МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ АЕРОНАВІГАЦІЇ, ЕЛЕКТРОНІКИ ТА ТЕЛЕКОМУНІКАЦІЙ
КАФЕДРА АВІОНІКИ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
_________С.В. Павлова
«___»___________2021

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ
БАКАЛАВР ЗА СПЕЦІАЛЬНІСТЮ 173 «АВІОНІКА»

Тема: «Запобігання авіаційних пригод засобами суб’єктивного та об’єктивного контролю повітряного судна»

Виконавець: __________ (підпис) О.М. Турак
Керівник: __________ (підпис) Л.В. Сібрук
Нормоконтролер: __________ (підпис) В.В. Левківський

Київ 2021

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF AIR NAVIGATION, ELECTRONICS AND TELECOMMUNICATIONS DEPARTMENT OF AVIONICS

APPROVED
Head of department
________S.V. Pavlova
'___'___________2021

GRADUATION WORK

(EXPLANATORY NOTES)

FOR THE DEGREE OF BACHELOR
SPECIALTY 173 'AVIONICS'

Theme: 'Prevention of aviation accidents by means of subjective and objective control of the aircraft'

Done by: __________ O.M. Turak
(signature)

Supervisor: __________ L.V. Sibruk
(signature)

Standard controller: __________ V.V. Levkivskyi
(signature)

Kyiv 2021

NATIONAL AVIATION UNIVERSITY

Faculty of Air Navigation, Electronics and Telecommunications
Department of avionics
Specialty 173 ‘Avionics’

APPROVED
Head of department
_________S.V. Pavlova
‘___’___________2021

TASK for execution graduation work

Oleksii Turak

1. Theme: ‘Prevention of aviation accidents by means of subjective and objective control of the aircraft’, approved by order №469/ст of the Rector of the National Aviation University of 23 March 2021.
2. Duration of which is from 10.05.2021 to 10.06.2021.
3. Input data of graduation work: Representation of Objective and Subjective control as a communicative analysis system. Possible use during accident investigation as well as workplace analysis.
4. Content of explanatory notes: 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; References; Conclusions.
5. The list of mandatory graphic material: figures, charts, graphs.

6. Planned schedule

№	Task	Duration	Signature of supervisor
1.	Validate the rationale of graduation work theme	18.05-20.05	
2.	Carry out a literature review	21.05-24.05	
3.	Develop the first chapter of diploma	25.05-30.05	
4.	Develop the second chapter of diploma	31.05-05.06	
5.	Develop the third chapter of diploma	06.06-08.06	
6.	Tested for anti-plagiarism and obtaining a review of the diploma	09.06-15.06	

7. Date of assignment: ‘____’___________ 2021

Supervisor _______________
(signature) (surname, name, patronymic)

The task took to perform _______________
(signature) (surname, name, patronymic)

ABSTRACT

Explanatory notes to bachelor work ‘Prevention of aviation accidents by means of subjective and objective control of the aircraft’ contained 64 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.

CONTENTS

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.

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 by the use of stricter subjective and objective control regulation.

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.

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);

КАФЕДРА АВІОНІКИ				НАУ 21 09 48 000 ПЗ			
Розробив	Турак О.М.			PREVENTION OF AVIATION ACCIDENTS BY MEANS OF SUBJECTIVE AND OBJECTIVE CONTROL OF THE AIRCRAFT	Літ.	Арк.	Аркушів
Керівник	Сібрук Л.В.					10	
					173 Авіоніка		
Н – контр.	Левківський В.В.						
Зав. каф.	Павлова С.В.						

- 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

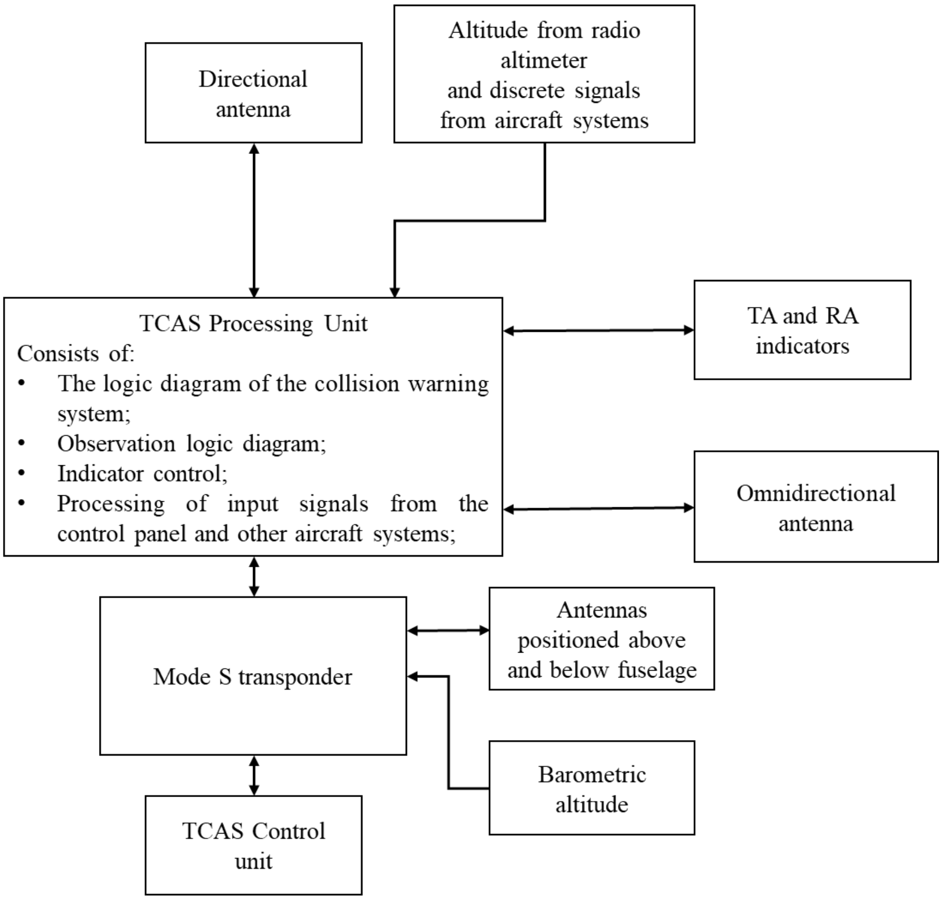


Figure 1.1 Main elements of TCAS

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.

