazards on the development of aviation events. The ETA-FTA analysis results in the construction of an aviation event development tree, a logical scheme reflecting probable scenarios of development and manifestation of hazards and their combinations through intermediate (undesirable) events and safety barriers in Aircraft (Fig. 4.6). It is proposed to analyse only probable scenarios of AA development, excluding improbable ones. This condition will allow the construction of tree models suitable for practical application in an airline. One of the main objectives of the analysis being conducted is to identify the shortest paths to Aircraft that reflect the greatest risk in possible scenarios.



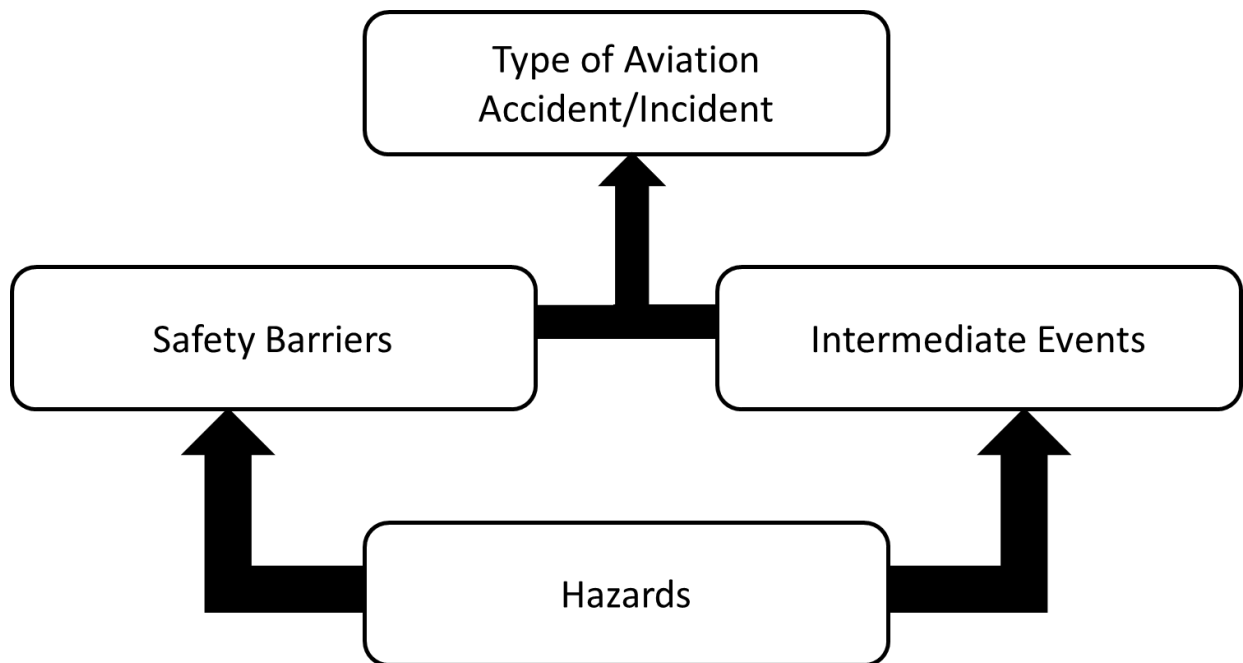


Fig.4.6 Structure of an Aviation accident/incident tree

The hazard factor is only able to influence the development of the Incident/Accident if both the barriers of prevention and the barriers of paralysis are "broken". This condition must be implemented in the development of the Incident/Accident development tree. It should be noted that failures of safety barriers are also manifestations of hazard factors.

The analysis performed has shown that the approach to aviation event risk calculation based on the construction of event trees, using the ETA-FTA methodology, is applicable to airline incident/accident probability forecasting tasks. The proposed methodology substantially simplifies the procedure and reduces the time to construct trees compared to the use of classical probabilistic safety analysis, makes it acceptable for practice to solve the problem of calculating safety indicators characteristic of FTA and the problem of calculating criticality of systems failures, which ETA is focused on. However, the exceptional complexity of FTAs will require additional specific research both in terms of ensuring the comprehensiveness of FTAs, in particular the psychophysiological characteristics of pilots, and in developing methods to describe the impact on the development of events (in probabilistic measures) of hazard factors. Overall, the method shown is good for visual representation of particular possible incidents/accidents, however lacks the statistical database back-up to truly be usable regularly.

