MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

Department of aircraft design

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«___» _______ 2020.

MASTER THESIS
(EXPLANATORY NOTE)
GRADUATE OF EDUCATIONAL DEGREE
«MASTER»

ACCORDING TO THE EDUCATIONAL PROFESSIONAL PROGRAM
«AIRCRAFT EQUIPMENT »

Theme: «The development of a system for tracking the occurrence of operational damage for the aircraft»

Prepared by: ___________ **Y.R. Haideshchuk**

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Ph.d., associate professor ___________**L.I. Pavliukh**

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Kyiv 2020

NATIONAL AVIATION UNIVERSITY

Faculty aerospace
Department of aircraft design
Educational degree «Master»
Specialty 134 «Aviation and space rocket technology»
Educational professional program «Aircraft equipment»

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TASK

for the master thesis

YARYNA HAIDESHCHUK

1. Topic: «The development of a system for tracking the occurrence of operational damage for the aircraft», approved by Rector's order № 1906/ст from 5 october 2020 year.

2. Period of work execution: from 5 October 2020 year to 13 December 2020 year.

3.Initial data assessment of modern aircraft maintenance methods, sees scheduled maintenance of aircraft, analysis of the area and types of damage 4.Content (list of topics to be developed): analysis of measures to maintain the operation of the aircraft, methodology, preliminary design of the aircraft as an object for the implementation of the research project, development of a system for tracking the occurrence of operational damage to the airframe, analysis of harmful and hazardous production factors, calculations of lighting of the workplace of the maintenance laptop during use of the Built–in Operational Damage Recognition System.

5. Required material: general view of the airplane (A1×1); layout of the airplane (A1×1). Graphic materials are made in CATIA V5.

6. Thesis schedule

№	Task	Time limits	Done
1	Obtaining the task, processing statistical data	5.10.2020 – 12.10.2020	
2	Methodology	13.10.2020 – 14.10.2020	
3	Aircraft layout and determining the alignment of the aircraft	15.10.2020 – 23.10.2020	
4	Review and analysis of the process of monitoring the condition of the unit with modern technologies	24.10.2020 – 1.11.2020	
5	Development of a block diagram of the system	2.11.2020 – 16.11.2020	
6	Calculation of ramp strength	17.11.2020 – 26.11.2020	
7	Development of maintenance process in accordance with system requirements	27.11.2020 – 5.12.2020	

7. Special chapter consultants

Chapter	Consultant	Date, signature	
		Task Issued	Task Received
Labor protection	Ph.d., associate professor O.V. Konovalova		
Environmental protection	Ph.d., associate professor L.I. Pavliukh		

8. Date of issue of the task: «___»___________2020 year.

Thesis supervisor _____________ S. S. Yutskevych

Task accepted for execution _____________ Y. R. Haideshchuk

ABSTRACT

Explanatory note to the diploma work "The development of a system for tracking the occurrence of operational damage for the aircraft":

93 p., 20 fig., 8 tables, 20 references and 2 drawings

Object of study – is a process of approving the method of preparing the planning maintenance.

Subject of study – is a development of a system for tracking the occurrence of operational damage for the airframe.

Aim of master thesis – to simplify the process of aircraft maintenance.

Research and development methods – analysis and selection of the most modern technical solution while simplifying scheduled maintenance.

Novelty of the results: the obtained results are based on the latest data collected in this field.

Practical value: methods` approve of track the formation of cracks, delamination and corrosion in real time, and give an assessment for further work with these damages.

The results of the work can be implemented not only in aviation field, but also other branches of engineering.

AIRCRAFT, MAINTENANCE, STRUCTURAL HEALTH MONITORING, BUILT-IN AIRCRAFT INSPECTION SYSTEM

CONTENT

LIST OF ABBREVIATIONS, SYMBOLS, TERMS

AHM - Aircraft Health Monitoring;

SHM - Structural Health Monitoring;

NDI - Non-Destructive Inspection

NDT - Non-Destructive Testing

INTRODUCTION

The main goal of the aviation industry has always been, is and will be - to obtain maximum profit provided that the safety conditions for passengers and crew. To this end, various committees, supervisory boards, organizations, and others were established to oversee compliance with all conditions, processes, and procedures. One such procedure in the aviation industry has always been to monitor the condition of the aircraft. This process is called service. Initially, the essence of this process was to repair the existing damage, but over time, the main idea was not only to eliminate existing problems, but also to prevent those that could occur in the near future.

The service process is quite complex in both understanding and execution, so only people with the appropriate qualifications and work experience are allowed to implement it, because the lives of people on board the aircraft depend on it. There are often cases of the 'human factor' where mistakes were made, leading to numerous casualties. Due to such cases and other cases, statistical data were collected on problem areas, on the most common areas of operational damage, on the causes that led to various damage and others. Based on them, a schedule of scheduled inspections of aircraft (there are four types) was invented and developed, during which work was carried out according to the type of inspection:

- A Check - this type of check is performed every 400–600 flight hours or 200–300 cycles. This inspection, which takes approximately 50–70 man-hours.
- B Check - his check is conducted every six to eight months, and it requires approximately 160–180 man-hours.
- C Check - performed every 20–24 months. C Check is more extensive than the A and B checks. It take least two weeks and up to 6,000 man-hours.
- D check
- The D check is the most comprehensive check designed for aircraft. It is conducted every 6–10 years. The repair jobs generally take up to two months, approximately 50,000 man-hours, and about one million dollars to complete.

The schedules of such inspections were not only intertwined, but also often overlapped. If for one type of work it was enough to allocate from half an hour to 3 hours, then others took several days or even months (D check). During such services, new ‘invisible’ damage is detected in the aircraft and the damage that was detected earlier is repaired. On the one hand, this method prevents new, ‘unplanned’ damage, which is undoubtedly good, and on the other hand, airlines lose a fairly large amount of revenue for the period of inspections.

To simplify some types of maintenance, the Non-Destructive Inspection method was invented, which allowed to check the condition of the structure at which its suitability for use and operation should not be violated. This method of control uses a variety of physical phenomena and processes, which under certain conditions does not harm the object of control and does not affect its performance. But this method, again, does not significantly reduce the time spent on maintenance procedures. Yes, it simplifies the process of performing the tasks themselves, but it is difficult to say that it saves time.

Later, due to the rapid development of technology, a direction was developed - Structure Health Monitoring, the main idea of which is to review the structures over a period of time to understand its behavior in the future. The new technology could collect data and draw conclusions about the formation of structural damage that was invisible to the human eye. Sensors that collected information were used for tracking. Certain types of sensors are used for each type of damage, and several types can be used in one ‘field’. Then all the collected information is collected and either stored in a specific repository for later use, or transmitted online to the appropriate department, which immediately processes it.

At first, such technology was used in bridge construction, but over time it took its place in aviation. Unfortunately, at the moment SHM use in aviation is not very common. It can most often be found in avionics and systems. Such information suggests that this industry has great potential for development, because if we delve into the idea of SHM, we can conclude that this is a fairly broad sector.

In this thesis it is proposed to explore the principle of SHM, data transmission and processing, derivation of results and decision making. And based on the results, develop a system that will track the formation of cracks, corrosion and delamination (in composite materials), in the early stages, and which will decide on the type and timing of maintenance procedures.

This system can collect information from any type of sensor that will be installed in certain areas, process information, and analyze the criticality of the situation. Zones are selected based on statistics, ie these are the places where structural damage is most common.

From the data that were collected during the writing of this paper, we can conclude that this system effectively performs its task.

1 STATE OF THE ART LITERATURE REVIEW ABOUT THE DEVELOPMENT OF THE AIRCRAFT MAINTENANCE PROCEDURES

1.1 Review of publications on the topic of the thesis

Aircraft maintenance always play an important role in life of the aircraft technical activity. It is need for to keep the aircraft in state airworthiness ability. And in accordance with the development of aviation, the need to improve all areas of maintenance service - increase, so the requirements for such procedures became increasingly stringent. If before it was enough only use decision logic to develop scheduled maintenance, for nowadays it is not at all.

Typical modern system of the aircraft maintenance program is based on a special method, which is call Maintenance Steering Group (MSG) [1]. Present in aviation is used MSG-3 that was created in 1980 and is using by nowadays. It introduce a top-down approach by focusing on 'failure` consequences' (Figure 1.1). Also MSG-3 introduce elements related to the Structural Health Monitoring (SHM).

The main idea of the MSG-3 is to present a methodology for developing scheduler maintenance to avoid unnecessary maintenance tasks (decrease time for unnecessary procedures) and increase efficiency of the tasks:

- Maintenance is effective in the case when task is applicable
- Maintenance is not need in the case when failure is cheaper
- Needless tasks can introduce error of the human
- There is no reliability improvement by excessive maintenance
- As usual, monitoring is more effective than hard-time overhaul Condition-Based Maintenance (CBM) [3].

Control process according to MSG-3:

- Hard Time – maximum interval of the component by maintenance task performing.
- On condition – during component life do it`s inspections to measure part integrity and determine its conditions
- Condition Monitoring – component with no regular inspection. Is not permitted for units that can effect operational safety

- Zonal Inspectional Program - to do regular inspection to the component according to different inspection programs.

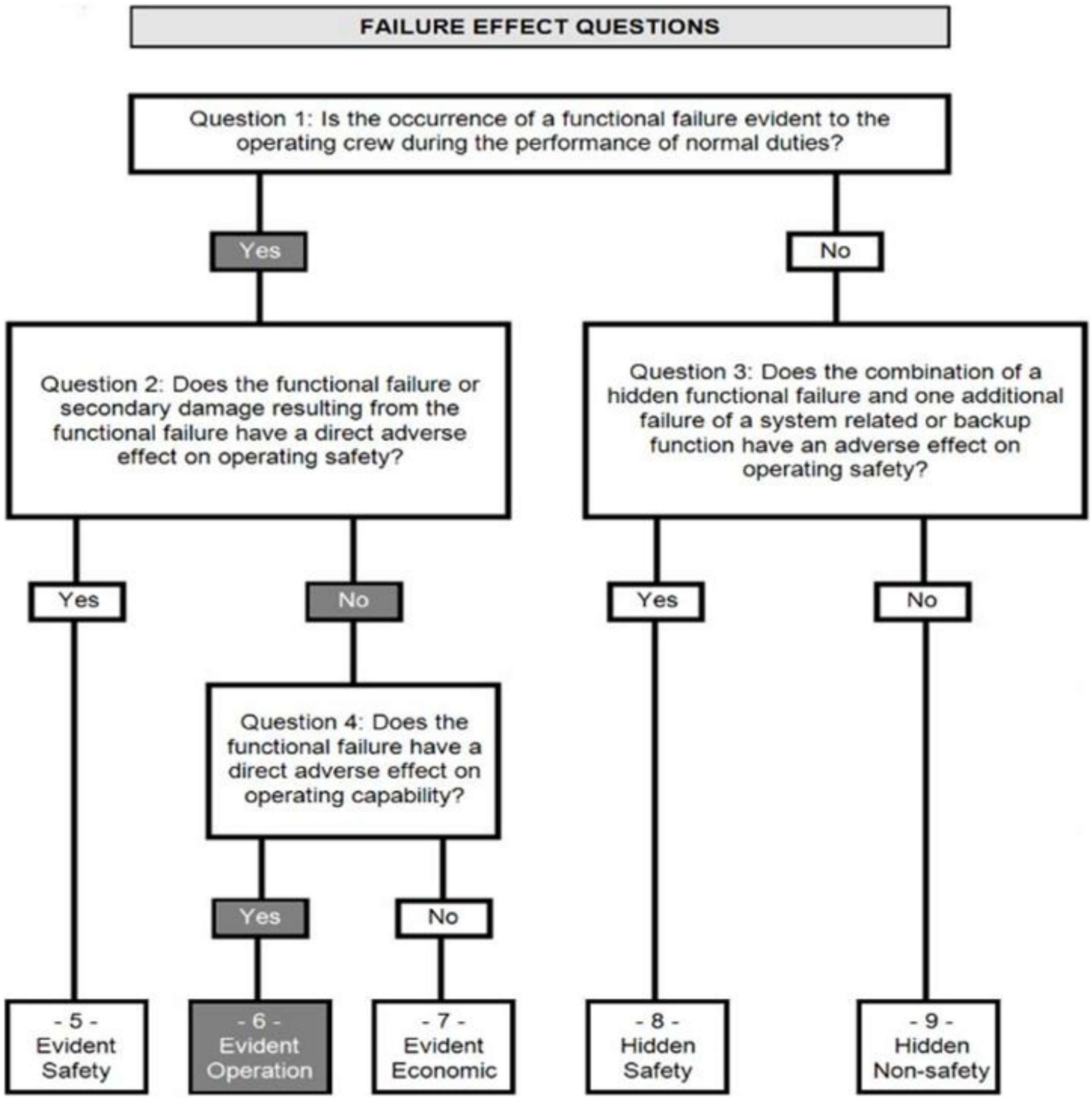

Figure 1.1 - Detail report for all MSG-3 forms [2]

The content of the scheduled maintenance itself consists of two groups of tasks:

a) A group of scheduled tasks to be accomplished at specified intervals. The objective of these tasks is to prevent deterioration of the inherent safety and reliability levels of the aircraft. The tasks in scheduled maintenance may include:

    (1) Lubrication/Servicing (LU/SV)

    (2) Operational/Visual Check (OP/VC)

    (3) Inspection/Functional Check (IN*/FC)

- General visual inspection (GVI) – (to detect obvious damage) take place in regular time intervals and its purpose is visually detections.
- Detailed visual inspection (DET) - to detect damage (mirrors, magnifying lenses, cleaning of the surface, access procedures, etc).
- Special detailed inspection (SDET) – similar to the detailed inspection, but require using of the special techniques (NDI) - intensive examination.
- Scheduled Structural Health Monitoring (S-SHM)

(4) Restoration (RST)

(5) Discard (DIS)

b) A group of non-scheduled tasks which result from:

(1) The scheduled tasks accomplished at specified intervals.

(2) Reports of malfunctions (originated by the operating crew).

(3) Data analysis.

(4) Reports of potential failures (e.g. originated by the aircraft monitoring) [4].

According to the operational requirements MSG 3, let to look into a modern detailed inspections procedures, Intervals between maintenance scheduler inspection checks is develop according the Flight Hours (FH)/ Flight Cycles (FC) and calendar time, and for allowing greater flexibility in their planning.