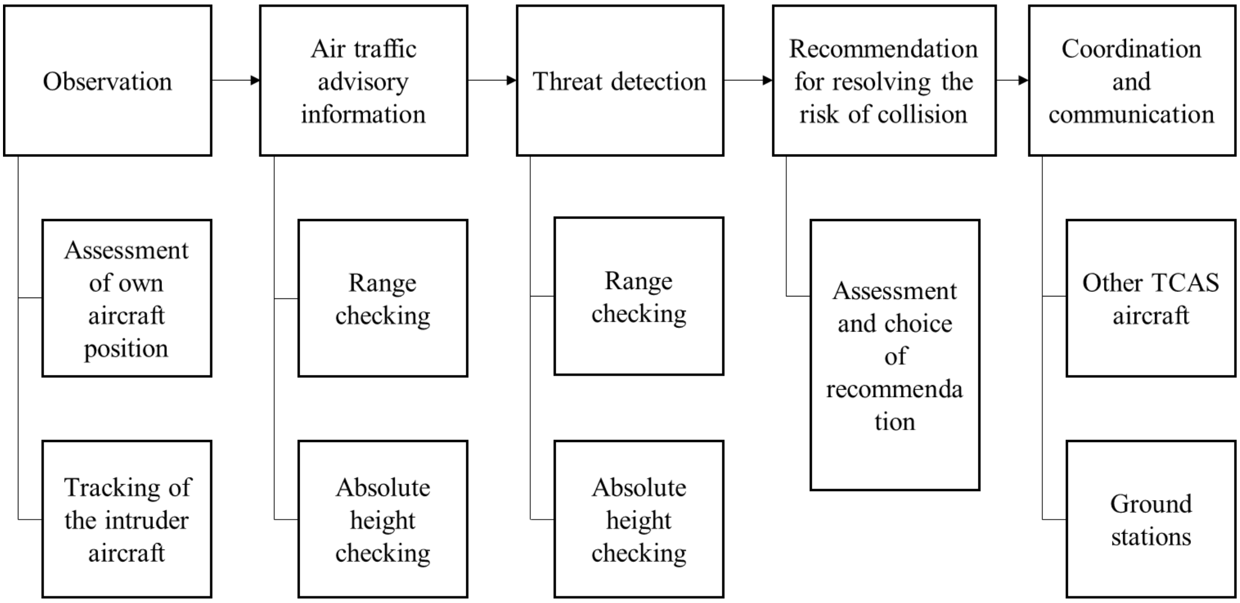


Figure 1.2 Functions of TCAS

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).

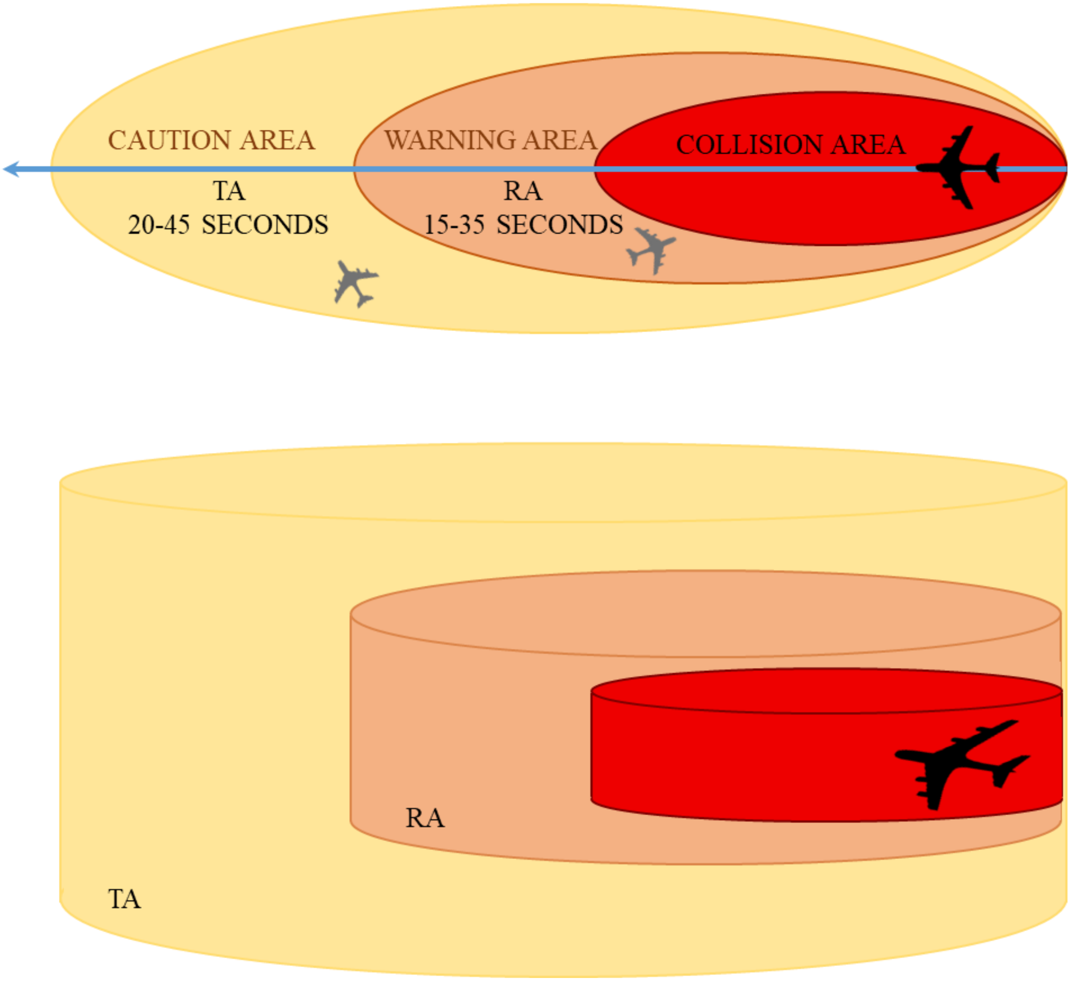


Figure 1.3 TCAS Protection volume/Area (Not to scale)

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):

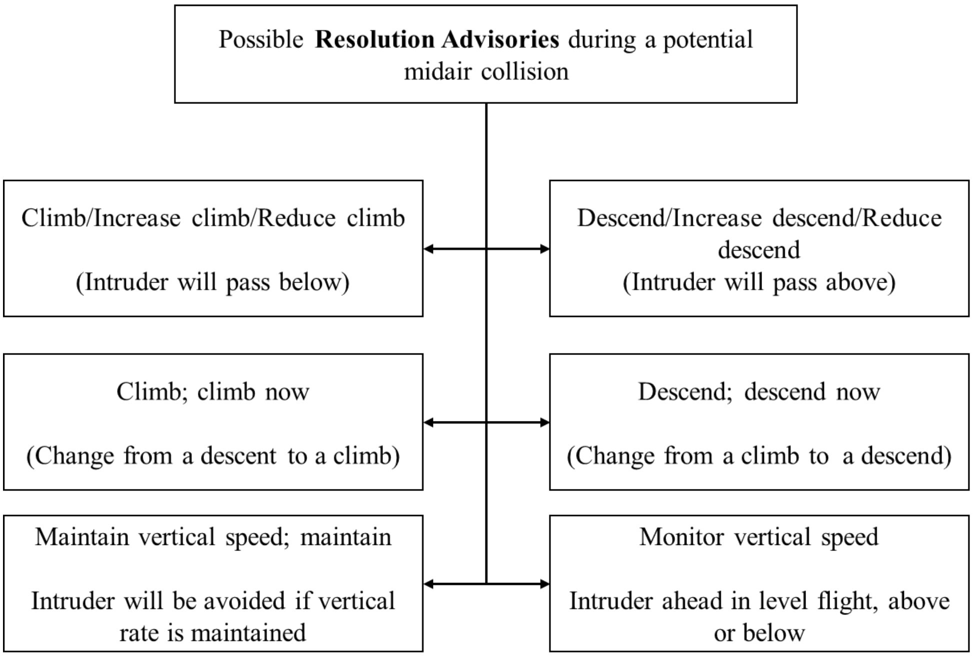


Figure 1.4 Possible resolutions for solving dangerous situation with intruder aircraft

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 fight 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.