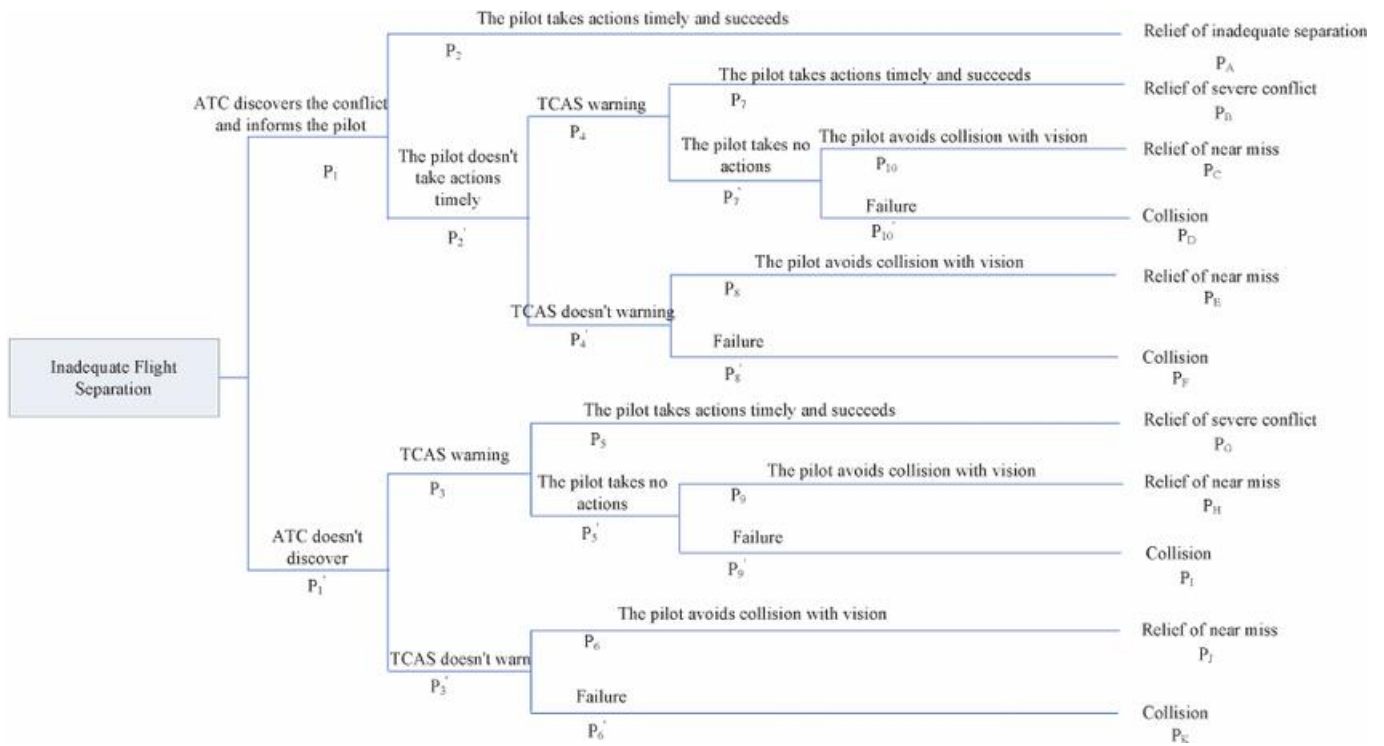


Figure 4.7 Example of Event Tree of Inadequate Flight Separation

### 4.3. Risk Assessment with the help of event triggers.

Ongoing Monitoring and Assessment of safety performance can be reached through periodic reviews, inspections and audits, risk assessments and the risk management process itself, with the aim to strive for a continuous reduction in the risk level.

Information about identified hazards received and gathered every day and summarized each month by Safety Department, Risk assessment department later reassess the risks.

Aircompany, in its operations, in this case, is guided by ALARP (translated as As Low As Reasonably Practicable) principle. (Fig. 4.8)

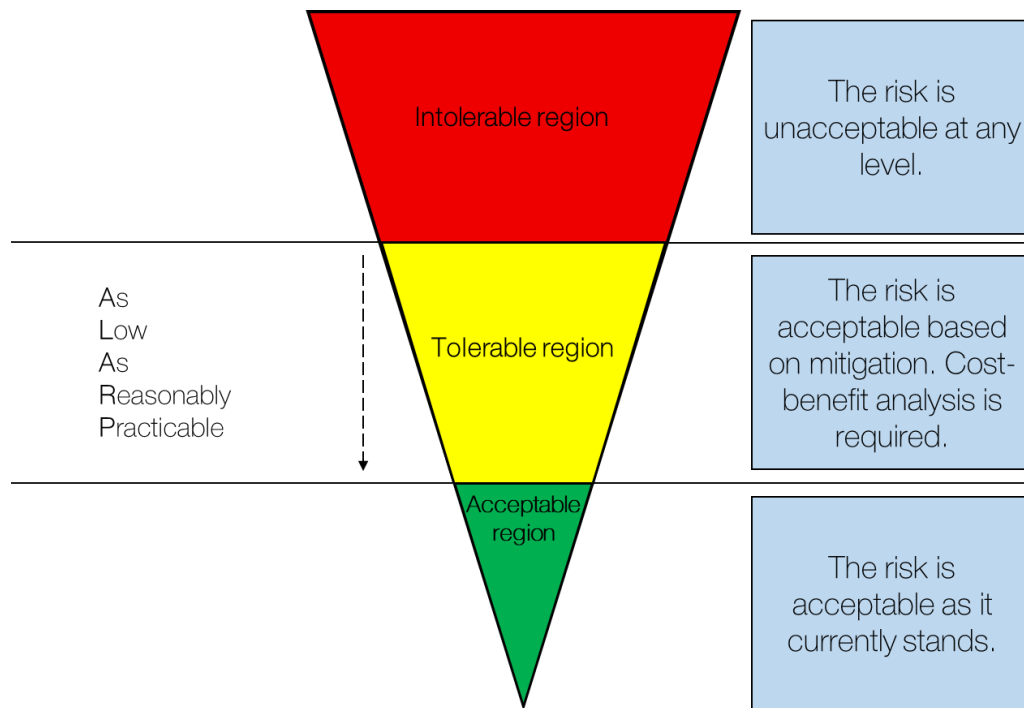


Figure 4.8 ALARP Model

All data related to risk reassessment and risk mitigation materials as well as influence of their's factors are entered into the table Hazard Log and Risk Assessment (further Hazard Log). It is used as a database for risk monitoring, risk reassessment and improvement of system control. The mentioned table is carrying information for each operational department.

**The components of monthly reassessment and formalization of prepared risk mitigation materials:**

1. Collection and analysis of statistical information provided to the Safety Department..
2. The summarizing of information that was collected through internal and external hazard identification means.
3. The analysis of collected information (The recognizing, identification of hazards and risk assessment).
4. The risk calculation and it`s alert/ trigger levels.