A Check – (light check) approximately every 500-800 flight hours and needs about 20-50 man-hours.

B Check - (light check) approximately every 4-6 months and needs about 150 man-hours (1-3 days at airport` hangar).

C Check - (hard check) approximately every 20-24 months and needs 1-2 weeks to complete the check (can require up to 6000 man-hours).

D Check - (hard check) Heavy Maintenance Visit (HMV), approximately every 5 years and takes up to 2 months to complete (can require up to 50 000 men-hours).

The biggest disadvantage of such checks is that, the airplane can be out of service for a long time and involvement a big number of human-resources.

All of the given above inspections – are scheduler, to wit all maintenance actions are noted in the Maintenance Planning Data (MPD), that as approved by the special committee.

To the scheduler maintenance belong a Structural Health Monitoring (S-SHM). The main idea of which is to read or use the information from the SHM devise at interval marked in fixed scheduler.

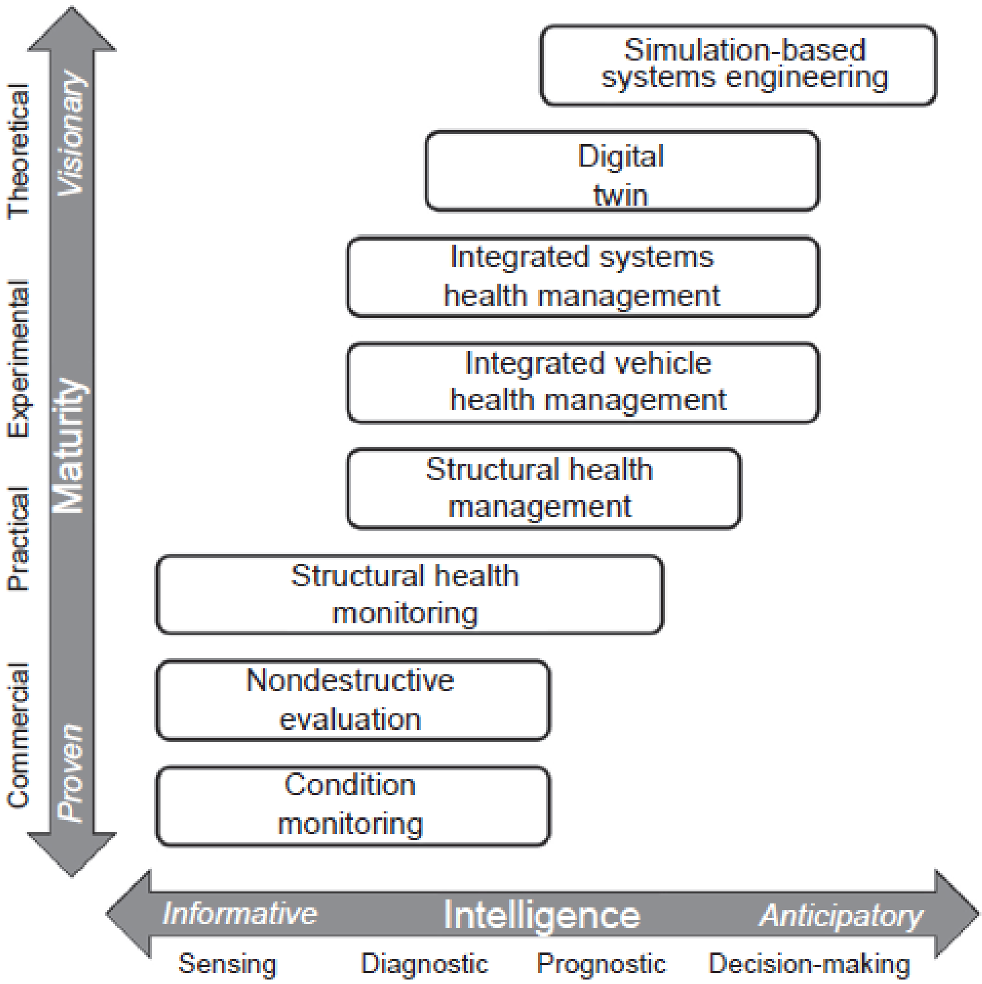

Figure 1.2 - Current and future Health management technologies

SHM is a method of monitoring structural state of any vehicle (in aviation Aircraft Health Monitoring (AHM)). It refers to a connected sensors to collect and analyze data. The goal of such system is to identify damage in the system, which can occur during the service life. A typical SHM system consists of a diagnosis component (low level), which includes the levels of detection, localization, and assessment of any damage, and a prognosis (high level), which involves the generation of information regarding the consequences of the diagnosed damage.

Considering just the first function - the diagnosis, it could estimate that SHM (AHM) is a new and improved way to make Non Destructive Inspection quicker and easier. It involves the integration of sensors, possibly smart materials, data transmission, computational power, and processing ability inside the structures. With the time-dimension of monitoring, it allows to consider the full history database of the structure and allow determining behavior of the structure future (Figure 1.2).

Implementing SHM systems is a step forward towards proactive maintenance systems. Existing maintenance protocols are in general based on reactive strategy; it means that repairs and interventions are usually perform when a damage has already happened. SHM systems can help identify and quantify these structural defects in early stages, when repair and rehabilitation will be more cost effective, and more efficient [5].

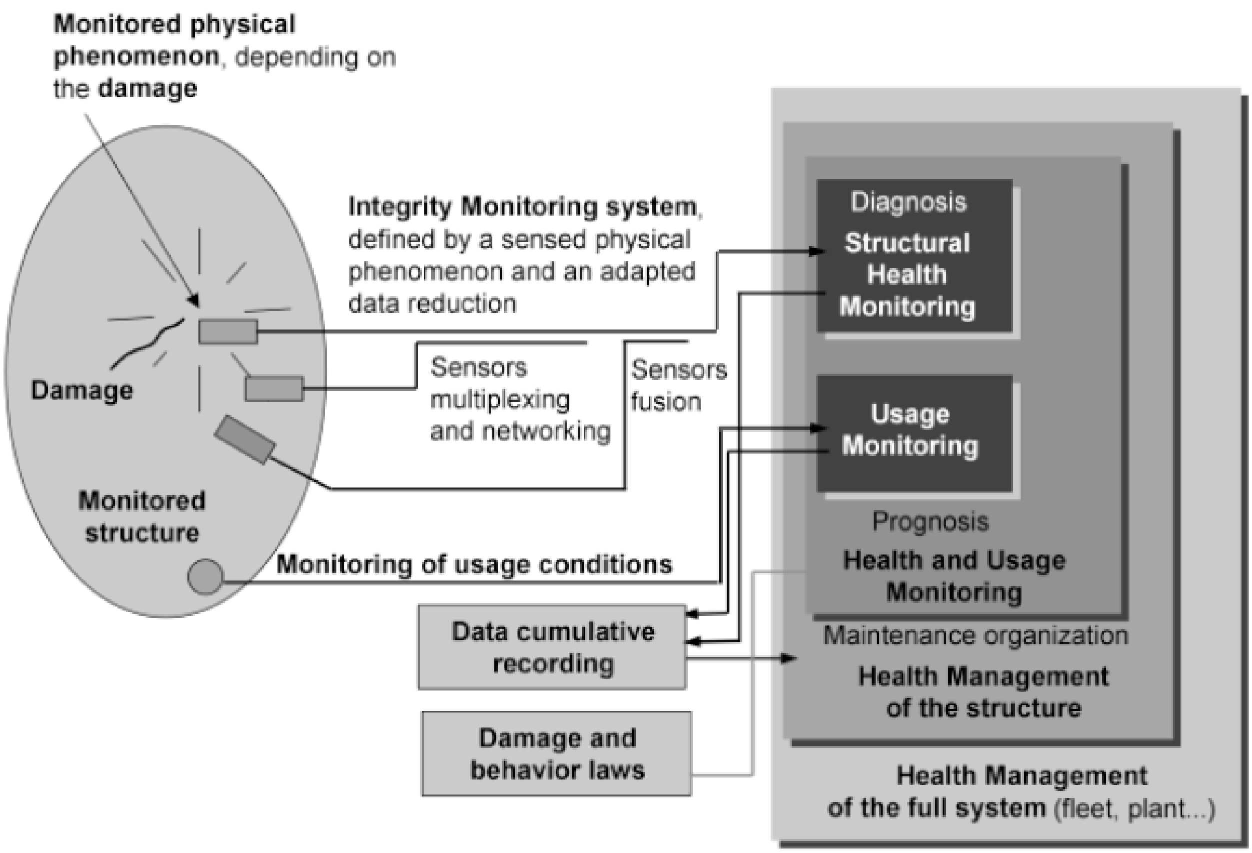

Figure 1.3 - Principle of a Structural Health Monitoring system.

1.2 Motivation for the SHM development

The improvement of safety seems to be a strong motivation, in particular after some spectacular accidents due to:

- unsatisfactory maintenance
- ill-controlled manufacturing process

In both fields the problem of aging structures was discovered and subsequent programs established. Figure 1.4 shows that maintenance is only responsible of 14% of hull loss. Furthermore, it can be noticed that only 4% of all accidents are due to structure weakness. It can be concluded that, thanks to the introduction of SHM, even an improvement of maintenance and a decrease of structure-caused accidents by a factor of 2 would lead to a global reduction of accident lower than 10 %, which is far from what is needed to avoid an important increase of accidents number in the near future if air traffic still increases [5].

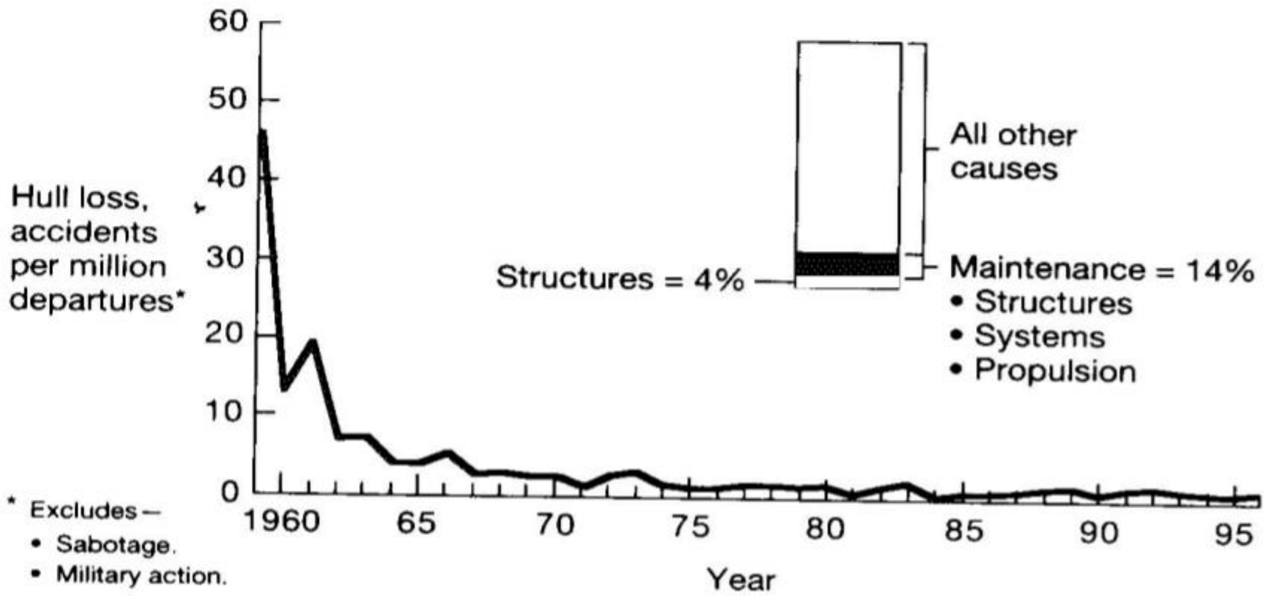

Figure 1.4 - Origin of hull losses [6]

Big influence on developing of aviation is economic. The deployment of SHM has not been widespread, mainly due to the cost associated with the technology and installation of these systems. Most existing SHM solutions are relatively expensive, but more expensive is regular maintenance procedures of the aircraft. The economic impact of the introduction of SHM for aircraft is not easy to evaluate. From a life-cycle cost analysis perspective, this can be a more expensive option for the organization, then the NDI. It depends on the usage conditions, and furthermore, it is difficult to appreciate the impact on the fabrication cost of the structure. The price of SHM systems must not cancel the expected maintenance cost savings. Easier is the evaluation of time saved by the new type of maintenance based on SHM introduction.

In Table 1.1 presents the data about the time saved on inspection by the use of Structural Health Monitoring, for modern fighter aircraft, according to the modern recent researches [7].

Table 1.1 - Estimated time saved on inspection operations by the use of Structural Health Monitoring [7].

Inspection type	Current inspection time (% of total)	Estimated potential for smart systems	Time saved (% of total)
Flight line	16	0.40	6.5
Scheduled	31	0.45	14.0
Unscheduled	16	0.10	1.5
Service Instructions	37	0.60	22.0
	100		44.0

1.3 The most remarkable characters of SHM

Several sensors of the same type, constituting a network and their data connected with those from other types of sensors (the others sensors can monitoring the environment conditions).

Structural Health Monitoring is remarkable by the variety of techniques used. For a given damage several techniques can be satisfy apply.

Table 1.2 - Materials for sensor design [8]

Physical effect	Materials	
	Polymers	Inorganics
Passive sensors		
Piezoelectricity	Polyvinylidene fluoride Polyvinylidene fluoride trifluoroethylene Polyhydroxibutyrate Liquid crystalline polymers (flexoelectricity)	Piezoelectric zirconate titanate Zinc oxide Quartz
Pyroelectricity	Polyvinylidene fluoride Langmuir-Blodgett ferroelectric superlattices	Triglycine sulfate Lead-based lanthanum-doped zirconate titanate Lithium tantalate
Thermoelectricity (Seebeck effect)	Nitrile-based polymers Polyphthalocyanines	$Cu_{100}/Cu_{57}Ni_{43}$ Lead telluride Bismuth selenide
Photovoltaic	Polyacetylene/n-zinc sulfide Poly(N-vinyl carbazole)+merocyanine dyes Polyaniline	Silicon Gallium arsenide Indium antimonide
Electrokinetic	Polyelectrolyte gel ionic polymers	Sintered ionic glasses
Magnetostriction	Molecular ferromagnets	Nickel Nickel-iron alloys
Active sensors		
Piezoresistivity	Polyacetylene Pyrolized polyacrylonitrile Polyacequinones Polyaniline Polypyrrole Polythiophene	Metals Semiconductors
Thermoresistivity	Poly(p-phenylene vinylene)	Metals Metal oxides Titanate ceramics Semiconductors
Magnetoresistivity	Polyacetylene Pyrolized polyvinylacetate	Nickel-iron alloys Nickel-cobalt alloys
Chemioresistivity	Polypyrrole Polythiophene Ionic conducting polymers Charge transfer complexes	Palladium Metal oxides Titanates Zirconia
Photoconductivity	Copper phthalocyanines Polythiophene complexes	Intrinsic and extrinsic (doped) semiconductors

The sensors that can be used are based on various physical phenomena, structure type, its environment and different aspect of structural and durability performance are made of very different materials. Although not considering the optical sensors, Table 1.2 shows the diversity of physical phenomena and sensor materials which can be used. All this explains why SHM, as all research in Smart Materials and Structures, is eminently multidisciplinary [5].