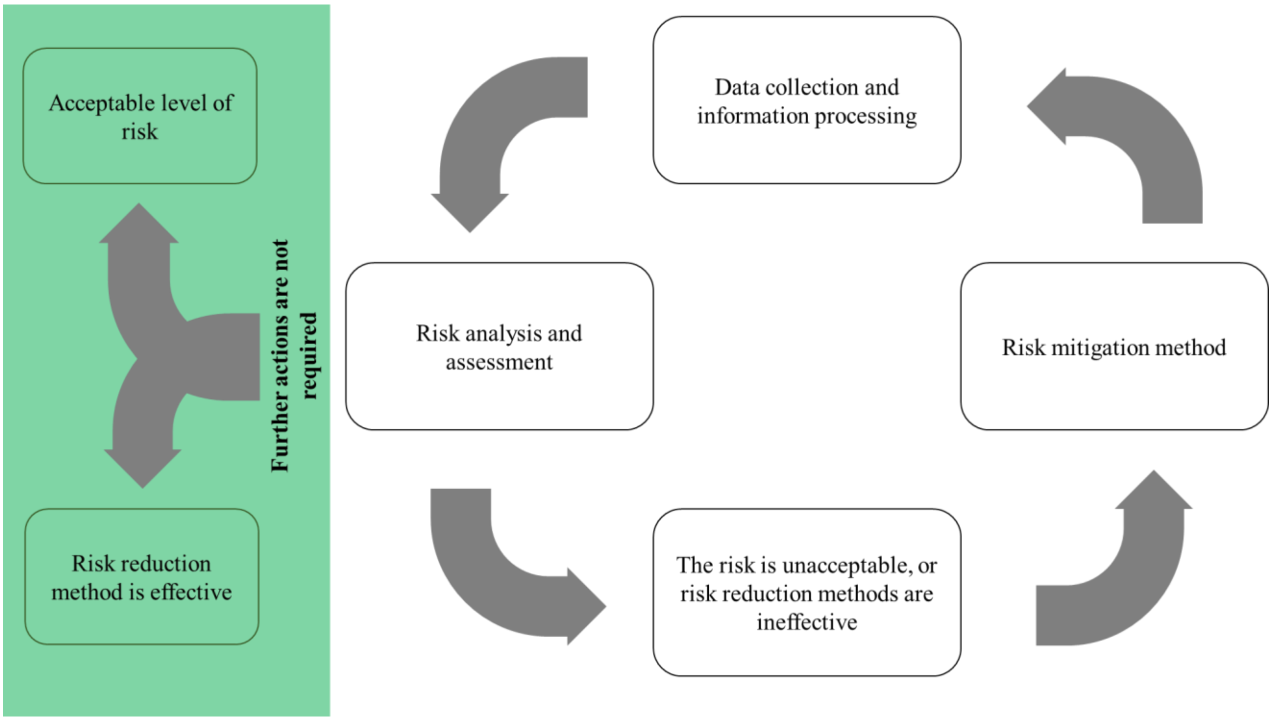


Figure 1.5 Risk reduction scheme

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.

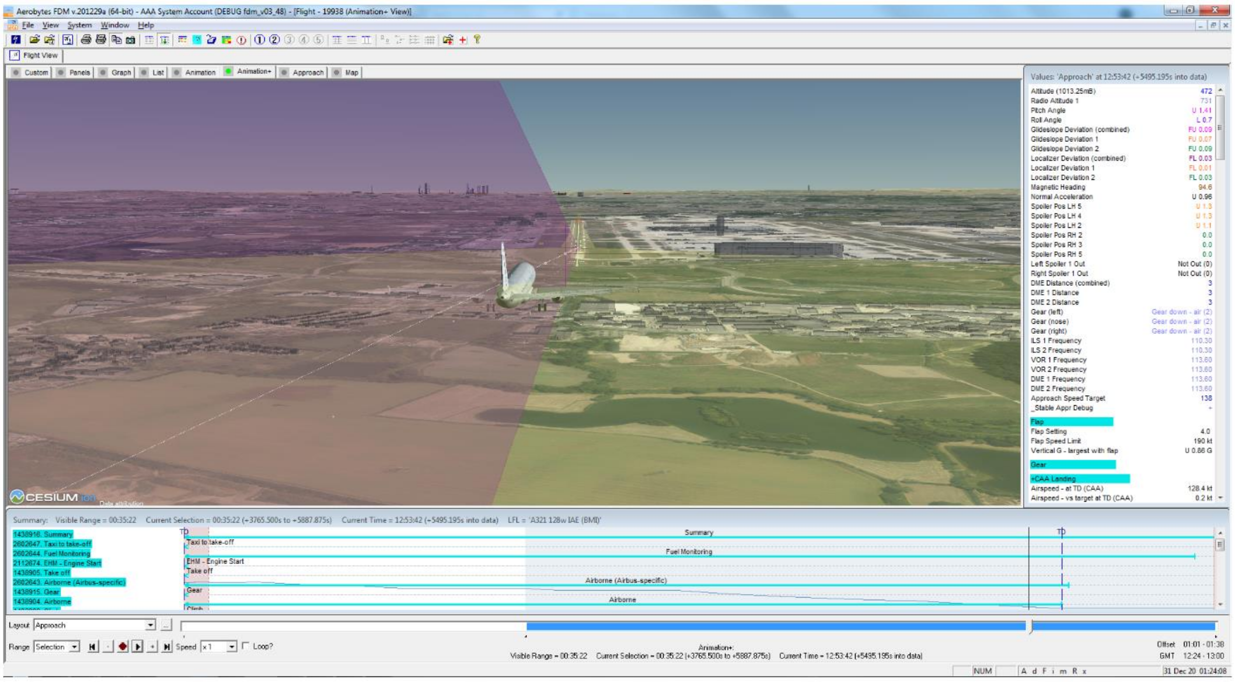
Provision of data for flight economics analysis, which is a secondary function of the FDA Programme to collect fuel consumption data and Aircraft Performance

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.