This calculation allows guaranteeing and clearly demonstrates the effectiveness/ ineffectiveness of taken mitigation actions. The calculation of risk alert/ trigger level

performs on the basic safety metrics standard deviation criteria (in accordance with SMS ICAO Doc 9859) by using following formula:

$$SD = \sigma = \sqrt{\frac{\sum(x - \mu)^2}{N}}$$

SD – Standard Deviation

$\sigma$  – Sigma notation

$\sum$  – sum up

X – Frequency of occurrences

$\mu$  - Average

N – Quantity of months

For finding number X we need the frequency of occurrences divided on flight hours and multiplied by 1000.

For finding number  $\mu$  need to find mean of frequency of occurrences.

## 5. Risk analysis.

Performed calculations allow us to define the exceedance of acceptable value of risk and necessity of its further reassessment, as well as developing of new corrective actions.

The following markers were accepted for gradation of actions in case of alert levels exceedance by any of risk:

**Warning!!!** (in red)

- the point above Average + 3 Standard Deviation

(needs to take mandatory corrective actions and increasing of risk index during assessment).

**Warning!** (in amber)

- the point above Average + Standard Deviation

(needs to control the risk or take corrective actions and negligible increasing of risk index during assessment).

Normal (in green)

- the point below Average + Standard Deviation

(don't need to take mandatory corrective actions and the risk index is stay the same or reduced).

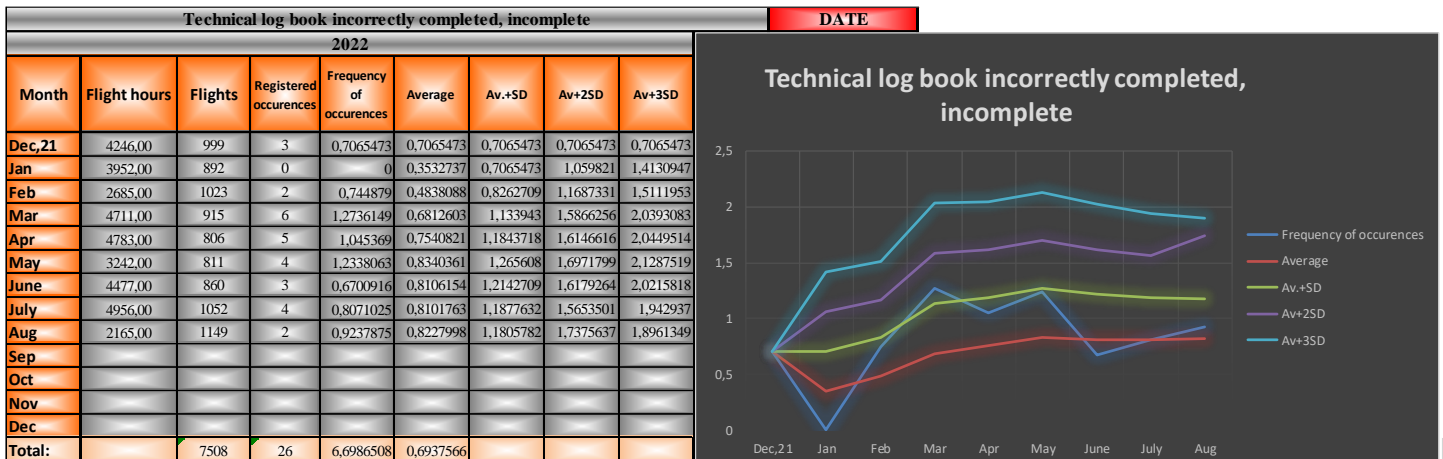


Figure 4.9 Example of Hazard log for a Hazard of incorrectly completed Technical Log Books

## 6. Sharing information about risk assessment / reassessment.

After identification and risk assessment Manager of Risk assessment department add its to Hazard Report.

Hazard Report Form is filled for each operational directorate separately.

After that, Hazard Reports are sent to manager of responsible operational directorate.

When the corrective actions has been developed/taken (risk mitigation actions taken) the manager of responsible operational directorate shall inputs description to Report.

If description of risk mitigation actions taken are enough and exhaustive, they are printed and sent for approval to manager of responsible operational directorate and Director General.

If description of risk mitigation actions taken are not enough, Hazard Report return to manager of responsible operational directorate for refilling.

Signed Hazard Report print and with table Hazard Log and Risk Assessment send to:

- manager of responsible operational directorate.

In conclusion to the proposed method of analysis, the method itself is rather versatile requiring minimum input from the personnel in terms of objective database analysis.

However, it does require a bit of time before enough data is acquired to truly be considered accurate.

### **4.3. Risk Assessment with the help of barriers.**

It is known that the ICAO matrix, which is not designed for quantitative calculations, does not directly account for the response of the system to Hazard impacts. The recommendations and experience of the ARMS group have been studied and revised in the development of the BMS system. This system uses two procedures to assess risk:

- 1) calculation of a past event severity ratio (PERS);
- 2) a safety risk assessment (SRA).

The calculation of the CMP uses the event flowchart shown in Figure 4.10. The majority of hazards manifestations are countered by prevention barriers (actions of the crew, ATC controller, ground personnel, etc.) If these barriers fail, an intermediate event (IA) occurs. Parry barriers, such as crew response to failures and redundancy of the aircraft's main systems, prevent SARs from moving to the final event. Damage is a random variable and can take on different values depending on the effectiveness of the barriers and on many random factors. The CPS methodology is based on the fact that in assessing the severity of an event, it is important to find out two questions - what is the most likely negative outcome of an SAR when it develops; - to what extent the fact that the SAR did not develop into a major damage event is due to effective barriers to parry and to what extent it is due to chance. The safety risk that existed at the time of the event is determined by a

matrix (see table) in notional units. The matrix is based on insurance statistics. The resulting CPS values can be used as an indicator of BP. The management of the risk of adverse consequences consists of a number of procedures:

- 1) identification of serious hazards based on general analysis and monitoring of KSS;
- 2) assessment of risks associated with these hazards using special matrices;
- 3) development of management decisions (MDs) to strengthen barriers;
- 4) implementation of selected MDs and assessment of their effectiveness.