The types of sensors used to monitor structural health is strongly depending on the types of structures to monitor. Figure 1.5 presents the main types of sensors used in the two main fields of application: civil engineering and aerospace engineering. These statistics are based on the communications given in the two first International Workshops on SHM held at the University of Stanford (1997 and 1999)[5].

For a narrower field defined by a specific type of structure and a specific type of damage, the structural health monitoring of composite structures with delamination, the distribution of the various types of methods is given in Figure 1.6, for the period 1997-2003. The statistics are based in this case on a wider bibliographical database counting near of 1150 references. The distribution is similar to the one found for aerospace engineering (Figure 1.5). As shown in Figure 1.6, in each family of sensors, there are wide varieties of specific sensors [5].

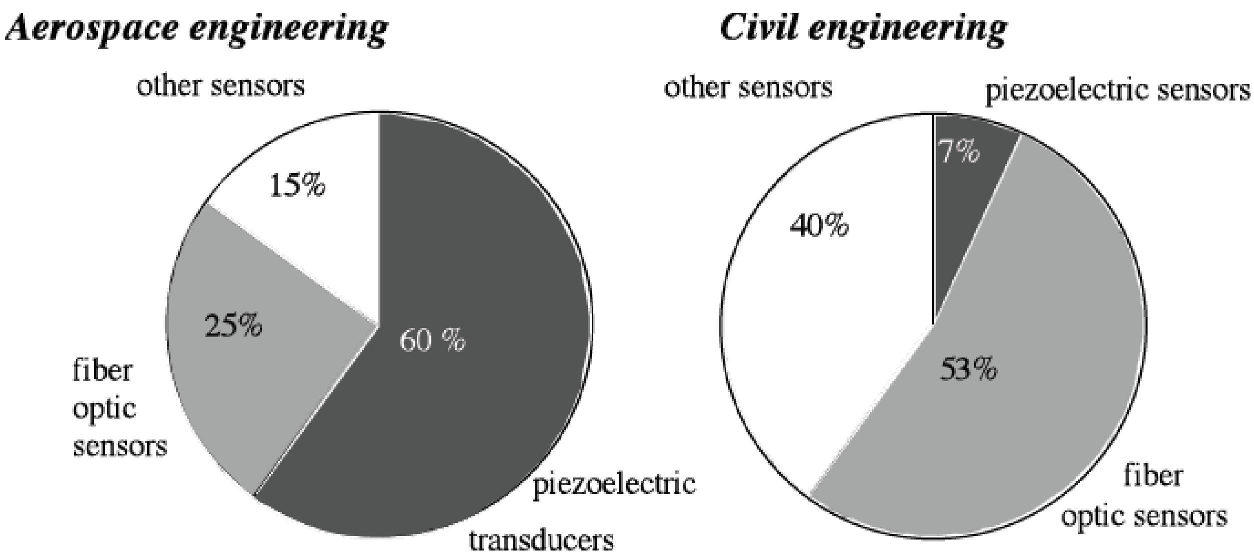

Figure 1.5 - Main types of sensors used for structural health monitoring, depending on the types of application: comparison between aerospace engineering and civil engineering [9].

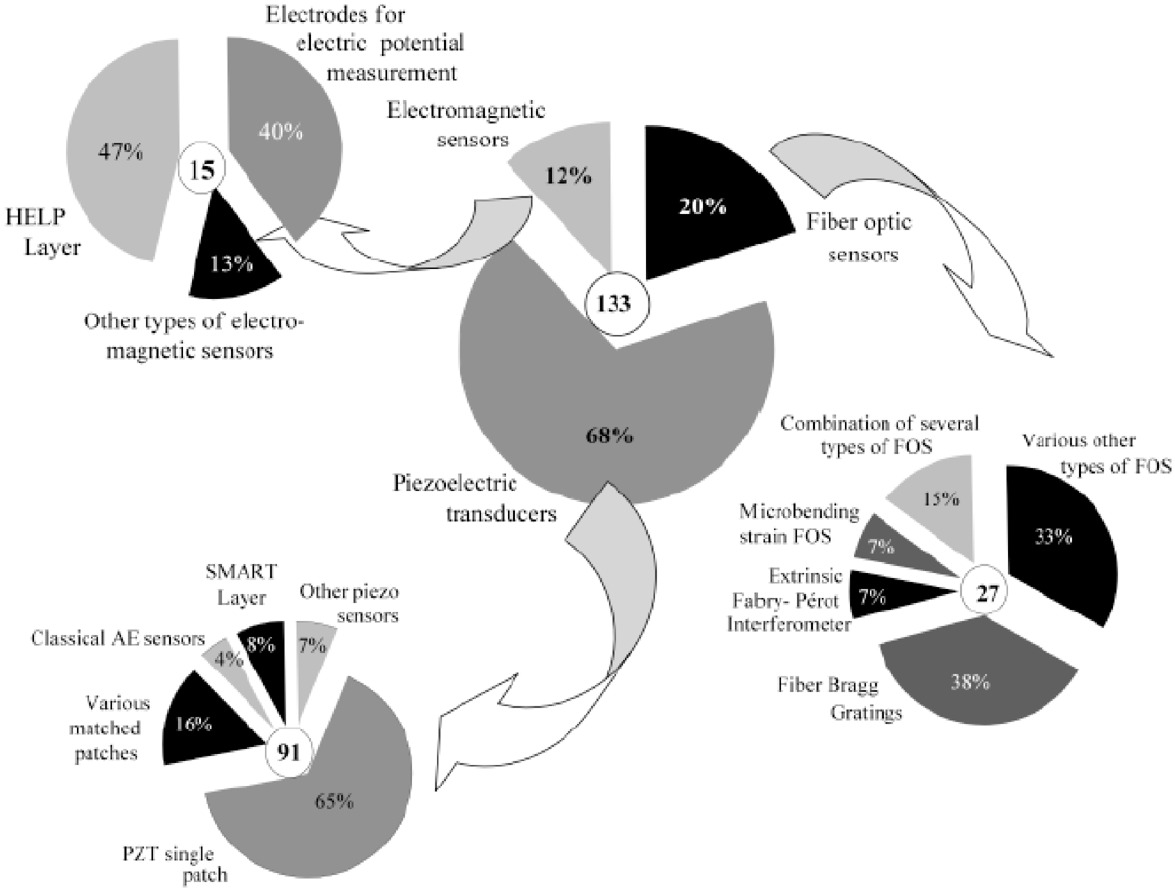

Figure 1.6 - Type of sensors used in the references related to the monitoring of delaminations in composite structures. Statistics based on a general survey of SHM literature for the period 1997-2003.

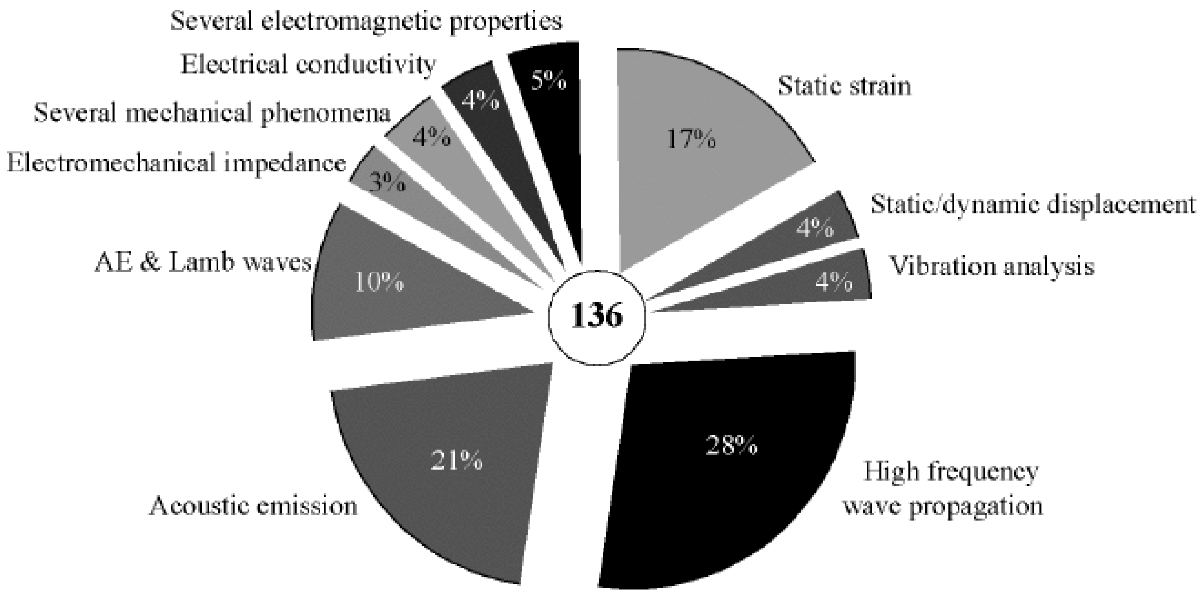

Figure 1.7 - Methods used for the monitoring of delaminations in composite structures

If we consider now the methods of monitoring, independently of the type of sensor used, one more time a very wide variety exists too. This is shown in Figure 1.7, which presents the distribution of monitoring methods used in the same references.

In addition, for each specific sensor, several methods can exist, varying on the way to use the sensor or to identify the characteristics of the damage. For example, piezoelectric patches can be used for monitoring techniques as varied as: electromechanical impedance, acoustic emission, propagation of high-frequency waves like Lamb waves, analysis of random or modal vibrations, etc [5].

1.4 Types of Structural Health Monitoring

Structural Health Monitoring, like Non Destructive Evaluation can be passive or active (Figure 1.8).

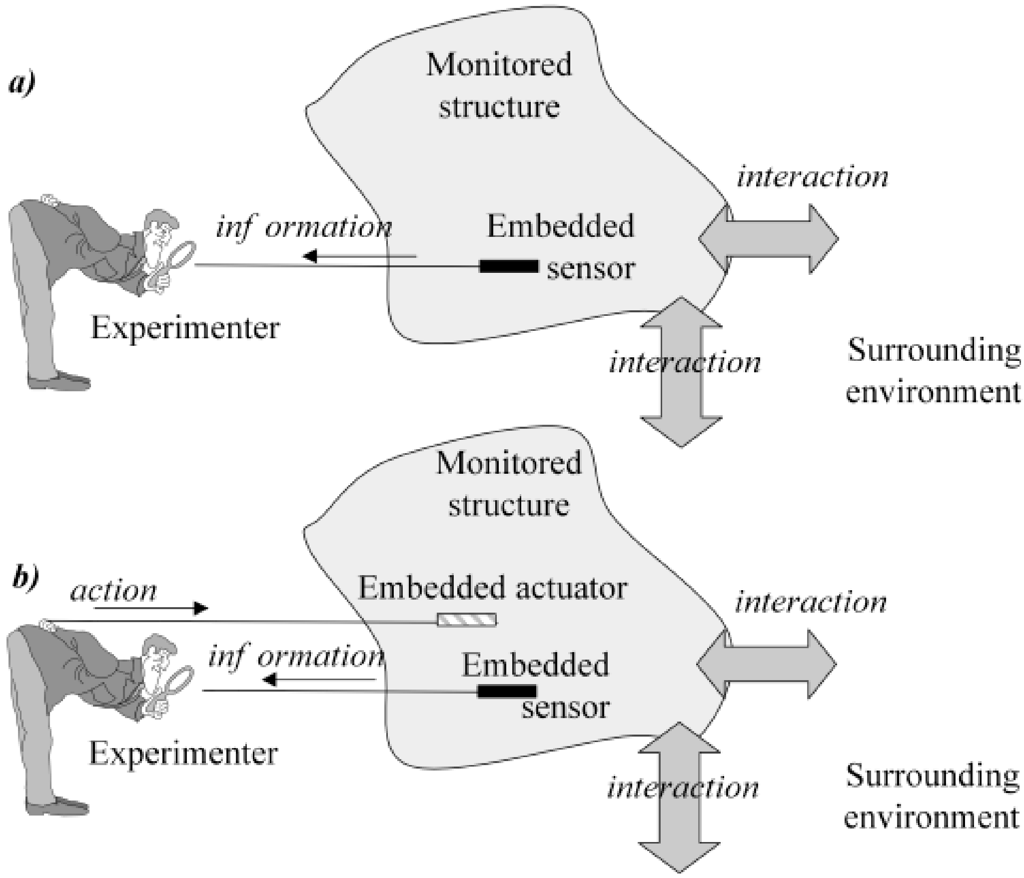

Figure 1.8 - The two possible attitudes of the experimenter defining passive and active monitoring.

The structure is equipped with sensors and is in interaction with the surrounding environment in such a way that it state and its physical parameters are evolving.

If the experimenter is just monitoring this evolution thanks to the embedded sensors, we can call his action a "passive monitoring". For SHM such situation is encountered with acoustic emission technique detecting for example the progression of damage in a loaded structure or the occurrence of a damaging impact.