Aerobytes FDM v.201229a (64-bit) - AAA System Account (DEBUG fdm_v03_48) - [Flight - 19938 (Animation+ View)]

Values: 'Approach' at 12:53:42 (+5495.195s into data)

Altitude (1013.25mB)	472
Radio Altitude 1	731
Pitch Angle	U 1.41
Roll Angle	L 0.7
Glideslope Deviation (combined)	FU 0.09
Glideslope Deviation 1	FU 0.07
Glideslope Deviation 2	FU 0.09
Localizer Deviation (combined)	FL 0.03
Localizer Deviation 1	FL 0.01
Localizer Deviation 2	FL 0.03
Magnetic Heading	94.6
Normal Acceleration	U 0.96
Spoiler Pos LH 5	U 1.3
Spoiler Pos LH 4	U 1.3
Spoiler Pos LH 2	U 1.1
Spoiler Pos RH 2	0.0
Spoiler Pos RH 3	0.0
Spoiler Pos RH 5	0.0
Left Spoiler 1 Out	Not Out (0)
Right Spoiler 1 Out	Not Out (0)
DME Distance (combined)	3
DME 1 Distance	3
DME 2 Distance	3
Gear (left)	Gear down - air (2)
Gear (nose)	Gear down - air (2)
Gear (right)	Gear down - air (2)
ILS 1 Frequency	110.30
ILS 2 Frequency	110.30
VOR 1 Frequency	113.60
VOR 2 Frequency	113.60
DME 1 Frequency	113.60
DME 2 Frequency	113.60
Approach Speed Target	138
_Stable Appr Debug	+
Flap	
Flap Setting	4.0
Flap Speed Limit	190 kt
Vertical G - largest with flap	U 0.86 G
Gear	
+CAA Landing	
Airspeed - at TD (CAA)	128.4 kt
Airspeed - vs target at TD (CAA)	0.2 kt

Summary: Visible Range = 00:35:22 Current Selection = 00:35:22 (+3765.500s to +5887.875s) Current Time = 12:53:42 (+5495.195s into data) LFL = 'A321 128w IAE (BMI)'

1438916. Summary
2602647. Taxi to take-off
2602644. Fuel Monitoring
2112674. EHM - Engine Start
1438905. Take off
2602643. Airborne (Airbus-specific)
1438915. Gear
1438904. Airborne

Layout Approach
Range Selection
Speed x 1
☐ Loop?

Animation+:
Visible Range = 00:35:22 Current Selection = 00:35:22 (+3765.500s to +5887.875s) Current Time = 12:53:42 (+5495.195s into data)

Offset 01:01 - 01:38
GMT 12:24 - 13:00

31 Dec 20 01:24:08

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.

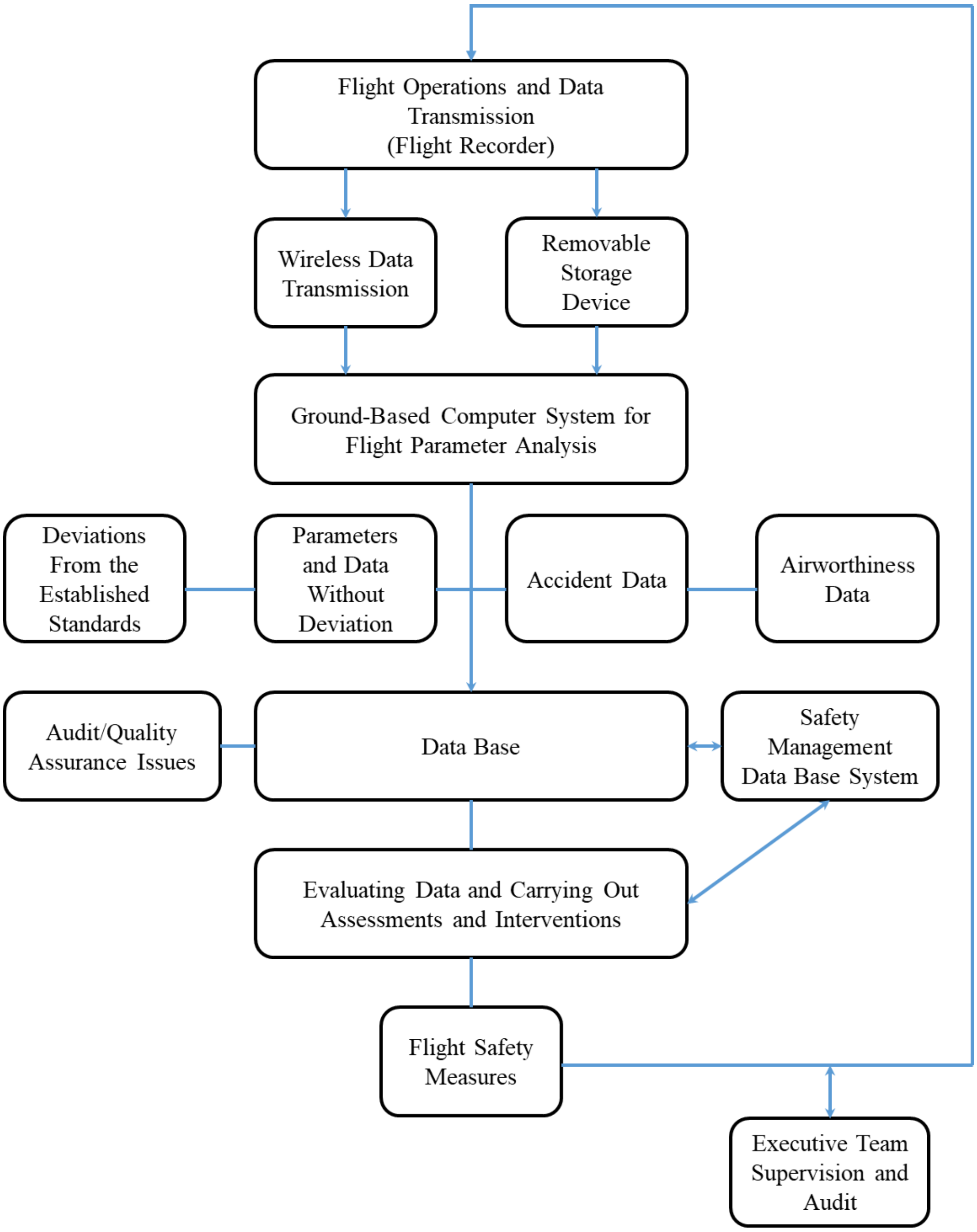


Figure 1.7 An example of Flight Data information exchange within an airline company.

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.

КАФЕДРА АВІОНІКИ				*НАУ 21 09 48 000 ПЗ*			
Розробив	*Турак О.М.*			*PREVENTION OF AVIATION ACCIDENTS BY MEANS OF SUBJECTIVE AND OBJECTIVE CONTROL OF THE AIRCRAFT*	*Літ.*	*Арк.*	*Аркушів*
Керівник	*Сібрук Л.В.*					*30*	
					173 Авіоніка		
Н – контр.	*Левківський В.В.*						
Зав. каф.	*Павлова С.В.*						

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.