Risk assessment is performed using three special matrices (Figure 4.11). The first matrix assesses the frequency of occurrence of hazards and barriers to prevention. The frequency of occurrence of hazards is calculated from statistical data. The prevention barriers cope with part of the hazards, which is expressed in terms of their failure rate. The second matrix uses the same scale for the barriers to paralysis and combines them with the severity level of the likely outcome. Expert judgement is used. The intermediate result obtained using the two matrices in the form of an alphanumeric risk indicator, as shown in Figure 4.11 serves as input to a third matrix that produces traffic light risk levels. An example of the risk calculation shown in Fig. 4.11 is described in detail in. In practice, a special program, the ARMS Tool, which is an ARMS tool adapted by the author in the form of an MS Excel spreadsheet, is used to calculate the ARBs.

What damage could have been in the worst-case scenario?	What is the effectiveness of the barriers left between the event and possible scenario of a risk event?			
	Absent	Insignificant	Medium	High
Catastrophic Damage	2500	500	100	50
Accident/Serious Damage	500	100	20	10
Medium Damage	100	20	4	2
Negligible Damage	1			

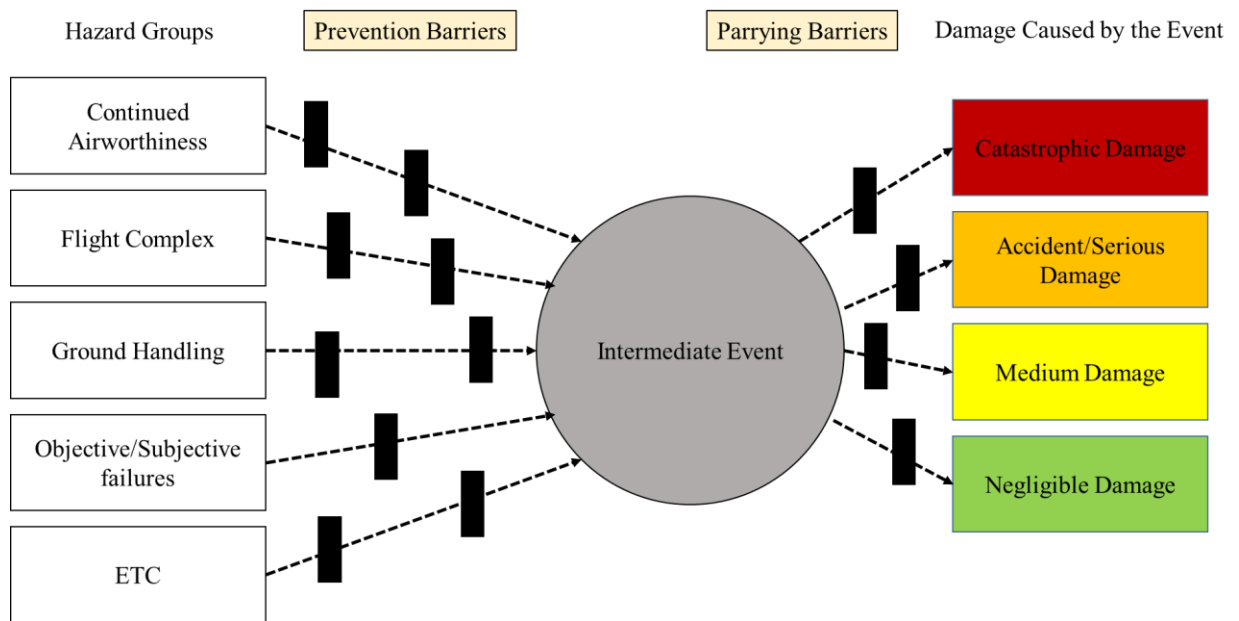


Figure (4.10) Severity coefficient matrix and a scheme of development of an accident/incident



## CONCLUSIONS TO CHAPTER 4

When quantifying SMS risks (both in terms of value and notional units), it is not so much the absolute values that are important for practice, but rather their ratios and dynamics. The purpose of BP risk management is to prioritize decisions on the allocation of resources allocated to BP. The described methods of risk management for BPs at the level of an airline company have proved their practical effectiveness. The development and implementation of one or another method depends on the specifics of the aviation enterprise, on the amount of data used, management priorities and resources allocated. In this chapter we have looked at different methods of analysing and mitigating safety related parameters, such as risk, severity and probability, as well as, looked at how the themes of objectivity and subjectivity influence safety. One of the main problems being that, first of all, there is no perfect system of safety analysis and each company must find and understand what does it need for the specific field that they work at. And secondly, that even if SMS is perfect setup with the most objective data and automated analysis the main decision will still be held on the subjective opinion of a safety inspector/specialist.

## CHAPTER 5

### LABOR SAFETY

4.1. The list of dangerous and harmful production factors during the technical operation of the projected object

Knowledge of the causes of injuries and occupational diseases allows to identify in the technological processes dangerous and harmful production factors, as well as to develop measures to protect working staff from the influence of these factors.

Damage to the body can occur from both direct contact external actions (mechanical, chemical electrical, etc.) and remote (light, heat, etc.).

Damage can occur immediately or after a certain period of time (for example, after radiation exposure). According to ДСТУ 2293-99 (44), among the various factors of production, there is a factor of safety (production), the impact of which on an employee in certain conditions leads to injuries, acute poisoning or other sudden sharp deterioration of health or death, as well as harmful (industrial) ) factors which, under certain conditions, may cause diseases, impairment of work and (or) negative impact on offspring health. An unsafe production factor can lead to injury as a result of direct external action on a person, and a harmful production factor can cause illness or impair performance as a result of remote external action.