Attribute	NDI	SHM
Application	Locate and quantify damage	Monitor critical components, reduce operational and maintenance costs, improve performance and efficiency, extend useful life
Placement	Fixed locations in laboratories or portable for field use	On-board, often used in locations that are difficult to access
Inspection intervals	Infrequent; health data acquired during periodic inspections	Health data acquired continually or on demand
Data recording	Recorded during inspection	Recorded locally for later download or retrieval, or transmitted for off-board storage
Automation	Mostly manual; human intervention required	Mostly automated
Coverage	Localized damage near the sensor, or scanned for wide-area coverage	Localized damage using discrete sensors or wide-area coverage using guided waves or fiber optics
Accuracy	Highly accurate	Moderately accurate
Equipment size	Moderate (handheld) to large (laboratory test stand) inspection equipment size	Small sensors and sensing system equipment size
Portability	Portable or fixed location	In situ
Weight	Moderate to heavy	Light to moderate
Hardware cost	Moderate to high	Low to moderate
Operational cost	Moderate to high; depends on periodic inspection intervals	Low to moderate; not linked to periodic inspections

Figure 1.9 - Comparison of Non-Destructive Inspection (NDI) and Structural Health Monitoring (SHM)

If the experimenter has equipped the structure with both sensors and actuators, he can generate perturbations in the structure thanks to actuators and use sensors to monitor the response of the structure. In that case the action of the experimenter is an "active monitoring". In the aforementioned example, the monitoring becomes active by adding to the first piezoelectric patch used as acoustic emission detector a second patch used as an emitter of ultrasonic waves. The receiver here is registering signals resulting from the interaction of these waves with a possible damage, allowing its detection [10].

In classical NDE, the excitation is generally achieved using a device external to the examined structure (Figure 1.9), but the philosophy is the identical.

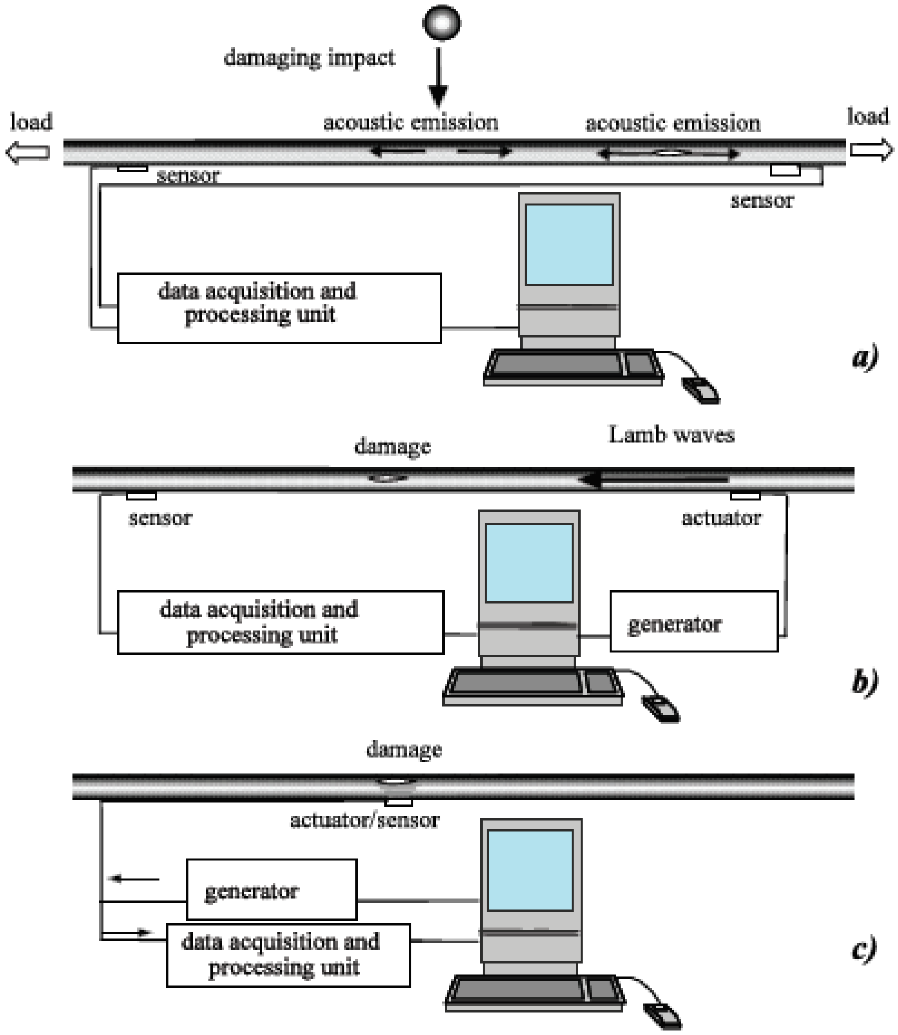

Figure 1.10 - Monitoring with using piezoelectric patches: a) passive: acoustic emission technique, b) active: acousto-ultrasonic technique with generation of Lamb waves, c) active: electromechanical impedance technique [5].

In SHM, the actuator and the sensor can be different or identical in nature. For instance excitation by a piezoelectric patch and detection of the waves by a fiber optic sensor [11] or by the other piezoelectric patch. In the case of piezoelectric transducers, it is worth to note that the same device can work as both emitter and receiver, which gives flexibility to the monitoring system by alternating the roles. This is illustrated in Figure 1.10. With piezoelectric patches, a unique transducer can even play the two functions at the same time like in the electromechanical impedance technique.

CONCLUSION TO PART 1

The main condition for the modern implementation of aircraft maintenance - is compliance with the requirements of MSG-3, in which in addition to safety criteria, the main criterion is economy. To find a balance between these two main criteria, health monitoring was invented, the main task of which is to save not only time for maintenance, but also time saving human resources, which in total gives significant financial savings for airlines. However, now the question arises in the implementation of such a direction in the aviation sector. The main task is the possibility to implement a system that meets the requirements of MSG-3 and does not require additional intervention in the work process.

2 ANALYSIS OF THE DAMAGE RECOGNITION SYSTEM CREATION

2.1 General information about the developing of a new system

During a long time safety of airplane and passengers was in the first place. The most common way to determine any structural damage is Non-Destructive Testing (NDT) [12], which use the non-destructive testing techniques to examine materials and components before they enter in the service and while they are in service, without destroying them. But the biggest disadvantage is this inspection method is enough time consuming, that is increase time allocated for maintenance procedures. Unlike the NDT, the SHM does not need so much time for maintenance. Instead of this, it save a lot time of maintenance procedures.

During development of any aircraft system, it goes through the three basic engineering actions (Figure 2.1).

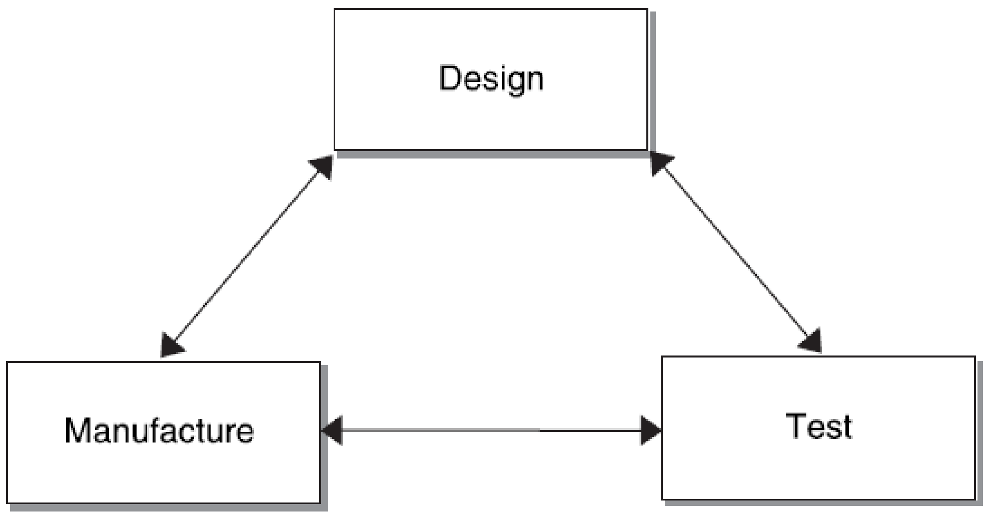

Figure 2.1 - the three basic engineering actions

- The designing process – is the process of creating. Hardware and software have to meet requirements of design specifications.
- The testing process – is the process of testing the system to make sure that the system work correctly and it does not lead to fault.
- The manufacturing process (in this case installation) should ensure the system work correctly in definite environment, all the components are install in right manner.

Testing provides ensure about design, to involve faults as they occur (during development, manufacture and service life):

- ✓ Meet the customer requirements
- ✓ Meet the standards requirements
- ✓ Technically correct and usable
- ✓ Is in working state in the intended environment
- ✓ Does not include any fault (hardware and software)
- ✓ Provides feedback to identify any problems with the work process

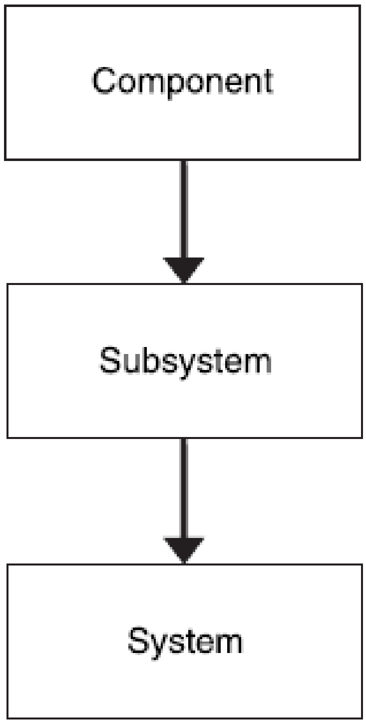

Figure 2.2 – levels of the aircraft system

During development process, product is testing at different zones in different levels (Figure 2.2)

- At component level – passive components (inductors, resistors, etc), cables, integrated circuits… all these components tot into subsystem
- Subsystem level – connectors, passive components, etc. Subsystems make up the system itself.

2.2 Designing of the System

To be able to perform a system this is the important to identify the condition of the structure.

The first step is the problem statement. Identification of the parameters that have to be monitored is the most important task (whole concept can fail if it is not performed in the appropriate way):

- Special care about new complicated design
- Check that the measurements will be comparable with the analytical models, calculations, etc.
- Surfaces` condition inspection, need for scaffolding for installation, access to electricity, possible placement for equipment, etc.

More information is provided, when handling existing structures (maintenance actions, inspection protocols, strengthening of the structure, verified structural weakness, etc).

The second step - is the chosen of the sensors, which will fulfil the requirements. In complex projects it can be need several kinds of sensors.

A design of the System would not contain any functional errors. During designing it have to meet requirements not only according to costumer request, but also it have to follow a number of standards.

One of such standards is DO-254. It is a requirements-driven process-oriented safety standard used on commercial electronics that go into aircraft. (Conceptually speaking, this standard applies to all electronics in anything that flies or could crash and pose a hazard to the public.)

Based on their safety criticality, different parts of the aircraft are designated different Design Assurance Levels, or DALs for short (Figure 2.3). A system that is highly critical will receive a higher DAL, with DAL A reserved for the most critical systems. This criticality is determined by a safety assessment of the aircraft and interacting systems to determine the required target failure rate. For DO-254, the difference between meeting DAL A and DAL B is minimal, so they are frequently referred to as "DAL A/B" in various writings, including aspects of this whitepaper [13].

Design Assurance Level (DAL)	Description	Target System Failure Rate	Example System
Level A (Catastrophic)	Failure causes crash, deaths	<1 x 10-9 chance of failure/flight-hr	Flight controls
Level B (Hazardous)	Failure may cause crash, deaths	<1 x 10-7 chance of failure/flight-hr	Braking systems
Level C (Major)	Failure may cause stress, injuries	<1 x 10-5 chance of failure/flight-hr	Backup systems
Level D (Minor)	Failure may cause inconvenience	No safety metric	Ground navigation systems
Level E (No effect)	No safety effect on passengers/crew	No safety metric	Passenger entertainment

Figure 2.3 - Design Assurance Levels (DALs)

Testability Design Requirements. It is difficult to specify reasonable and cost-effective testability requirements that can be contractually stated and enforced. The following design guides are generic in nature and represent the typical standards that exist throughout the industry. It is suggested that they serve as a basis for defining testability design requirements for both the designer and the procurement activity:

- Module Layout - Provide sufficient space between adjacent components and place components in a standard orientation
    - Edge Connector
    - Utilize a standard connector with keying capability
    - Use a standard location for common function, e.g. ground, and analog signals
    - Provide adequate edge connector pins for the control and visibility of the circuits
    - Ensure that adjacent connector pins cannot short and cause damage to the circuitry on the modules

- Partitioning
    - Design modules into easily testable functional partitions- do not divide functions between two or more modules

- Isolate analog and digital circuitry
- Subdivide large 1ogic circuits with low visibility into partitions

• Test Points
  - Provide sufficient test points for fault diagnosis / visibility
  - Types - DIP pins, external connecter, stand-offs, and pads
  - Also consider space for IC 1ocations, built-in multiplexer for selection of test points, and shift registers to shift out test point data

2.3 Testing of the System

Testing is necessary not only to maintain quality of the system, but also to improve it. Main mission of the testing is to discover different faults in electronic circuit before the use. All the information have to summarized in the Rule of Ten [14] (Figure 2.4).

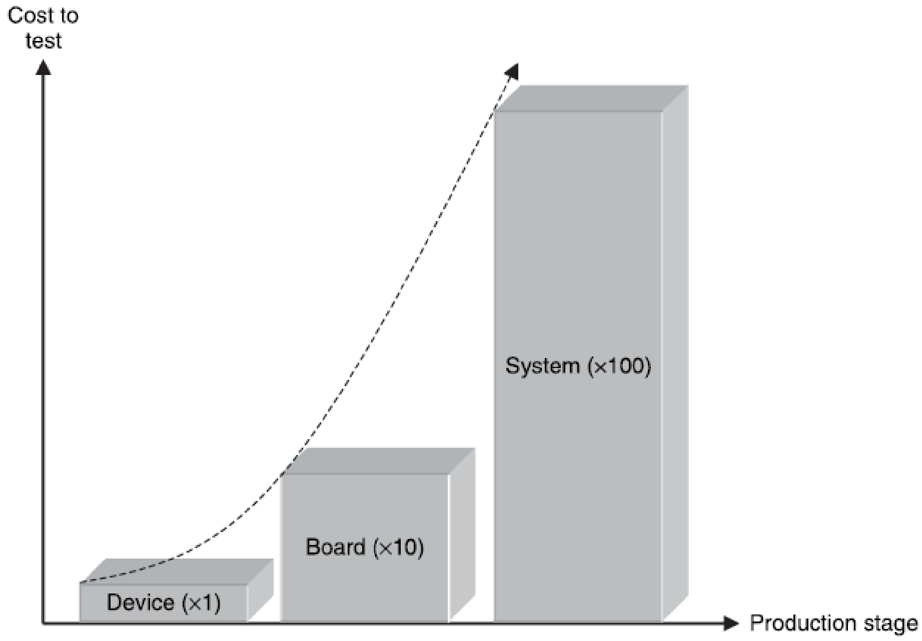

Figure 2.4 - Rule of Ten

During testing of the system, developer have to face with such standards:

- DO-160 is one of the most important standard that officially titled Environmental Conditions and Test Procedures for Airborne Equipment, is a living document of environmental testing standards for airborne equipment. DO-160 is published by the Radio Technical Commission for Aeronautics (RTCA).