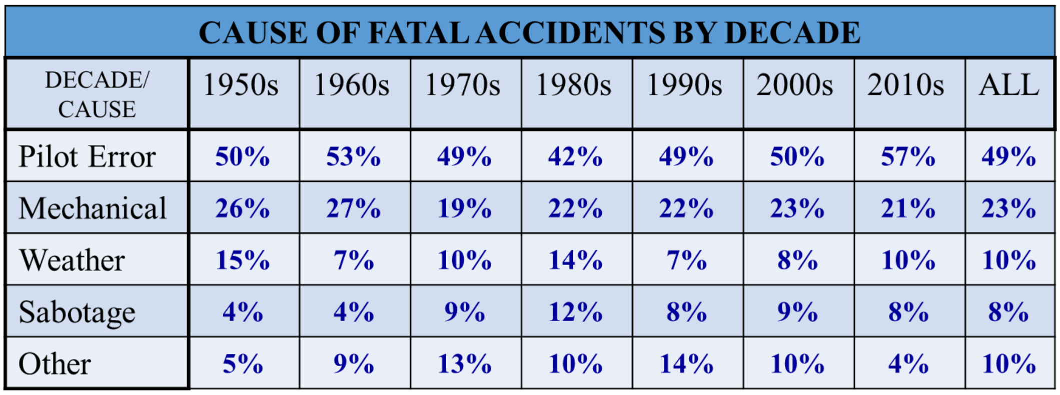
However, pilots are not the only ones who are responsible for aviation accidents, as there are other frequently reported causes most of which carry SC. For example:

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

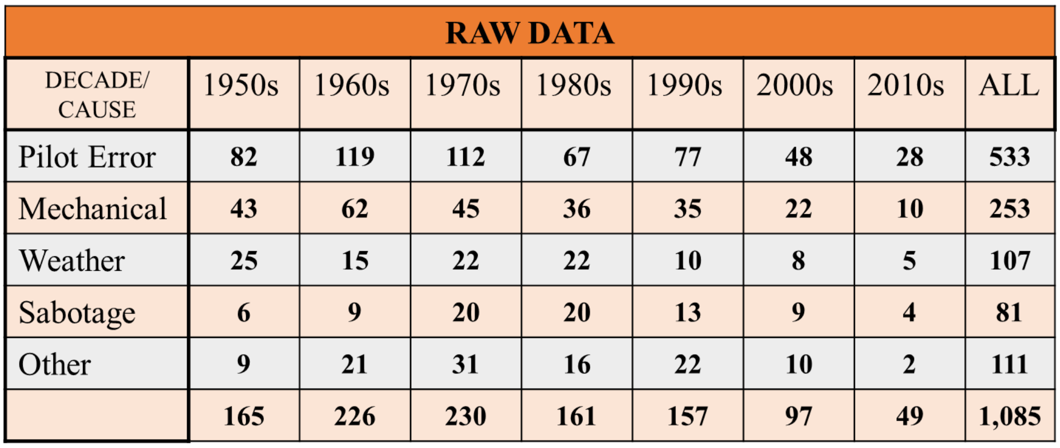
Crew member mistakes, similar to pilot's, can result in human injuries or in some cases death. These mistakes may not result in any crashes but crew members that fail to correctly perform on-board duties, such as properly storing luggage. An example of a similar mistake that led to an accident is China Eastern Airlines Flight 583. During the flight above the Pacific Ocean near the Aleutian Islands one of the crew members accidently 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.

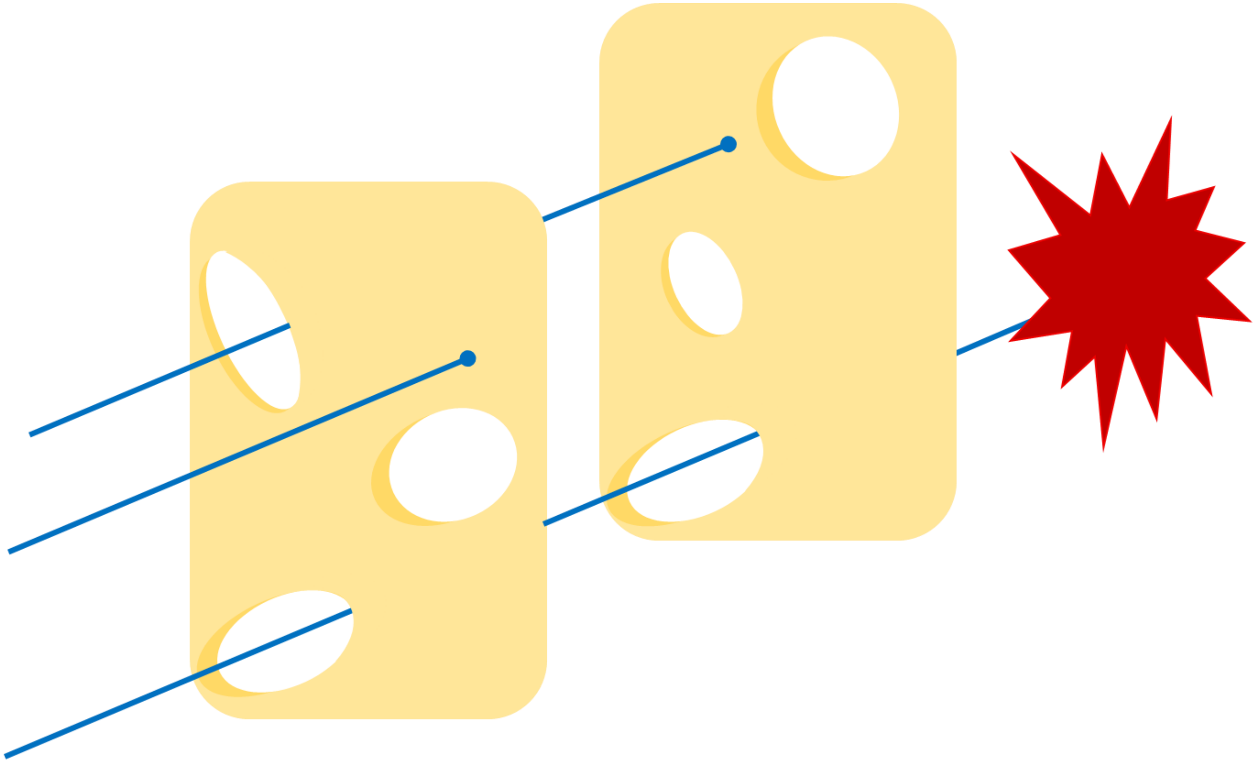


Figure 2.1 Reason’s Swiss Cheese model

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.