In addition, hazardous production factors are divided into explicit ones when their danger is obvious and appropriate measures are needed to eliminate them, and potential factors that can only become dangerous as a result of abnormal human behavior. At the same time, the connection of potentially dangerous production factors with an accident is usually seen only in the deviation from the norm in the behavior of the individual. An industrial accident is regarded as a sudden deterioration in the health or death of an employee while performing his / her duties as a result of a short (no more than one work shift) influence of a dangerous or harmful factor. However, there is no absolute certainty that an accident can only occur as a result of the worker acting on a dangerous production factor. For example, when a worker on a clean, level and non-slip floor lifts a leg and thus receives an injury, this event usually qualifies as an accident. Thus, this injury should be considered not as a result of an unsafe production factor, but as a consequence of unsafe employee behavior.

**КАФЕДРА АВІОНІКИ**

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Н – контр.	Левківський В.В.					82
Зав. каф.						

During operation, the projected device may be affected by the following hazardous and harmful production factors:

- self-propelled and manually-moving machines, mechanisms and devices for carrying out the work - airfield electric power supplies for aircraft and engine starter equipment, airfield oxygen-charging stations (AOCS), automobile mobile electric units, inspection and testing kits efficiency of the device, as well as their movable unprotected parts;
- moving unprotected elements of aircraft - shutters of chassis compartments, doors and hatches, flaps, steering surfaces, snowler flaps, brake guards, air screws;
- movable rods and brackets for moving power lines and plug sockets for aerodrome power of a stationary airfield power source for starting an aircraft engine;
- movable parts of the glider, which are held by locking support rods and special locks, dielectric antenna fairings, Doppler meters of radio altimeters and radio compasses, hatches of mechanical compartments and locations of electromechanisms, electric motors, fire engines;
- movable and hinged covers and panels of switchgear, junction boxes and other equipment, as well as movable panels of automatic protection devices (APD) and dashboards;
- speakers - antennas, sensors, receivers of air pressure and ambient temperature;
- products, tools and materials that can fall during the high-altitude maintenance work of units and equipment located at height, including the use of mechanized lifts;
- sharp edges of the equipment and ends of the quotation wire when disassembling the dashboard units;
- increased air temperature in the work area, during work in the technical compartments;
- reduced air temperature and surface of equipment during maintenance of devices in conditions of negative temperatures;
- increased level of vibration, ultra - and infrasound during the operation of aircraft power plants;

- increased AC voltage of electrical circuits, which can be closed through the human body, an electric arc during a short circuit;
- increased level of electromagnetic radiation during maintenance and checking of the airplane radio equipment;
- physical overload during maintenance of the installation on high-lying parts of the airplane and in difficult-to-reach places of the technical compartments, during removal, arrangement and transportation of units and units manually.

Work with the airplanes is classified as work in a particularly hazardous area and work in a laboratory as work in a non-hazardous area.

#### **4.2. Technical measures limiting the impact of hazardous production factors for the technical personnel**

The following types of labor protection control and supervision operate within the enterprise occupational health and safety management system:

- control that carried out directly at the enterprise  
(public-administrative; administrative; public);
- departmental control by higher organizations; supervision,  
carried out by state bodies.

For the implementation of decisions of higher organizations or in accordance with the plans of work of the labor protection service complex or targeted inspections of labor protection can be organized by specially appointed commissions.

Control should be considered as a general function of the system of verification of executive discipline in resolving all the above-mentioned issues, and as a special function of state oversight bodies, special services and authorized representatives of the public.

***The main normative documents on electric safety in Ukraine:***

Rules of the electrical device installations (ПВЭ-84). The PUE operation is extended to 500 kV of under construction or under reconstruction. ПВЭ-86 set the general requirements for the structure of the electric power system, the sewerage (transmission) of electricity, protection and automation, switchgear and substations, power plants, electric lighting and the electrical equipment of special installations.

ДНАОП 0.00-1.32-01. Rules for the construction of electrical installations. Electrical equipment of special installations. This document is approved by the Ministry of Labor of Ukraine and includes some issues of electric lighting and equipment of special installations with changes and additions in accordance with the current in Ukraine and international regulations.

Rules of arrangement of electrical installations. Section 1. General rules. See 1.7 Grounding and safety measures. (ПВЭ-2006). Chapter PUE 1.7, introduced from 1 January 2007. The requirements of the chapter apply to AC and DC systems that are designed, constructed or reconstructed and contain general requirements for their electrical safety. The requirements of this chapter may also apply to existing electrical installations.

НПАОП 40.1-1.01-97 (ДНАОП 1.1.10-1.01-97) Rules for safe operation of electrical installations - industry normative document (energy). Its effect extends to the energy sector of the electrical installation up to 500 kV. It sets requirements for safe operation of the electrical installation.

ДНАОП 0.00-1.21-98. Rules for safe operation of consumer electrical installations - interbranch normative act, which defines requirements for safe operation of consumer electrical installations, its effect extends to electrical installations up to 220 kV.

Rules for the technical operation of consumer electrical installations - establish the basic organizational and technical requirements for the operation of the consumer's electrical system and apply to the operating electricity of up to 150 kV inclusive.

ДНАОП 1.1.10-1.07-01. Rules of operation of electrical protective equipment which sets the requirements for the required list of electrical protective equipment, depending on

the specific conditions, to storage, testing, checking the status and use of electrical protective equipment.

ДНАОП 0.00-8.19-99. Procedure for certification of consumer electrical installations. ДНАОП 0.00-8.20-99. The procedure for examination of consumer electrical installations. Developed on the basis of НПАОП (ДНАОП) sectoral regulations on electrical safety for the energy industry and enterprises of other industries.