DO-160 environmental testing isn't a hard-and-fast requirement. It has been adopted by numerous equipment suppliers, airlines and compliance testing facilities to establish an industry-wide consensus on the quality and reliability of airborne equipment.

Procedures are included in DO-160. There are 23 test procedures [15]:

- Temperature and Altitude
- Temperature Variation
- Humidity
- Operational Shocks and Crash Safety
- Vibration
- Explosive Atmosphere
- Waterproofness
- Fluids Susceptibility
- Sand and Dust
- Fungus Resistance
- Salt Fog
- Magnetic Effect
- Power Input
- Voltage Spike
- Audio Frequency Conducted Susceptibility – Power Inputs
- Induced Signal Susceptibility
- Radio Frequency Susceptibility
- Radio Frequency Susceptibility (Radiated and Conducted)
- Emission of Radio Frequency Energy
- Lightning Induced Transient Susceptibility
- Lightning Direct Effects
- Icing
- Electrostatic Discharge
- Fire and Flammability

Each of the DO-160 sections is customer-specific and highly tailored to the eventual environment of the equipment or rugged computer system [15].

- DO-178 - is a software produced by Radio Technical Commission of Aeronautics Inc. (RTCA), used for guidance related to Equipment certification and software consideration in airborne systems. It is a corporate standard, acknowledged worldwide for regulating safety in the integration of aircraft systems software. The Federal Aviation Regulations, Part 21, Subpart O explicitly establishes the requirement of airworthiness certification process. DO-178 provides one of the mandatory certification requirements, but alone does not guarantee all software safety aspects.

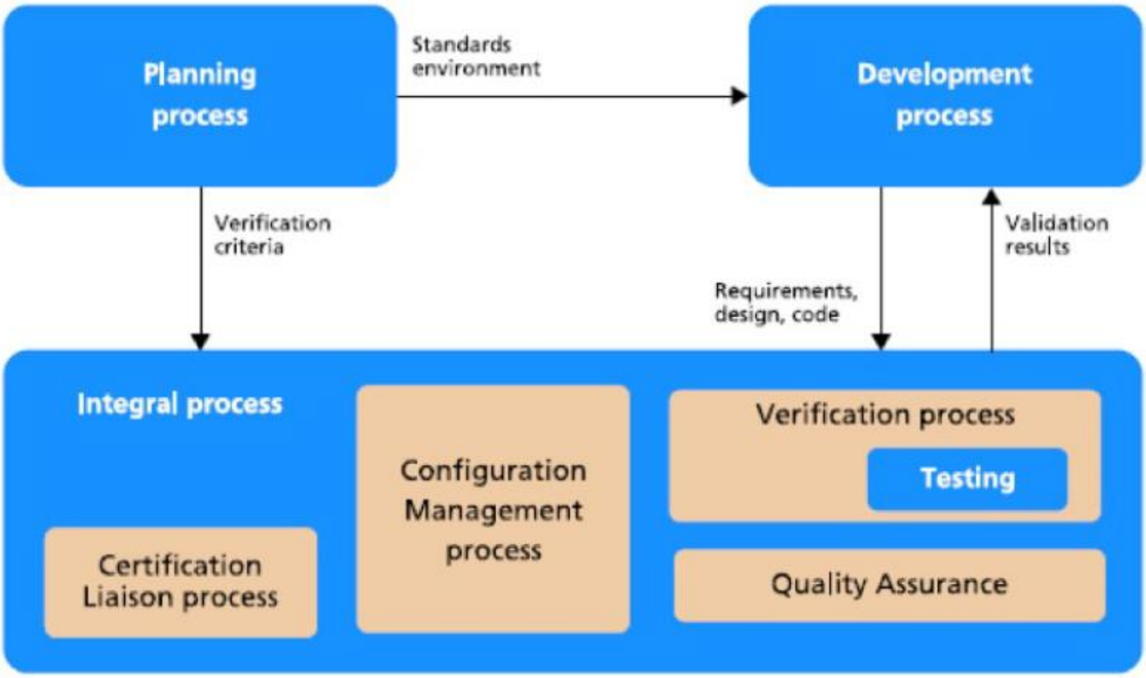

Figure 2.5 - Rule of Ten

In airborne systems, the software level also known as design assurance level is determined from the safety assessment process as well as the hazard analysis process by determining the effects of a failure condition in the system. The failure conditions are categorized by their effects as follows:

- Level A - Catastrophic: Failure may cause a crash

- Level B - Hazardous: Failure reduces the ability of the operators of the aircraft to operate it properly and hence may impact the safety or at least performance
- Level C – Major: Failure has less impact than a hazardous failure but is significant in nature or at least significantly increases the workload of the operators
- Level D - Minor: Failure has lesser impact than a major failure but is at least noticeable
- Level E - No Effect: Failure has no impact on safety of aircraft or the operation or workload of operators

DO-178 is mainly divided into 5 major processes. They are:

•Software Planning

•Software Development

•Software Verification

•Software Configuration Management

•Software Quality Assurance

Each of these processes has a set of expected documented outputs that need to be maintained for complying with the Federal Aviation Regulations requirements [16].

2.4 The manufacture of the System

In this situation, the manufacturing step can be missed, and instead of this talk about the installation. When the final decision is taken about the system it is time to make an installation plan. This is a very important step and if it is not done correctly it might jeopardize the whole system [17].

All the systems in the airplane, which are created for the damage monitoring, have to meet some specifications:

- technical description
- capabilities of the damage detection
- capabilities of the system monitoring (inspection rate)
- system` reliability (including the MSI systems analysis result).

Main requirements according to the standards:

FAR 25 Subpart C—Structure

§25.609 Protection of structure. Each part of the structure must

- Be suitably protected against deterioration or loss of strength in service due to any cause, including

(1) Weathering

(2) Corrosion

(3) Abrasion

- Have provisions for ventilation and drainage where necessary for protection.

CONCLUSION TO PART 2

Developing of the Built-In Operational Damage Recognition System is very complicate process, during which it must be taken into account a lot of the factors, such as economical, agronomical, prognosis of accuracy work of the system, ease in operation, specifics of system elements, etc. But thanks to its maintenance of the airplanes skin will be quicker, cheaper and will not require additional invention of maintenance staff.

3 PRELIMINARY AIRCRAFT DESIGN

3.1 Geometry calculations for the main parts of the aircraft

Layout of the aircraft consists from composing the relative disposition of its parts and constructions, and all types of the loads (passengers, luggage, cargo, fuel, and so on).

Choosing the scheme of the composition and aircraft parameters are directed by the best conformity to the operational requirements.

3.1.1 Wing geometry calculation

Geometrical characteristics of the wing are determined from the take of weight m_0 and specific wing load P_o.

Full wing area with extensions is:

$$S_{wfull} = \frac{m_0 \cdot g}{P_0} \quad (3.1)$$

Where: m_0 – take-off weight;

P_0 – specific wing load.

$$S_{wfull} = 141.75 \text{ (m}^2\text{)}$$

Relative wing extensions area is 0.1

Wing area is:

$$S_w = \frac{S_{0 \cdot full}}{k_{rw}} \quad (3.2)$$

Where: k_{rw} – relative wing extensions area.

$$S_w = \frac{141.75}{0.1} = 128.84 \text{ (m)}$$

Wing span is:

$$l = \sqrt{S_w \cdot \lambda_w} \tag{3.3}$$

Where: .λ_w – wing aspect ratio.

$$l = \sqrt{7.83 \cdot 193.88} = 38.02 \text{ (m)}$$

Root chord is:

$$b_0 = \frac{2S_w \cdot \eta_w}{(1+\eta_w) \cdot l_w} \tag{3.4}$$

Where: η_w – wing taper ratio.

$$b_0 = \frac{2 \cdot 128.75 \cdot 3.48}{(1+3.48) \cdot 38.02} = 5.87 \text{ (m)}$$

Tip chord is:

$$b_t = \frac{b_0}{\eta_w} \tag{3.5}$$

$$b_t = \frac{5.87}{3.48} = 1.59 \text{ (m)}$$

Maximum wing width is determined in the forehead i-section and by its span it is:

$$C_i = \overline{C} \cdot b_i\,. \tag{3.6}$$

On board chord for trapezoidal shaped wing is:

$$b_{ob} = b_0 (1 - \frac{\eta - 1 \cdot D_f}{(\eta \cdot 1)}) \tag{3.7}$$

Where: D_f– fuselage diameter.

$$b_{ob} = 5.87\cdot(1 - \frac{3.48 - 1\cdot 3.76}{(3.48\cdot 1)}) = 5.87 \text{ (m)}$$

At a choise of power scheme of the wing we determine quantity of longerons and its position, and the places of wing portioning.

On the modern aircraft we use xenon double – or triple – longeron wing; longeron wing is common to the light sport, sanitary and personal aircrafts. Our aircraft has three longerons.

I use the geometrical method of mean aerodynamic chord determination (Figure 3.1). Mean aerodynamic chord is equal: $b_{MAC} = 2.741$ m.

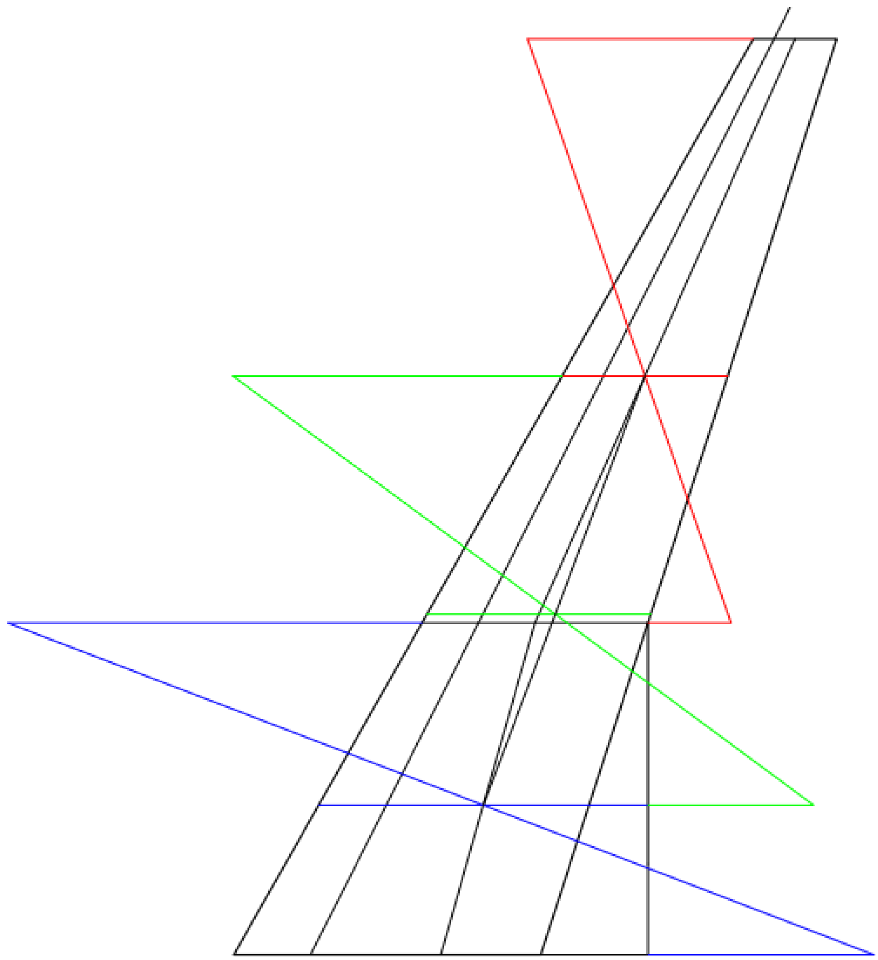

Figure 3.1 – Determination of mean aerodynamic chord

After determination of the geometrical characteristics of the wing we come to the estimation of the ailerons geometrics and high-lift devices.

Ailerons geometrical parameters are determined in next consequence:

Ailerons span:

$$l_{ai} = (0,3\ldots0,4)\cdot l/2 \qquad (3.8)$$

$$l_{ai}=2,58\ (m);$$

Aileron area:

$$S_{ai} = (0,05\ldots0,08)\cdot S_w/2 \qquad (3.9)$$

$$S_{ai} = 1,84\ (m^2)$$

Increasing of l_{ail} and b_{ail} more than recommended values is not necessary and convenient. With the increase of l_{ail} more than given value the increase of the ailerons coefficient falls, and the high-lift devices span decreases. With b_{ail} increase, the width of the xenon decreases.

In the airplanes of the third generation there is a tendency to decrease relative wing span and ailerons area. So, lail =0,122. In this case for the transversal control of the airplane we use spoilers together with the ailerons. Due to this the span and the area of high-lift devices may be increased, which improves take off and landing characteristics of the aircraft.

Range of aileron deflection

Upward $\delta'_{ail} \geq 25°$;

Downward $\delta''_{ail} \geq 15°$.

The aim of determination of wing high-lift devices geometrical parameters is the providing of take off and landing coefficients of wing lifting force, assumed in the previous calculations with the chosen rate of high-lift devices and the type of the airfoil profile.

Before doing following calculations it is necessary to choose the type of airfoil due to the airfoil catalog, specify the value of lift coefficient $C_{y\max bw}$ and determine necessary increase for this coefficient $C_{y\max}$ for the high-lift devices outlet by the formula:

$$\triangle C_{y\,max} = \frac{C_{y\max l}}{C_{y\max bw}} \tag{3.10}$$

Where $C_{y\max l}$ is necessary coefficient of the lifting force in the landing configuration of the wing by the aircraft landing insuring (it is determined during the choice is the aircraft parameters).

In the modern design the rate of the relative chords of wing high-lift devices is:

b_{sf} = 0.25..0.3 – the split edge flaps;

b_f = 0.28..0.3 – one slotted and two slotted flaps;

b_f = 0.3..0.4 – three slotted flaps and Faylers flaps;

b_s = 0.1..0.15 – slats.