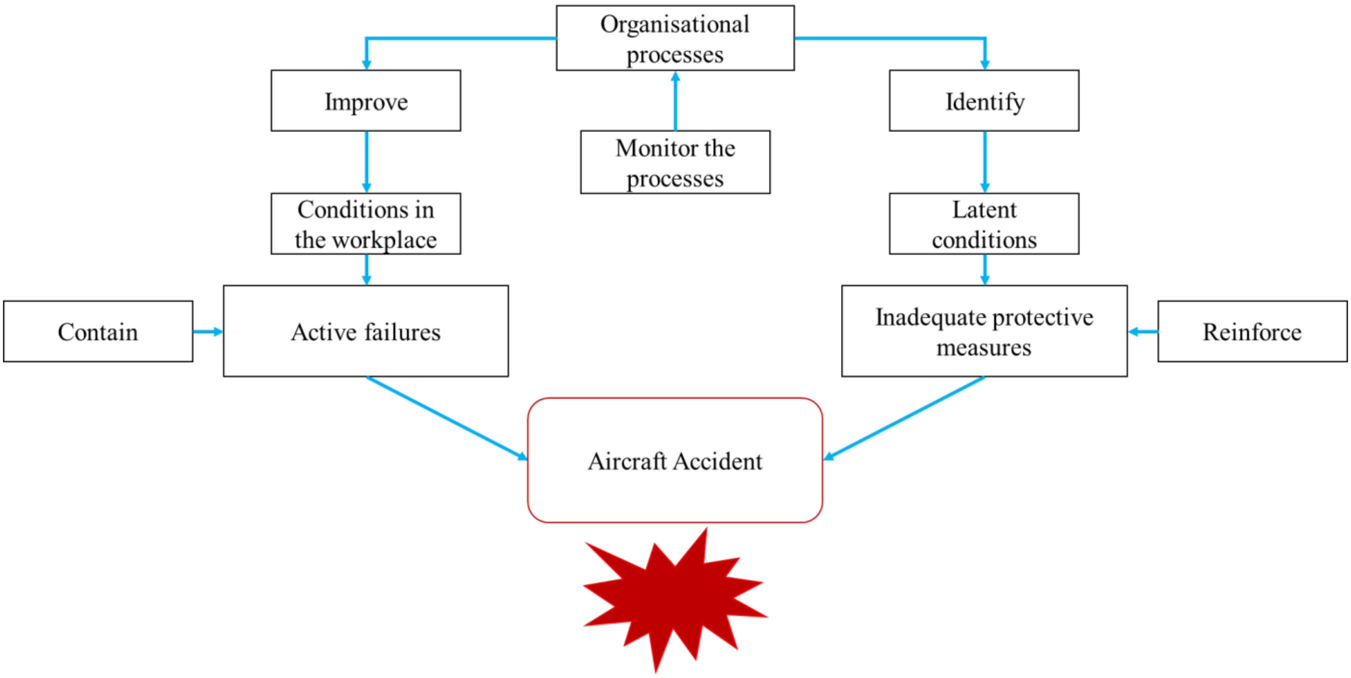


Figure 2.2 Modular representation of Reason's model

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 analysisists 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 a 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 were 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).

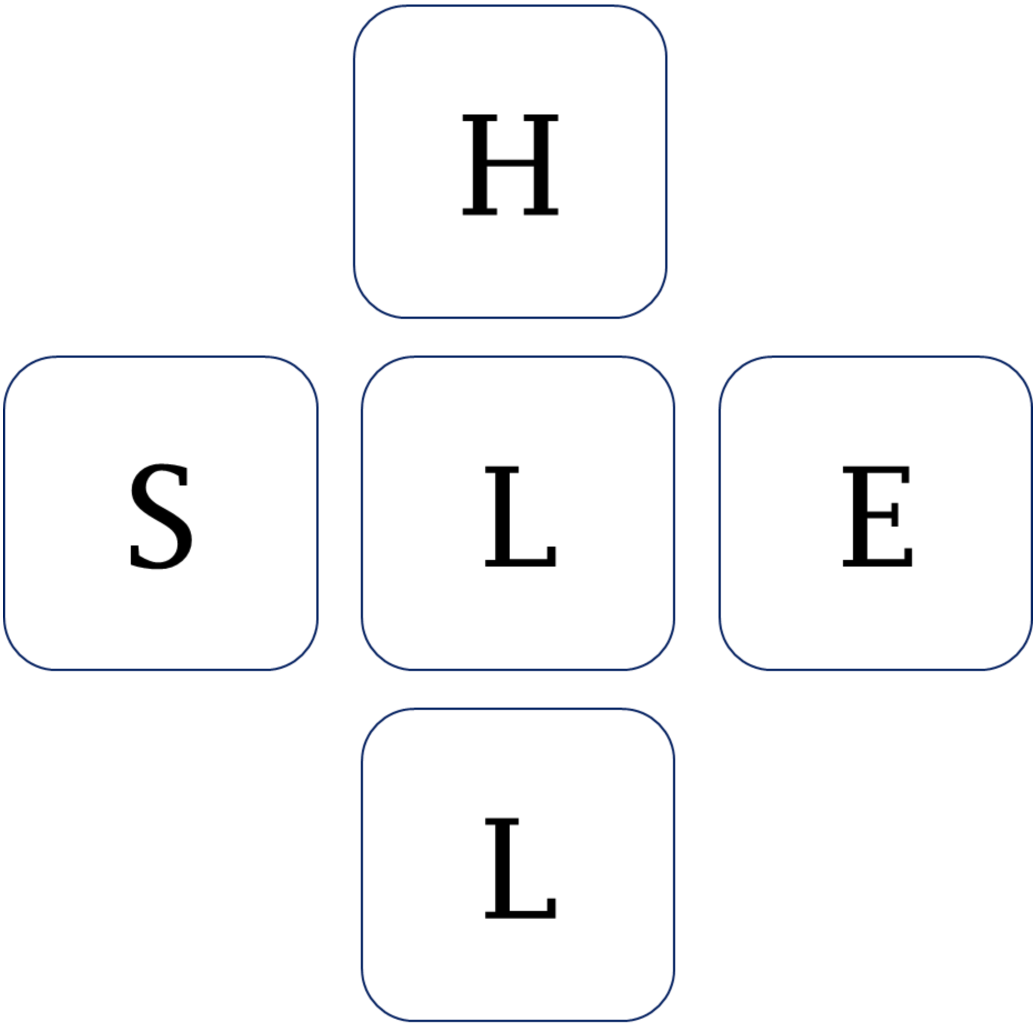


Figure 2.3 Visual representation of the SHELL model.

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 and 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 DISAGRRE 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.