The projected device is a closed-circuit unit that eliminates the possibility of contact with live parts. The PCBs of the device are made in the form of separate cells, which have standard means of mechanical attachment and electrical connection. As material for printed circuit boards used fiberglass STF-2 brand thickness 3mm, which assumes the influence of temperature from -60 to + 1500C. The cells are covered with an insulating lacquer СТФ-2, which eliminates the possibility of electric shocks by accidentally touching the circuit board elements and short-circuiting the tool. The connectors are ГПИИМ5 type connectors, which have contacts (pins and sockets) pointing in the same plane as the board.

The power cable is made of ПИИИ brand wire and has double rubber insulation. The first layer is made of heat-resistant silicone rubber. Insertion of the cable through the plastic sleeve, which prevents the cable from rubbing against the housing of the installation.

The front panel provides a grounding terminal that is used to protect against electric shock during insulation breakdowns and voltage transitions to the metal body. The protective earth resistance must meet the requirement  $R_3 < 4 \text{ Ohms}$  (for installations with low earth fault currents and voltages up to 1000 V) according to the PEU-86.

A small voltage of 27V DC is used to power the projecting device.

As already noted, the AC has an increased voltage 208V AC, so to work with the installation on the aircraft provides:

- admission to work on the aircraft;

- registration of an outfit for work execution;
- appointment of persons responsible for the organization and performance of works;
- the movement of self-propelled cars and those moving manually, the release and removal of movable unsecured aircraft elements under the direction of persons responsible for carrying out the work.

### ***Protection against electromagnetic radiation of the radio frequency range***

As the device is being designed to improve aircraft navigation, it is coupled to an altimeter and other navigation devices and devices (such as radar) from which it receives information about the location of the aircraft in space. These navigation devices emit electromagnetic waves that affect the environment and humans.

Means and measures for protection against EM radiation of the radio frequency range are divided into individual and collective. The latter can be subdivided into organizational, technical and therapeutic-preventive ones.

Organizational measures of collective protection include:

- placement of objects that emit EMF in such a way as to minimize the possible exposure of people;
- "time protection" - the stay of personnel in the area of EMF is limited to the minimum necessary for work;
- "distance protection" - the removal of jobs to the maximum permissible distance from EMF sources;
- "quantity protection" - the power of the radiation sources should be minimally necessary;
- allocation of EMF radiation zones with appropriate safety signs. Technical means of collective protection include:
  - shielding of EMF radiation sources;
  - screening jobs;

- remote control of installations, which include EMF sources; - the use of alarms.

Collective protection measures include:

- preliminary and periodic medical examinations;

- providing additional paid leave and reducing the duration of work shift;

admission to work with EMF sources of persons at least 18 years of age, as well as those who do not have contraindications for health

Personal Protective Equipment (PPE) should be used where other methods of preventing ESAs are impossible. Radioactive protective clothing and goggles are used as PPEs. As a material for radioprotective clothing use a special radiotechnical fabric, built on the principle of a mesh screen and which is a cotton cloth with a micro wire. In the structure of such fabric, a thin copper wire is twisted with cotton threads that protect it from external influences and are at the same time insulating. The attenuation of the EMF field by this fabric in the frequency range 600 ... 10000 MHz is from 40 to 20 dB.

Protective cotton fabric with a microdro made of personal protective equipment such as a radio hood (helmet), a radio gown, a radio overalls and. others At midrange microwave band, such individual remedies provide a total attenuation of 25 ... 30 dB, at the extreme microwave band frequencies, their defenses are reduced.

### **4.3 Fire and explosion safety when servicing the designed facility.**

Causes of fire in electrical equipment and electrical lighting can be: overload of wires (above the calculated), which causes the heating of the conductive parts, the ignition of their insulation and, as a consequence, the ignition of various materials in contact with them; poor performance of electrical wiring connections; overloading of various electrical devices (electric motors, generators, transformers, relays, switchgears, etc.), which leads to their heating and therefore to possible ignition; faulty cooling of the appliance, switching it on incorrectly; short circuits, arcing on the collector or rings of the motor and generators, as well as in the on and off devices; excessive wear of electric bearings, which can result in overheating of the bearings or jamming of the bearings and then ignition.



The fire safety rules are regulated by such normative documents as the Civil Protection Code and the HAПБ Fire Safety Rules A.01.001-2015.

Various safety devices (fuses, relays, protection devices, etc.), properly matched to this electrical press, are able to prevent the ignition of electrical appliances in the event of overloads and short circuits. The fire-fighting requirements for electrical equipment are set out in the PUE.

The strict implementation of them allows to avoid fires and explosions of electrical equipment.

The greatest danger is the electrical equipment of explosive and fire-proof premises and installations. Depending on the design of electrical equipment of modern industrial enterprises (electric motors, generators, switches, rheostats, lamps) can be open, closed and explosion-proof.

For example, for artificial lighting of fire and explosion-proof rooms, the industry produces safe lamps: closed (dust-proof), explosion-proof (explosion-proof, high-explosion-proof, intrinsically safe, special).

A fire hazard during the installation of the unit with the device is provided:

- fire prevention system;
- fire protection system;
- organizational and technical measures.