Effectiveness of high-lift devices (C^*_{ymaxl}) rises proportionally to the wing span increase, serviced by high-lift devices, so we need to obtain the biggest span of high lift devices ($l_{hld} = l_w - D_f - 2l_{ail} - l_n$) due to use of flight spoiler and maximum diminishing of the are of engine and landing gear nacelles.

During the choice of structurally-power schemes, hinge-fitting schemes and kinematics of the high-lift devices we need to come from the statistics and experience of domestic and foreign aircraft construction. We need to mention that in the majority of existing constructions elements of high-lift devices are done by longeronstructurally-power schemes.

3.1.2 Fuselage layout

During the choice of the shape and the size of fuselage cross section we need to come from the aerodynamic demands (streamlining and cross section).

Applicable to the subsonic passenger and cargo aircrafts (V < 800 km/h) wave resistance doesn't affect it. So we need to choose from the conditions of the list values friction resistance C_{xf} and profile resistance C_{xp}.

During the transonic and subsonic flights, shape of fuselage nose part affects the value of wave resistance C_{xw}. Application of circular shape of fuselage nose part significantly diminishing its wave resistance.

For transonic airplanes fuselage nose part has to be:

$$l_{fnp} = 2.1 \cdot D_f \quad (3.11)$$

$$l_{fnp} = 2.1 \cdot 3.76 = 7.89 \text{ (m)}$$

Except aerodynamic requirements consideration during the choice of cross section shape, we need to consider the strength and layout requirements.

For ensuring of the minimal weight, the most convenient fuselage cross section shape is circular cross section. In this case we have the minimal fuselage skin width. As the partial case we may use the combination of two or more vertical or horizontal series of circles.

To geometrical parameters we concern:

- fuselage diameter D_f;
- fuselage length l_f ;
- fuselage aspect ratio λ_f ;
- fuselage nose part aspect ratio λ_{np};
- tail unit aspect ratio λ_{TU} . Fuselage length is determined considering the aircraft scheme, layout and airplane center-of-gravity position peculiarities, and the conditions of landing angle of attack α_{land} ensuring.

Fuselage length is equal:

$$l_f = \lambda_f \cdot D_f \quad (3.12)$$

Where: λ_f– fuselage aspect ratio.

$$l_f = 10{,}5 \cdot 3{,}76 = 39{,}48 \text{ (m)}$$

Fuselage nose part aspect ratio is equal:

$$\lambda_{fnp} = \frac{l_{fnp}}{D_f} \quad (3.13)$$

$$\lambda_{fnp} = \frac{7.22}{3.76} = 1.9 \text{ (m)}$$

Length of the fuselage rear part is equal:

$$l_{frp} = \lambda_{frp} \cdot D_f \quad (3.14)$$

Where: λ_{frp}– fuselage aspect ratio.

$$l_{frp} = 2{,}8 \cdot 3{,}76 = 10{,}528 \text{ (m)}$$

During the determination of fuselage length we seek for approaching minimum mid-section S_{ms} from one side and layout demands from the other.

For passenger and cargo airplanes fuselage mid-section first of all comes from the size of passenger saloon or cargo cabin.

For short range airplanes we may take the height as: h_1 = 1.75 m; passage width b_p = 0.45 ... 0.5 m; the distance from the window to the flour h_2 = 1 m; luggage space h_3 = 0.6 ... 0.9 m.

For middle range airplanes correspondingly: the height as: h_1 = 1.9 m; passage width b_p = 0.6 m; the distance from the window to the flour h_2=1m; luggage space h_3 = 0.9...1.3 m.

I choose the next parameters:

Cabin height is equal:

$$H_{cab} = 1.48 + 0.17 B_{cab} \quad (3.15)$$

Where: B_{cab} – width of the cabin.

$$H_{cab} = 1.48 + 0.17 \times 3.55 = 2.0835 \text{ (m)}$$

From the design point of view it is convenient to have round cross section, because in this case it'll be the strongest and the lightest. But for passenger and cargo placing this shape is not always the most convenient one. In the most cases, one of the most suitable ways is to use the combination of two circles intersection, or oval shape of the fuselage. We need to remember that the oval shape is not suitable in the production, because the upper and lower panels will bend due to extra pressure and will demand extra bilge beams, and other construction amplifications.

Step of normal bulkhead in the fuselage construction is in the range of 360...500mm, depends on the fuselage type and class of passenger saloon.

Form the design consideration with the diameter less than 2800mm we don't use such shape and we follow to the intersecting circles cross section. In this case the flour of the passenger saloon is done in the plane of are closing.

The windows are placed in one light row. The shape of the window is round, with the diameter of 300 ... 400mm, or rectangular with the rounded corners. The window step corresponds to bulkhead step and is 500 ...5 10mm.

For economic salon with the scheme of allocation of seats in the one row (3 + 3) determine the appropriate width of the cabin:

$$B_{cab} = n_{3chblock} \times b_{3chblock} + b_{aisle} + 2\delta \qquad (3.16)$$

Where: $n_{3chblock}$ – width of 3 chairs;

$b_{3chblock}$ – number of 3 chair block;

b_{aisle} – width of aisle;

$$B_{cab} = 2 \times 1500 + 450 + 2 \times 50 = 3.550 \text{ (m)}$$

The length of passanger cabin is equal:

$$L_{cab} = L_1 + (n_{raws} - 1) \times L_{seatpitch} + L_2 \qquad (3.17)$$

Where: L_1 –distance between the wall and the back of first seat;

n_{raws} – number of raws;

$L_{seatpitch}$ – seat pitch;

L_1 – distance between the back of last seat and the wall.

$$L_{cab}=1200+(28-1)\times750+300=21.750\ (m)$$

From the design point of view it is convenient to have round cross section, because in this case it'll be the strongest and the lightest. But for passenger and cargo placing this shape is not always the most convenient one. In the most cases, one of the most suitable ways is to use the combination of two circles intersection, or oval shape of the fuselage. We need to remember that the oval shape is not suitable in the production, because the upper and lower panels will bend due to extra pressure and will demand extra bilge beams, and other construction amplifications.

Step of normal bulkhead in the fuselage construction is in the range of 350...550mm, depends on the fuselage type and class of passenger saloon.

Form the design consideration with the diameter less than 2800mm we don't use such shape and we follow to the intersecting circles cross section. In this case the flour of the passenger saloon is done in the plane of are closing.

The windows are placed in one light row. The shape of the window is round, with the diameter of 340...400mm, or rectangular with the rounded corners. The window step corresponds to bulkhead step and is 500...510mm.

3.1.3 Luggage compartment

Given the fact that the unit of load on floor K = 400… 600 kg/m^2

The area of cargo compartment is defined:

$$S_{cargo} = \frac{M_{bag}}{0.4K} + \frac{A_{cargo\&mail}}{0.6K} \quad (3.18)$$

Where: M_{bag} – mass of baggage;

$M_{cargo\&mail}$ – mass of cargo and mail.

$$S_{cargo} = \frac{20 \cdot 168}{0.4 \cdot 600} + \frac{15 \cdot 168}{0.6 \cdot 600} = 21 \text{ (m}^2\text{)}$$

Cargo compartment volume is equal:

$$v_{cargo} = v \cdot n_{pass} \quad (3.19)$$

Where: ν – relative mass of baggage;

n_{pass} – number of passengers.

$$v_{cargo} = 0.2 \cdot 168 = 33.6 \text{ (m}^3\text{)}$$

Luggage compartment design similar to the prototype

3.1.4 Galleys and buffet

International standarts provide that if the plane made mixed layout, be sure to made two dishes. If flight duration less than 3 hours at this time of food to pass. not issued in this caseprovded cupboard for water and tea. Kitvhen cupboard must place at the door, between cockpit and pass or cargoseparate doors.

Volume of buffets is equal:

$$v_{galley} = k_g \cdot n_{pass} \quad (3.20)$$

where ν – relative mass of baggage;

n_{pass} – number of passengers.

$$v_{galley} = 0.1 \cdot 170 = 19.3 \text{ (m}^3\text{)}$$

Area of buffets is equal:

$$S_{galley} = \frac{V_{galley}}{H_{cab}} \tag{3.20}$$

$$S_{galley} = \frac{19.3}{2.2922} = 8.42 \text{ (m}^2\text{)}$$

Number of meals per passenger breakfast, lunch and dinner – 0,8 kg; tea and water – 0,4 kg;

If food organized once it is given a set number 1 weighing 0,62 kg. Food passangers appears every 3.5…4 hour flight.

Buffet design similar to prototype.

3.1.5 Lavatories

Number of toilet facilities is determined by the number of passengers and flight duration: with t> 4:00 one toilet for 40 passengers, at t = 2 ... 4 hours and 50 passengers t <2 hours to 60 passengers.

The number of lavatories I choose according to the original airplane and it is equal:

$n_{lav} = 3$

Area of lavatory:

$S_{lav} = 1.5 m^2$

Width of lavatory: 1m. Toilets design similar to the prototype.

3.1.6 Layout and calculation of basic parameters of tail unit

One of the most important tasks of the aerodynamic layout is the choice of tail unit placing. For ensuring longitudinal stability during overloading its center of gravity should be placed in front of the aircraft focus and the distance between these points, related to the mean value of wing aerodynamic chord, determines the rate of longitudinal stability.

$$m_x^{C_y} = \bar{x}_T - \bar{x}_F < 0 \quad (3.21)$$

Where: m^{Cy}_x –is the moment, coefficient;

$x_{T,}$. x_F- center of gravity and focus coordinates.

If $m^{Cy}_x=0$, than the plane has the neutral longitudinal static stability, if $m^{Cy}_x>0$, than the plane is statically instable. In the normal aircraft scheme (tail unit is behind the wing), focus of the combination wing – fuselage during the install of the tail unit of moved back.

Static range of static moment coefficient: horizontal A_{htu}, vertical A_{vtu} given in the table with typical arm Htu and Vtu correlations. Using table we may find the first approach of geometrical parameters determination.

Determination of the tail unit geometrical parameters

Area of vertical tail unit is equal:

$$S_{VTU} = \frac{A_{VTU} * S_W * l_W}{L_{VTU}} \quad (3.22)$$

Where: L_{VTU} – length of vertical tail unit.

$$S_{VTU} = 17.35 \ (m^2)$$

Area o horizontal tail unit is equal:

$$S_{HTU} = \frac{A_{HTU} * S_W * b_{MAC}}{L_{HTU}} \quad (3.23)$$

Where: L_{HTU} – length of horizontal tail unit.

$$S_{HTU} = 30.14 \ (m^2)$$

Values L_{htu} and L_{vtu} depend on some factors. First of all their value are influenced by: the length of the nose part and tail part of the fuselage, sweptback and wing location, and also from the conditions of stability and control of the airplane.

Determination of the elevator area and direction:

Altitude elevator area:

$$S_{el} = 0.3 \dots 0.4 * S_{HTU} \tag{3.24}$$

Where: k_{el} – relative elevator area coefficient.

$$S_{el} = 0.3 \dots 0.4 * 30.14 = 10.4 \text{ (m}^2\text{)}$$

Rudder area:

$$S_{rud} = 0.35 \dots 0.45 * S_{vtu} \tag{3.25}$$

Where: k_r – relative rudder area coefficient.

$$S_{rud} = 0.35 \dots 0.45 * 17.35 = 6.07 \text{ (m}^2\text{)}$$

Choose the area of aerodynamic balance.

$$0.3 \leq M \leq 0.6$$

$$S_{eb}=(0.22..0.25)S_{ea} \tag{3.26}$$

$$S_{rb}=(0.2..0.22)S_{rd} \tag{3.27}$$

Elevator balance area is equal:

$$S_{eb} = 0.22 * S_{el} \quad (3.28)$$

Where: S_{eb} – relative elevator balance area coefficient.

$$S_{eb} = 0.22 * 10.04 = 2.2088 \text{ (m}^2\text{)}$$

Rudder balance area is equal:

$$S_{rb} = 0.2 * S_{rud} \quad (3.29)$$

Where: k_{rb} – relative rudder balance area coefficient.

$$S_{rb} = 0.2 * 6.07 = 1.214 \text{ (m}^2\text{)}$$

The area of altitude elevator trim tab:

$$S_{te} = 0.08 * S_{el} \quad (3.30)$$

Where: S_{el} – relative elevator trim tab area coefficient.

$$S_{te} = 0.08 * 10.04 = 0.8032 \text{ (m}^2\text{)}$$

Area of rudder trim tab is equal:

$$S_{tr} = 0.06 * S_{rud} \quad (3.31)$$

where k_{tr} – relative elevator trim tab area coefficient.

$$S_{tr} = 0.06 * 6.07 = 0.4249 \text{ (m}^2\text{)}$$

Tip chord of horizontal stabilizer is:

$$b_{0HTU} = \frac{2 * b_{0HTU}}{\eta_{HTU}} \quad (3.32)$$

$$b_{0HTU} = 1.32 \text{ (m)}$$

Root chord of horizontal stabilizer is:

$$b_{root}^{HTU} = \eta_{HTU} * b_{tip}^{HTU} \quad (3.33)$$

Where: η_{HTU} – horizontal tail unit taper ratio;
l_{HTU} – horizontal tail unit length.

$$b_{root}^{HTU} = 2.83 \text{ (m)}$$

Tip chord of vertical stabilizer is:

$$b_{tip}^{VTU} = \frac{2 * S_{VTU}}{(\eta_{VTU} + 1) * l_{VTU}} \quad (3.34)$$

$$b_{tip}^{VTU} = 3.72 \text{ (m)}$$

Root chord of vertical stabilizer is:

$$b_{root}^{VTU} = \eta_{VTU} * b_{tip}^{VTU} \quad (3.35)$$

$$b_{root}^{VTU} = 5.22 \text{ (m)}$$

3.1.7 Landing gear design

In the primary stage of design, when the airplane center-of-gravity position is defined and there is no drawing of airplane general view, only the part of landing gear parameters may be determined.

Main wheel axel offset is:

$$e = (0.15 \dots 0.2) b_{MAC} \quad (3.36)$$

Where: k_e – coefficient of axle offset;

b_{MAC} – mean aerodynamic chord.

$$e = 0.17 * 2.741 = 0.47 \text{ (m)}$$

With the large wheel axial offset the lift-of of the front gear during take of is complicated, and with small, the drop of the airplane on the tail is possible, when the loading of the back of the airplane comes first. Landing gear wheel base comes from the expression:

$$B = 0.45 * L_f \quad (3.37)$$

$$B = 13.52 \text{ (m)}$$

The last equation means that the nose support carries 6...10% of aircraft weight.