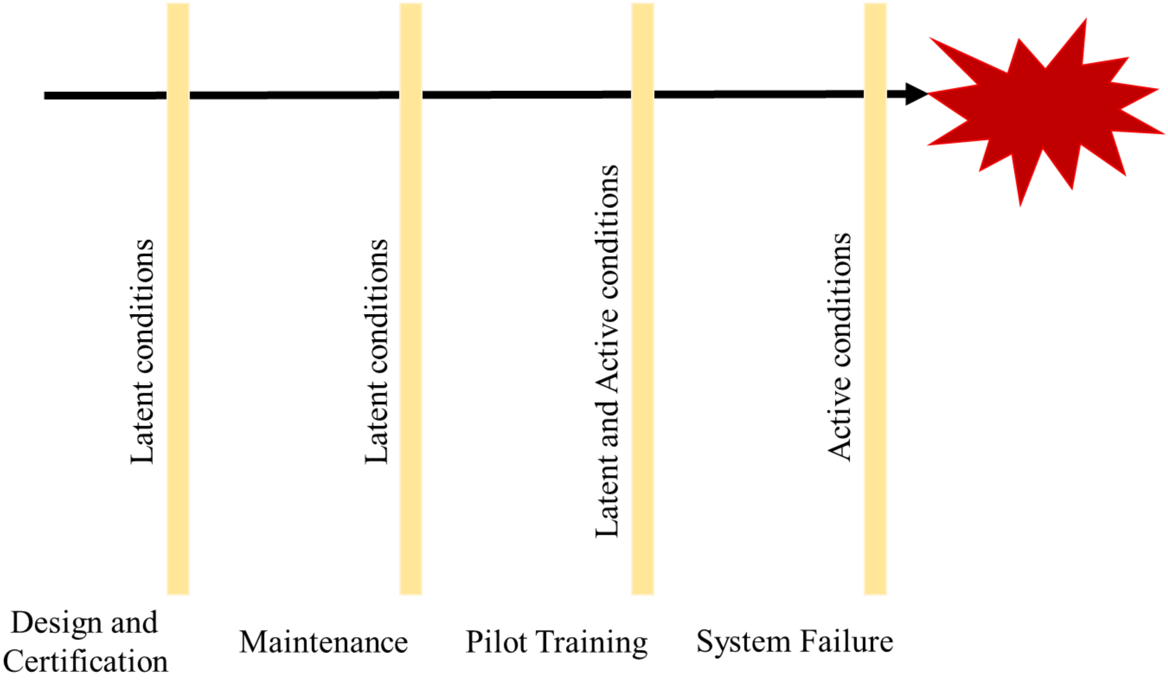


Figure 2.4 Reason's Swiss Cheese model being applied to Lion Air accident

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 2014Boeing 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.

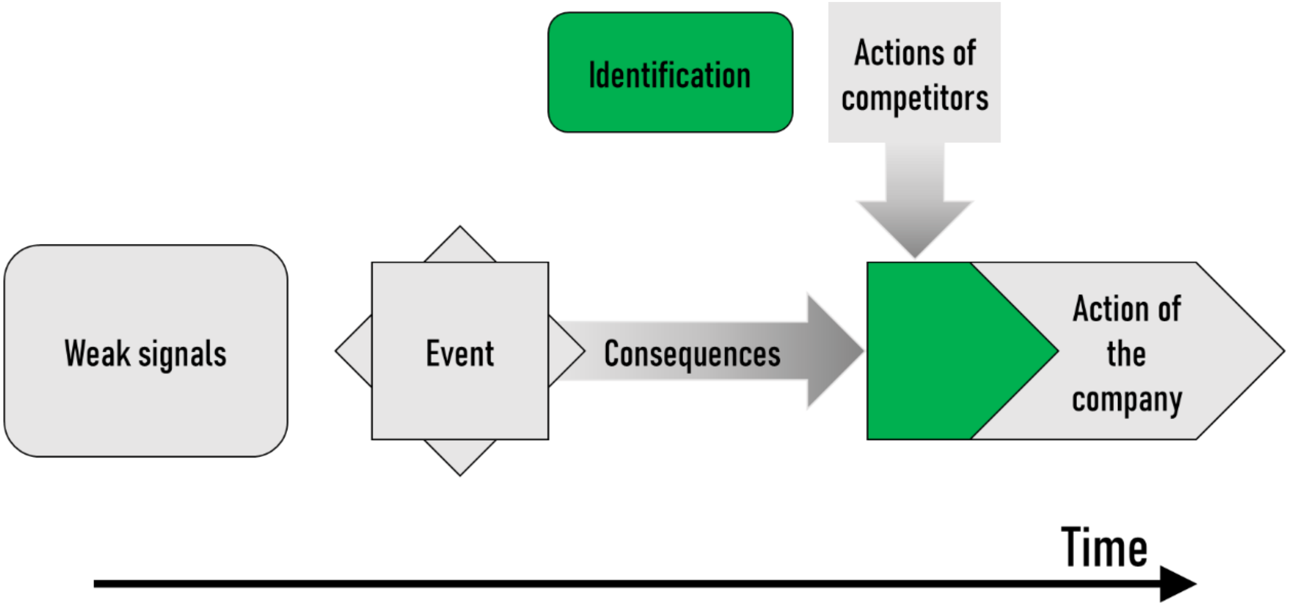


Figure 2.5 Scheme of late company market reaction due to a lack of market monitoring and strategic management system

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.

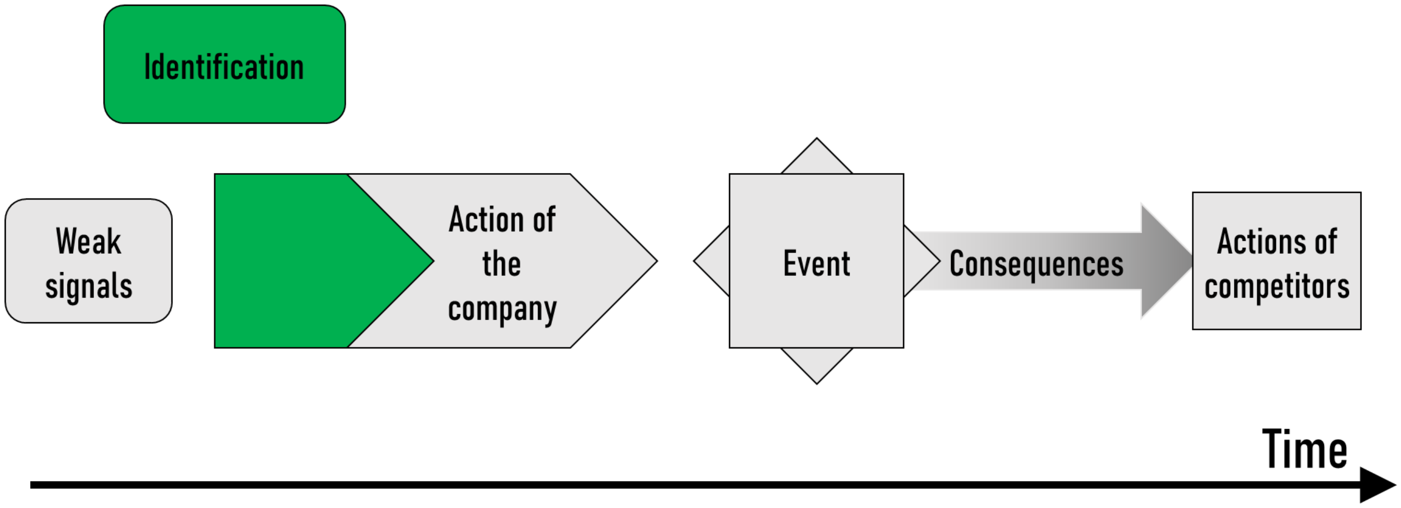


Figure 2.6 Early reaction towards weak signals puts the company ahead of the competitors.