Fire prevention is provided by the following:

- there are no easily flammable materials in the design of the installation;
- the cross-section of the mounting wires is selected according to the permissible current density  $j = 2 \div 3 \text{ A / mm}^2$ , which is equal to  $0.5 \text{ mm}^2$ , except for the input and output wires of the power supply unit, whose cross section is  $1.5 \text{ mm}^2$ ;
- all resistors used are selected according to the allowable scattering power;

- capacitors are selected with allowable voltage;

- in the projected installation, the possibility of an explosion or the formation of a spark is eliminated, since there are no open switching contacts in its design, all elements of the scheme are closed and sealed. The housing and faceplate are made of D16 grade duralumin, which does not produce sparks when struck with other metals;

- mounting details and printed circuits are covered with an insulating varnish, which eliminates the possibility of getting into the circuit elements of moisture, and, accordingly, circuit, corrosion and ignition;

- fuses are provided in the power supply to protect the network from overload and short circuits.

Fire protection is provided by:

- the use of automatic fire alarm, which is available in the laboratory;

- using fire extinguishing agents.

Organizational and technical means include:

- training of engineering and technical personnel to the rules of fire safety;

- organization of fire protection;

- developing instructions on how to handle substances and materials hazardous for fire.

#### **4.5 Special Occupational Safety Requirements**

Safe operation of the EC is ensured by the following three methods:

- application of stationary structural and circuit protection measures;

- the use of protective equipment, including electrical protection;

- observance of protective measures while performing work in the EU.

Structural and circuit protection measures are an integral part of the ES and ensure its operation at all times while the ES is energized. According to PUE-2006, they are divided into two groups:

- direct contact protection measures in the normal mode of operation of the EU;
- protection measures in case of indirect contact in case of single damage.

Protective Equipment (PPE) is a tool designed to prevent or reduce an employee's discharge of hazardous and / or harmful production factors.

Electro-protective means are means intended for providing electrical safety (these are tools and devices for safe work in the EU: insulating rods, pincers, voltage indicators, etc.), as well as dielectric clothing and shoes (gloves, boots, galoshes, etc.). .

Protective measures while performing work in the EU are a set of requirements for employees and the order of performance of works to ensure the operation of the EU.

Terms.

1. The engineering personnel who have studied this installation, the operating instructions, these instructions and passed the safety and fire safety test shall be permitted to operate the projecting device.

2. This instruction is valid within the enterprise for the maintenance of the device.

Safety requirements before you begin.

1. Before starting work, it is necessary to free the workplace from flaring objects and materials.

2. Make sure that the fuses are in the rating indicated on the front panel.

3. Check for ground on terminal “1” of installation.

Safety requirements during runtime.

1. Connect and disconnect the plugs of the installation cables when the power is off.

2. Replacement-related repair work and plug-in connections of the installation modules must be carried out in the off state.

Security requirements after work.

Disconnect the power to the installation and disconnect it from the network after completion of the work.

Safety requirements in emergencies.

The room where the installation is located must have a carbon dioxide extinguisher (OU-2 or OU-5).

Extinguishing fires on PS. Performing maintenance work on the aircraft at the parking lots, as well as refueling and starting the engines are associated with the possibility of a fire. Extinguishing it within the first 10-15 s after occurrence, as a rule, ends with the complete elimination of fire by automatic extinguishing means. If it takes 2-3 minutes of fire, it is already necessary to use large quantities of extinguishing agents and involve fire crews. Therefore, there should be a fire post (car) in the area of parking, refueling, and especially starting of engines, ready to start eliminating the ignition. When extinguishing a fire in the cockpit of the PS, when there are people, use fire extinguishers with CO<sub>2</sub>.

In the event of a fire during refueling of the PS, the fuel should be stopped, the shut-off valve of the refueling device and the fuel tank lid should be closed if it is outside the combustion zone, start extinguishing without delay, and take the refueler to a safe distance.

When the fire on the PS lasts more than 2 minutes and covers large surfaces, it is necessary to use air-mechanical foam as the most effective extinguishing agent.

In the event of such a fire, most of the metallic parts of the aircraft are glowing, and thus extinguishing will be difficult. At this point, it is necessary to first extinguish the combustible liquids or to prevent their re-ignition by means of air-mechanical foam, which has a certain permanent effect. The use of gaseous extinguishing agents is impractical because large combustible surfaces create upward airflows around them and remove the extinguishing agent from the combustion zone, minimizing the quenching effect.

The fire extinguishing tactics of a distressed aircraft are somewhat different from those considered earlier. First of all, as an additional measure, which allows to reduce or eliminate the possibility of fire during landing of the aircraft with a missed or malfunctioning chassis, cover the runway with a layer of air-mechanical foam. It is advisable to use fire trucks.

**Conclusions:**

As the proposed research only takes in mind the calculation and analysis methods the requirements for the work related precautions are minimal, pretty much the same as for any office related job or occupation. However, as these methods could be used in maintenance organisations that may not have the most ideal “white collar” working conditions, the ideas and requirements of working labs and maintenance hangars are brought into light.

## CHAPTER 6

### 5. ENVIRONMENTAL PROTECTION

#### 5.1. Environmental safety analysis of the developed device

Environmental protection and environmental issues in recent years have become one of the most important issues of our time. There is a huge struggle to preserve the nature of animals and everything that surrounds us.

Among the main tasks are:

- to increase the effectiveness of nature conservation measures;
- to introduce progressive, hopeless technologies and processes more widely;
- to develop combined production, providing a comprehensive and full use of natural resources and raw materials,
- a significant reduction in environmental impact.

One of the most active sources of air pollution is transport. Although today aviation is significantly (about 15 times) inferior to automobile transport in the amount of pollutants emitted into the air, it affects the ecology of the upper troposphere and lower stratosphere every day. Unlike other modes of transport, aviation covers vast distances, affecting air quality locally, regionally and globally.

When conducting my research, one of the main goals was to increase global safety levels and in turn slightly reduce pollution. As accidents and incidents can lead to catastrophic amounts of damage to the environment, introducing necessary precautions in the airlines and maintenance organisations not may but will reduce the probability of an accident or even an incident from occurring.