Front wheel axial offset will be equal:

$$d_{ng} = B - e \quad (3.38)$$

$$d_{ng} = 10.98 - 0.47 = 12.67 \text{(m)}$$

Wheel track is:

$$T = (07 \dots 1.4)B \quad (3.39)$$

$$T = 6.09 \text{ (m)}$$

On a condition of the prevention of the side nose-over the value K should be > 2H, where H – is the distance from runway to the center of gravity.

$$H_{cg} = (0.08 \dots 0.1)D_f = 0.09 * 3.76 = 0.338 \text{ (m)}$$

Wheels for the landing gear is chosen by the size and run loading on it from the take off weight; for the front support we consider dynamic loading also.

Type of the pneumatics (balloon, half balloon, arched) and the pressure in it is determined by the runway surface, which should be used. We install breaks on the main wheel, and sometimes for the front wheel also.

The load on the wheel is determined:

K_g = 1.5...2.0 – dynamics coefficient.

Nose wheel load is equal:

$$P_n = \frac{e * m_0 * 9.81 * k}{B * z} \quad (3.40)$$

Where: K_g – dynamics coefficient;

z – number of wheels.

$$P_n = 109367.11 \text{ (kg)}$$

Main wheel load is equal:

$$P_m = \frac{(B - B_m) * m_0 * 9.81}{B * n * z} \quad (3.41)$$

Where: n – number of main landing gear struts.

$$P_m = 44334.37 \text{ (kg)}$$

Table 3.1 – Aviation tires for designing aircraft

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
1100*330mm	16	950*350mm	8

3.1.8 Choice and description of power plant

The CFM International CFM56 series is a high-bypass turbofan aircraft engines with a thrust range of 18,500 to 34,000 pounds-force (82 to 150 kilonewtons).

The CFM56-7 series is the original variant of the CFM56. It is most widely used in military applications where it is known as the F108; specifically in the KC-135, the E-6 Mercury and some E-3 Sentry aircraft. The CFM56 comprises a single-stage fan with 44 blades, with a three-stage LP compressor driven by a four-stage LP turbine, and a nine-stage HP compressor driven by a single-stage HP turbine. The combustor is annular

Table 3.2. – origin variants of CFM56

Model	**Thrust**	**BPR**	**Dry weight**
CFM56-7B18	19,500 lbf (86.7 kN)	5.5	5,216 lb (2,370 kg)
CFM56-7B20	20,600 lbf (91.6 kN)	5.4	5,216 lb (2,370 kg)
CFM56-7B22	22,700 lbf (101 kN)	5.3	5,216 lb (2,370 kg)
CFM56-7B24	24,200 lbf (108 kN)	5.3	5,216 lb (2,370 kg)
CFM56-7B26	26,300 lbf (117 kN)	5.1	5,216 lb (2,370 kg)
CFM56-7B27	27,300 lbf (121 kN)	5.1	5,216 lb (2,370 kg)

3.2 Determination of the aircraft center of gravity position

3.2.1 Determination of centering of the equipped wing

Mass of the equipped wing contains the mass of its structure, mass of the equipment placed in the wing and mass of the fuel. Regardless of the place of mounting (to the wing or to the fuselage), the main landing gear and the front gear are included in the mass register of the equipped wing. The mass register includes names of the objects, mass themselves and their center of gravity coordinates. The origin of the given coordinates of the mass centers is chosen by the projection of the nose point of the mean aerodynamic chord (MAC) for the surface XOY. The positive meanings of the coordinates of the mass centers are accepted for the end part of the aircraft.

The example list of the mass objects for the aircraft, where the engines are located under the wing, included the names given in the Table 3.3.

The example list of the mass objects for the aircraft, where the engines are located in the wing, included the names given in the Table 3.3. The mass of AC is 91295 kg.
Coordinates of the center of power for the equipped wing are defined by the formulas:

$$X'_w = \frac{\sum m'_i * x'_i}{\sum m'_i} \tag{3.42}$$

Table 3.3 - Trim sheet of equipped wing masses

№ п/п	Name	Mass		C.G. coordinates	Moment (kgm)
		Units	Total (kg)		
1	2	3	4	5	6
1.	Wing (construction)	0,1269	12082,66	1,93	23263,04
2.	Fuel system (1,5%…2%)	0,0059436	565,91	1,93	1089,57
3.	Control system (30%)	0,00317	162,82	2,57	417,96
4.	Electrical equipment (10%)	0,00317	301,83	0,43	129,14
5.	Anti-icing system (70%)	0,010584	1007,74	0,43	431,16

End of the Table 3.3

1	2	3	4	5	6
6.	Hydraulic system (70%)	0,0112	1066,40	2,99	3193,81
7.	Main engines	0,04391	4180,85	-1,00	-4180,85
8.	Equipped engines, mounting nodes	0,0228332	2174,04	-0,86	-1879,46
9.	Fire protection system	0,0149294	1421,49	-0,86	-1228,88
Equipped wing			22963,73	0,92	21235,50
10.	Main L.G. support	0,030696	2922,69	3,00	8768,07
11.	Fuel	0,29718	28295,70	1,71	48425,26
Total			54182,12	1,45	78428,82

3.2.2 Determination of the centering of the equipped fuselage:

Origin of the coordinates is chosen in the projection of the nose of the fuselage on the horizontal axis. For the axis X the construction part of the fuselage is given. The example list of the objects for the AC, which engines are mounted under the wing, is given in Table 3.4.

The CG coordinates of the FEF are determined by formulas:

$$X_f = \frac{\sum m'_i * X'_i}{\sum m'_i} \tag{3.43}$$

$$Y_f = \frac{\sum m'_i * Y'_i}{\sum m'_i} \tag{3.44}$$

We can find fuselage center of gravity coordinate $\mathbf{X_f}$ by divided sum of mass moment of the fuselage (m_i', X_i) on sum of total mass of fuselage (m_i'):

$$X_f = 23{,}553 \text{ (m)}$$

Table 3.4 – Trim sheet of equipped fuselage masses

№ п/п	Name	Mass		C.G. coordinates	Moment (kgm)
		Units	Total (kg)		
1.	Fuselage	0,08382	7980,84	17,77	141787,56
2.	Horizontal tail unit	0,00879	836,93	38,08	31871,59
3.	Vertical tail unit	0,00868	826,46	36,52	30183,72
4.	Radar equipment	0,00648	616,99	17,77	10961,39
5.	Anti-icing system (30%)	0,004536	431,89	17,77	7672,97
6.	Pass. equipment	0,0126	1199,70	17,77	21313,81
7.	Decorative paneling	0,0063	599,85	17,77	10656,90
8.	Equipment	0,0152	1447,25	17,77	25711,89
9.	Hydraulic system (30%)	0,0048	457,03	17,77	8119,55
10.	Electrical equipment (90%)	0,02853	2716,46	15,79	42898,26
11.	Location equipment	0,003	285,64	0,39	112,77
12.	Air-navigation system	0,0045	428,46	1,97	845,79
13.	Radio equipment	0,0023	218,99	1,97	432,29
14.	Cargo compartment equipment	0,0053	504,63	1,58	796,92
15.	Control system (70%)	0,00399	379,90	19,74	7499,30
16.	Additional power unit	0,0061474	585,32	38,30	22415,12
17.	Crew		190,00	1,97	375,06
18.	Passengers		13200,00	17,77	234511,20
19.	Cargo		5174,40	18,56	96014,10
Total			41355,50	17,85	738267,90

3.2.3 Calculation of center of gravity positioning variants

The list of mass objects for centre of gravity variant calculation given in Table 2.5 and Center of gravity calculation options given in table 2.6, completes on the base of both previous tables.

We determined the mean aerodynamic chord center of gravity by formula:

$$m_f x_f + m_w (x_{MAC} + x_w^{/}) = m_0 (x_{MAC} + C) \tag{3.45}$$

$$X_{MAC} = 11.852 \text{ (m)}$$

where m_0 – aircraft takeoff mass, kg;

m_f – mass of equipped fuselage, kg;

m_w – mass of equipped wing, kg;

C – distance from mean aerodynamic chord leading edge to the center of gravity.

Table 3.5 – Calculation of C.G. positioning variants

Name	Mass, kg	Coordinates	Moment
Object	m_i	C.G. M	kgm
Equiped wing without fuel and L.G.	22963.73	0.92	21235.5
Nose landing gear (retracted)	730,67	6,20	730,67
Main landing gear (retracted)	922,69	3,00	68,07
Fuel	28295.70	1.71	48425.26
Equiped fuselage	21522.43	18.07	388838.35
Cargo	5174.40	18.56	96014.10
Crew	13200.00	17.77	234511.20
Nose landing gear (opened)	730	6.2	4533.53
Main landing gear (opened)	2922.69	3.00	8768.07

Table 3.6 – Airplanes C.G. position variants

№ п/п	Name of objects	Mass, kg	Momen, kgm	C.G. m	Centering
1	Take-off mass (L.G. opened)	95537,6159	816696,72	18,20	30,24
2	Take-off mass (L.G. retracted)	95537,6159	18,19	18,19	30,15
3	Landing variant (L.G. opened)	69225,3	772219,72	18,04	26,58
4	Transportation variant (without payload)	76435,2	471435,37	18,15	29,15
5	Parking variant (without fuel and payload)	46133,4	397816,9295	18,11	28,17

CONCLUSION TO PART 3

In this part was shown the main calculations of an airplane, checked the mass position of the main parts of the aircraft and determined the center mass position characteristic. After designing of the wing and the fuselage we have made the calculations of the center of gravity determination of the equipped aircraft. All the calculation give possibility of implementation a new system in the airplane, and give the ability to predict further behavior of center mass position characteristic.

4 DEVELOPMENT OF THE BUILT-IN OPERATIONAL DAMAGE RECOGNITION SYSTEM

4.1 General Information

The design of such system that can detect the structural damages without the use of external equipment test. That system have to include hardware sensors and software fault code.

The first purpose of the system is to detect a failure (give some alarm codes in maintenance screen), and the second one is to analyze if the damages are not within the critical limits (doesn`t require the immediate repair). Thanks to the second purpose, that system give us possibility to form the maintenance repair beforehand. Such type of maintenance can be consider as semi-scheduled (semi-planning).

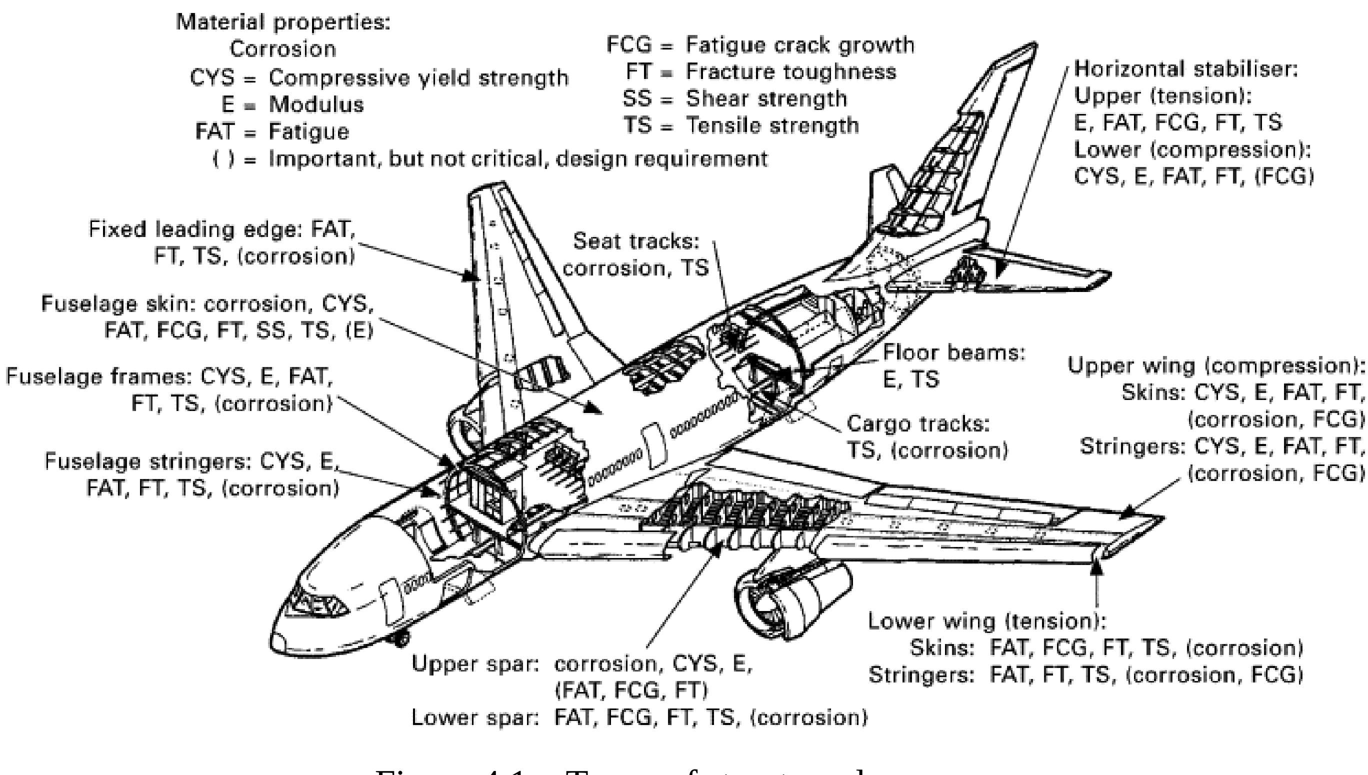

Figure 4.1 – Types of structure damages

4.2 Determining of zones under the formation influence

First step in implementation of such system – according to statistic data determine special zones on airplane skin, which have to be under monitoring at first place. On the Figure 4.1 are show all the zones that have to be under control.

Not all damages need immediate repair: if the parameters of new-find crack are not critical, and are allowable by aviation standards (Figure 4.2), or in case of corrosion formation and stratification in composite materials.

The main idea of such system is to determine of formation structural damages in early stages of it` formation. Thanks' to it, all data will collect, analyze and give the result as decision about the maintenance next actions.