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.

КАФЕДРА АВІОНІКИ				*НАУ 21 09 48 000 ПЗ*			
Розробив	*Турак О.М.*			*PREVENTION OF AVIATION ACCIDENTS BY MEANS OF SUBJECTIVE AND OBJECTIVE CONTROL OF THE AIRCRAFT*	*Літ.*	*Арк.*	*Аркушів*
Керівник	*Сібрук Л.В.*					*53*	
					173 Авіоніка		
Н – контр.	*Левківський В.В.*						
Зав. каф.	*Павлова С.В.*						

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 psycho-physiological 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).

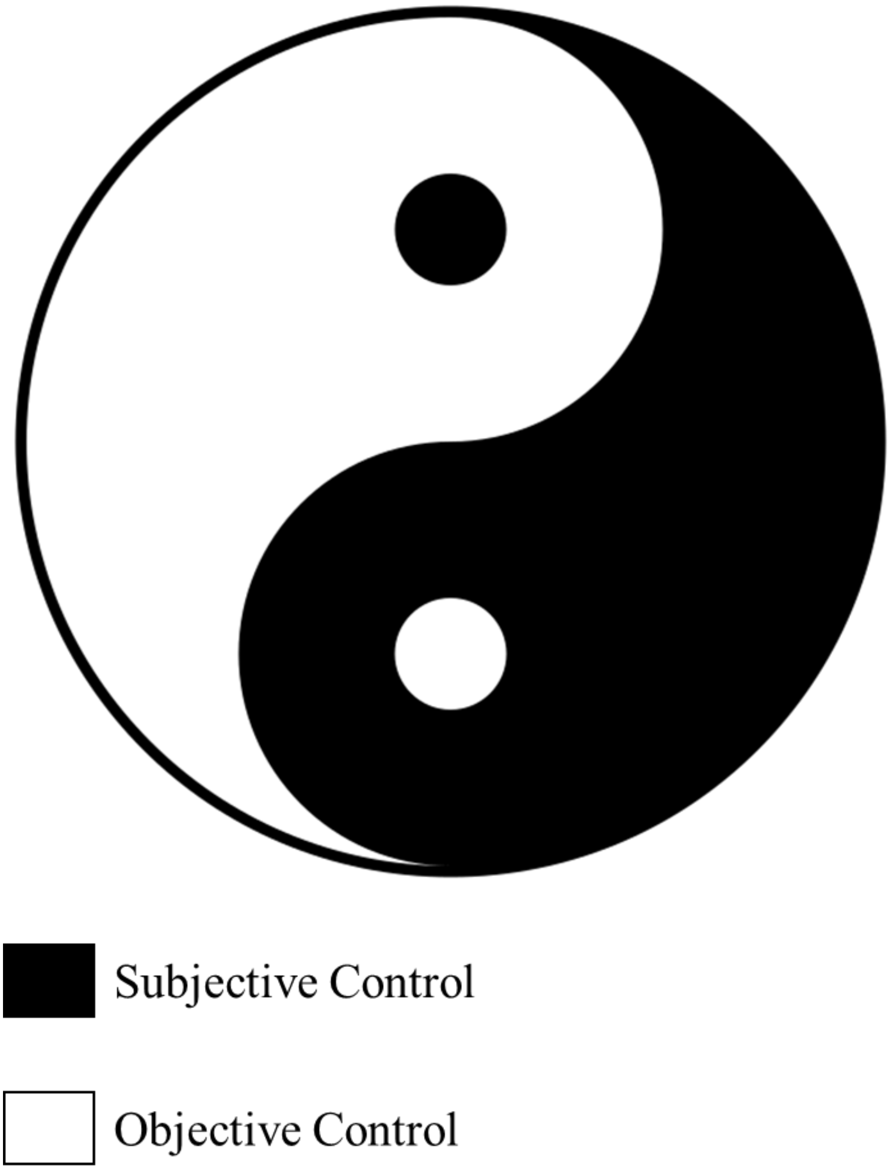


Figure 3.1 Allegorical representation of a balanced Objective and Subjective control systems

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.

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 undoubtable 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.

LIST OF REFERENCES

- Про затвердження Правил об'єктивного контролю в державній авіації України, Міноборони України; Наказ від 03.12.2014 № 860;
- Introduction to TCAS II Version 7.1, U.S. Department of Transportation Federal Aviation Administration, 28.02.2011;
- https://safetyfirst.airbus.com/flight-data-analysis-fda-a-predictive-tool-for-safety-management-system-sms/;
- https://www.aerobytes.co.uk/;
- https://aviation-safety.net/database/record.php?id=19930406-2;
- Accident Report, Loss of Control and Impact with Pacific Ocean Alaska Airlines Flight 261 McDonnell Douglas MD-83, N963AS About 2.7 Miles [4.3 km] North of Anacapa Island, California, January 31, 2000". National Transportation Safety Board. December 30, 2002. NTSB/AAR-02/01;
- http://www.planecrashinfo.com/;
- http://www.boeing.com/commercial/aeromagazine/articles/qtr_2_07/article_03_2.html;
- Aviation Accident Report: Runway Collision of USAir Flight 1493, Boeing 737 and Skywest Flight 5569 Fairchild Metroliner, Los Angeles International Airport, Los Angeles, California, February 1, 1991. National Transportation Safety Board. October 22, 1991. NTSB/AAR-91/08;
- "Revisiting the Swiss cheese model of accidents". Eurocontrol. October 2006;
- Hawkins, F.H., & Orlady, H.W. (Ed.). (1993). //Human factors in flight// (2nd ed.). England: Avebury Technical, 1993;
- "Aircraft Accident Investigation Report. PT. Lion Airlines Boeing 737 (MAX); PK-LQP Tanjung Karawang, West Java, Republic of Indonesia 29 October 2018" National Transportation Safety Committee;

- "Aircraft Accident Investigation Bureau Preliminary Report" (PDF). Ethiopian Civil Aviation Authority, Ministry of Transport (Ethiopia). March 2019;
- GIA (2006) Does Your Business Radar Work? Early Warning/Opportunity Systems for Intelligence. GIA White Paper series. Global Intelligence Alliance;
- Основы инженерной психологии. / под ред. Ломова. М 1986г;
- https://www.everycrsreport.com/reports/R45939.html;