**КАФЕДРА АВІОНІКИ**

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Furthermore, the proposed analysis and methods can be used for determining not only severity and probability of risk but of also of ecological risk and so on. Increased safety at workplace can also lead to increased effectiveness, which in turn can lead to decreased ecological impact. These can be as follows:

1. Good housekeeping is the regular carrying out of measures for conducting economic activities of the enterprise, which relate to the current repairs of premises, maintenance of the working condition of equipment, ensuring proper working conditions for personnel. It provides for the maintenance of the working condition and timely maintenance of production systems, control and optimal distribution of material and labor resources, which allows to improve the production parameters of the enterprise without additional costs.
2. Substitution of input materials is the process of replacing primary materials and resources with secondary ones or using less harmful or toxic substances in the manufacturing process to reduce production waste and improve its environmental performance. This approach increases production productivity and improves the environmental situation.
3. Improvement of technological processes control is the application of additional actions and measures for better control and accounting of technological indicators at all stages of production. Control of incoming and outgoing flows of resources (materials, energy, water) allows you to quickly respond to deviations in production indicators and parameters.
4. The use of modern equipment is a process of continuous improvement, modernization and updating of the technical and technological base of the enterprise to achieve the best production performance. Modification is carried out in order to achieve the best indicators of consumption and production, which can apply to both individual local elements of production systems and the entire production line.
5. Improvement of technological parameters of production is the replacement of the method of processing and transformation of input resources (materials, energy, water, etc.) at different stages of production without deterioration of its quality. This approach includes, for example, changes in temperature, pressure, equipment operating modes or the way raw materials are processed.
6. Improvement of the processes of recycling and reuse of resources available at the enterprise - this involves the implementation of technological operations related to changing the properties of the waste of the main production for their further use for the needs of the enterprise or their return to the technological process.
7. Production of by-products from production waste in order to increase the economic efficiency of production as opposed to their traditional disposal.

8. Improving the quality of products is a partial change in the products produced to improve the characteristics of the product and increase its environmental and economic attractiveness. This may include changes in appearance and other characteristics to extend its life cycle, improve disposal methods and reduce environmental impact.

The growing global environmental crisis has led to the fact that consciously or subconsciously environmentally hazardous economy is being reformed into an environmentally friendly one. This process is difficult and long-lasting, as it is associated with the transformation of technogenic thinking into social and environmental thinking. At the same time, the process of recognizing environmental priorities has begun with the creation of environmental legislation and appropriate environmental infrastructure.

Various organisations are increasingly interested in achieving and demonstrating good environmental performance by controlling the environmental impact of their activities, products or services, taking into account their environmental policies and environmental objectives. They do so in the face of increasingly stringent laws, economic policies and other measures aimed at protecting the environment, as well as growing stakeholder concerns about environmental and sustainability issues.

The environmental management system is very important to ensure the ability of organizations to define and achieve their environmental goals, as well as to ensure the continued compliance of activities, products and services with national and international requirements. Each production facility has its own environmental policy, which should be consistent with the national environmental policy.

Environmental policy (of the enterprise) - intentions and orientation of the organization regarding its environmental performance, officially proclaimed by its top management.

That is, these are the general goals and principles of the enterprise's activities in relation to the environment, which provide for compliance with all environmental regulations. 61 The environmental policy of the enterprise demonstrates the commitment of the management to environmental priorities.

Environmental management system is a part of the management system used to manage environmental aspects, fulfil mandatory compliance requirements and address risks and opportunities. It covers the organizational structure, planning activities, duties, responsibilities, expertise, methods, techniques, processes and resources for formulating, implementing, reviewing and improving environmental policy. An environmental management system is the part of an organization's management system used to develop and implement its environmental policy and manage its environmental aspects.

Thus, the purpose of environmental management is to minimize the negative impact on the environment directly at industrial enterprises and in business activities. The leading role in the practical implementation of the concept of environmental management is played by ISO standards of the 14000 series, developed by the Technical Committee "Environmental



Management" ISO/TC 202 of the International Organization for Standardization. And put into effect in 1996. In Ukraine, the system of Ukrainian standards of the DSTU ISO 14000-97 series, which is developed in accordance with international standards, has been put into effect since 1998. Currently, the new edition of DSTU ISO 14000-2015 is in force. The creation of an environmental management system should not only put environmental protection in the focus of the enterprise, but also make this area of activity profitable.

**Conclusions:**

Proposed research can be used in addition with the already established environment management system to further decrease potential damages from unnecessary, inefficient, and unsafe work practices.

## CONCLUSIONS

By introducing such parameters as OC and SC it becomes possible to more accurately identify specific reasons why the accident occurred with a prospect to prevent accidents of such manner from happening in the future. OC provides a definite categorization for measuring and recording devices with a possible further grouping as in-flight and post-flight (or post-factum) OC.

In addition, SC provides a further categorization of human input as not only direct actions of pilots, air traffic controllers and maintenance personnel, but general human input that could be found throughout airlines and aviation companies.

On the other hand, objectivity and subjectivity have to be considered in a balanced system as it is impossible to increase flight safety simply by increasing the level of objective control as the pilots (subjective/human input) have to be aware of all the intricacies of the automated systems that are installed on the aircraft. If the pilots are unaware of all the complex automated systems onboard, they will undoubtedly get confused as soon as one the system goes down or starts running irrationally. Thus, subjectivity and objectivity have to be balanced accordingly.

SC and OC have changed places throughout the years, as at the dawn of aviation most accidents were mostly caused by system failures and even the most skilled and experienced pilots had suffered injuries or even death despite their expertise in the field of aviation.

To conclude, by introducing OC and SC aircraft accidents can be analyzed with a new perspective and future accidents could be prevented as well. In addition, better understanding of human input can be achieved.

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