Cracks need to be detect in the early stages of their propagation. (Figure 4.2)

Take into account that all damages have admissible parameters for exploitation; it can be conclude that the system can be both passive and active.

Passive and active systems differ only in one thing – passive is without the pattern generator (special devise, that collect all initial data about skin state). That is, in the case of espy of stratification in composite materials, it is not a need in active detecting. Thanks to unique construction of smart layer, only new sensors will to give us a signal.

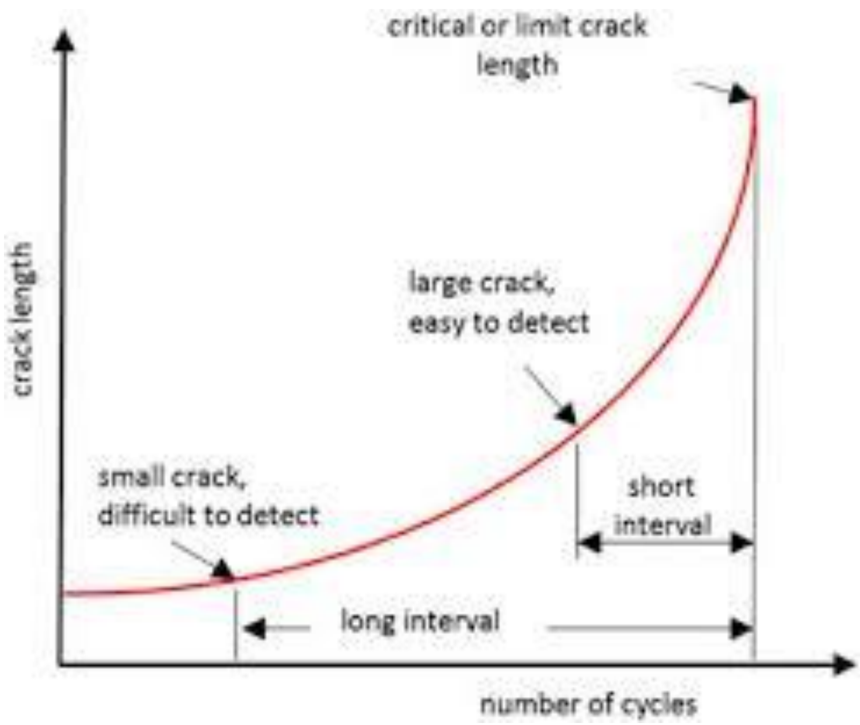

Figure 4.2 – Crack propagation of airframe skin

The system have to be on-line type of the work. All of the information, which the system gets during it operation, transmits to the server and from there to the ground crew.

Each damage detection system is distributed, but all the subsystems are centralized (all own microprogram and microdiagnostic).

One of the most important conditions is the present of the protective system that be designed in manner to be fail-safe. The system will understand and protect itself when the wire is break or any connector is disconnect.

4.3 Principle of the Built-In Operational Damage Recognition System

First step (Figure 4.3) of the system – is to collect the initial data from the sensors. All the sensors are installed on the zones that were determine as ``the most frequency formation zones``. This information was take according to the statistical data. (Types of sensors are not determine during this diploma work! It can be any type, according to the customer` request).

Data from the sensors is comparing with the External Data of skin deformation during loads, and characteristics of damages (Figure 4.3). External Data is load by the customers beforehand.

- In case, the result is less than the External Data, and then there is no damage in the zone and the action will begin again (until the opposite result).
- In case, the result is bigger than the External Data, and then there is a damage in given zone. Then the system continue its work.

Step (Figure 4.3) to determine damage state. All information from previous step system compare with the next External Data ``acceptable damage parameters``. External Data is load by the customers beforehand. With the help of the Neutral Network determines the stage of the damage and the emergency of it repair.

- If the result is less than the External Data, and then the damage has only formed, and the maintenance can be plane according the MSG-3 requirements.
- If the result is bigger than the External Data, and then there is a critical damage, that need an immediate repair actions.

All the damages type are encrypted in special Fault CODE - 46-XX-XX-XX

46 – mean the ATA chapter

46-XX – section of the airplane

46-XX-XX – section part

46-XX-XX-XX – how much the damage is in critical state (01- not critical; 10 – immediate repair)

The last step is to plan of the maintenance action according to the type of the CODE. All of the data, which get from the system supported by Onboard Network System (ONS). This system supports all flight, maintenance, and cabin operations. The main hardware component of this system is the Network File Server (NFS). The server controls communication between connected airplane systems. With optional communications equipment installed, the NFS can support network connections between airplane systems and ground-based networks. The NFS hosts the mass storage device (MSD) function that gives software parts and data storage capacity. The NFS can also operate installed applications that support maintenance actions and cabin operations.

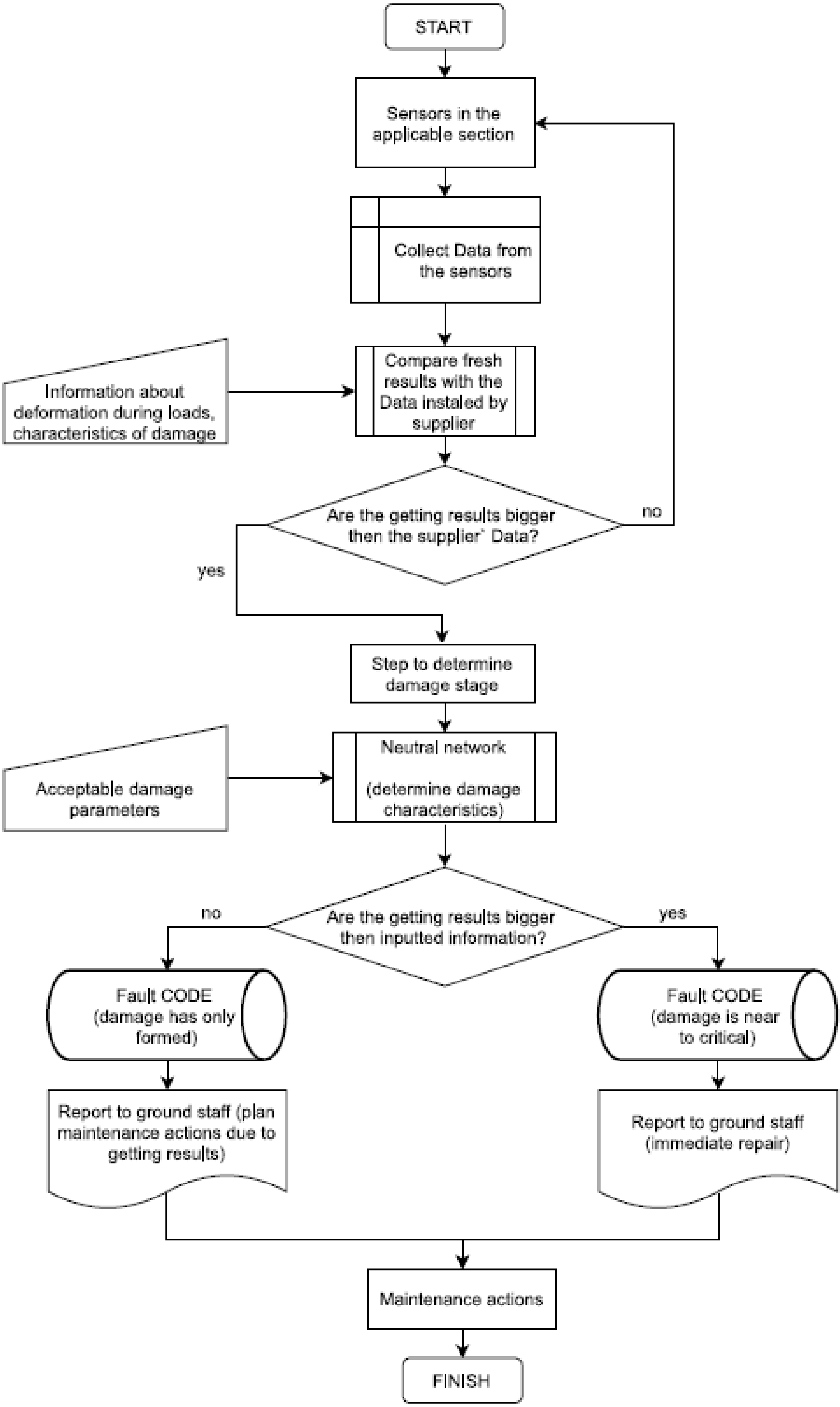

Figure 4.3 – diagram design of the system

4.4 Onboard Network System

An approved Portable Maintenance Device (PMD) gives access to the ONS (Figure 4.4) user interface. In addition, one of the two inboard Max System Displays in the flight compartment give access to the ONS user interface. The ML or PMD tool is connect to a network data port using an Ethernet cable, and can connect wirelessly if optional equipment is install. The NFS operates as a web server, and hosts the ONS maintenance browser interface known as the onboard maintenance function (OMF).

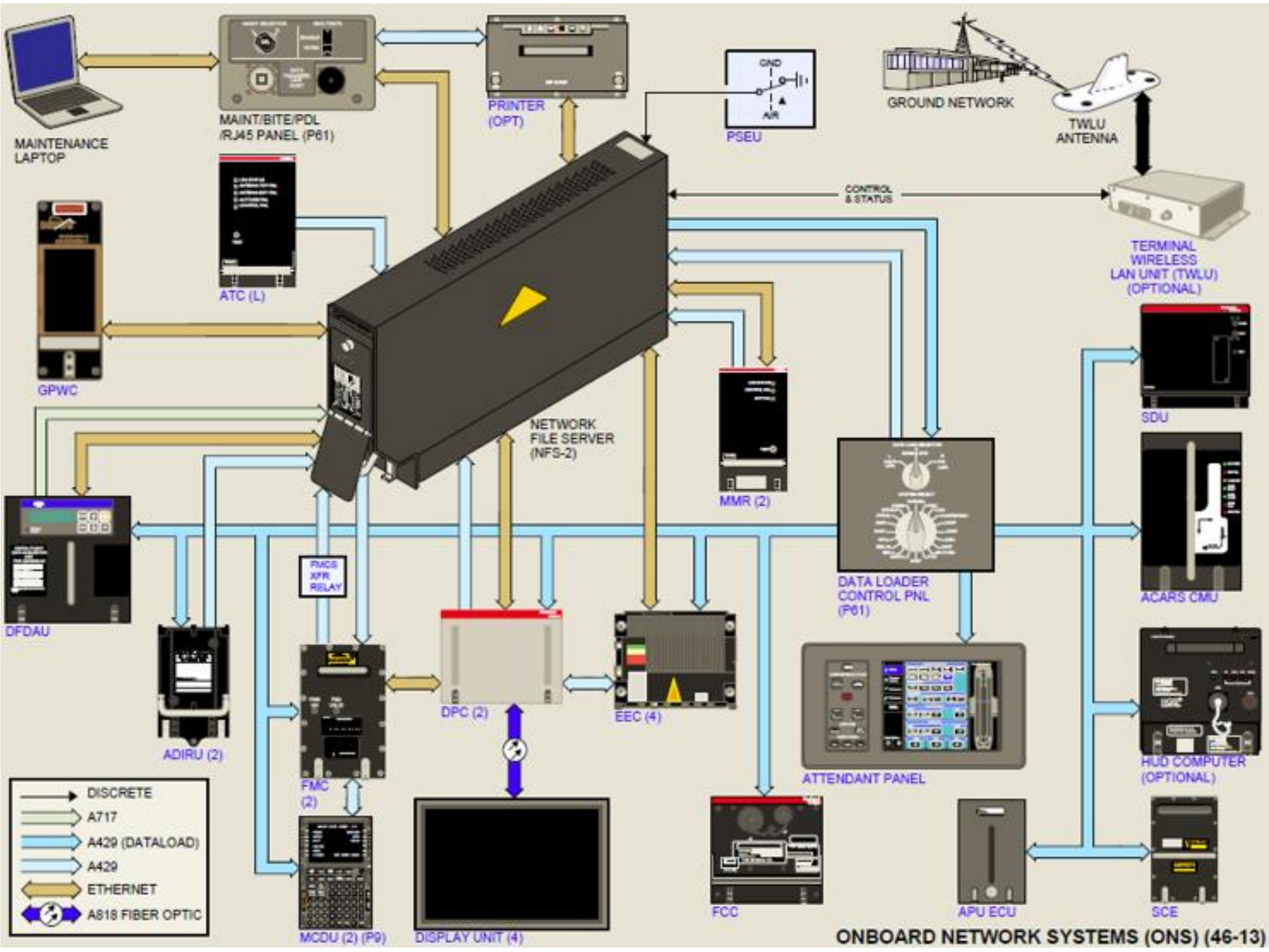

Figure 4.4 – Main components of the Onboard Network System

The Onboard Network System is an airplane-based server that provides:

- Data collection/storage/analysis
- Data loading
- Off-board connectivity
- Fault reporting

- Engine health management
- Ground tests.
- The ONS has these components:
- Network file server (NFS)
- P61 Maintenance/Bite panel
- Data load select panel
- Data load relay

CONCLUSION TO PART 4

If the monitoring design is perform carefully, it ensures monitoring with many profits. There are many obstacles in the way to the ideal monitoring as the field is new and associated technologies are still under development.

Advantages of monitoring:

- Real time monitoring with alarms increase the safety
- Down time reduction
- Control the behavior of the structure
- Decreased maintenance costs

Some disadvantages are present, too:

- Costly
- It can disturb and delay the work of the construction

Nevertheless, good knowledge of the features and planning brings a beneficial monitoring.

5 LABOR PROTECTION DURING USE OF THE BUILT-IN OPERATIONAL DAMAGE RECOGNITION SYSTEM

5.1 Analysis of harmful production factors for maintenance staff in work with the System.

During the maintenance check actions, aviation staff mostly work with laptop, which shows the finish result of the diagnostic System. The main task in this situation - is to analyze the getting results and makes conclusions about the further maintenance actions. In accordance to this, the biggest part of the workday they spend in front of the computer screen. That is why they face with such harmful factors (according to the ГОСТ 12.0.003-74) as: increased level of static electricity, increased voltage in the electrical circuit, increased level of electromagnetic fields, insufficient lighting of the working area, increased or decreased temperature of surfaces of equipment, increased or decreased air temperature of the working area, etc.

A big influence have physical overload, analyzer overvoltage, mental strain and emotional overload.

Increased level of static electricity – is a physical harmful production factor that occur in rooms equipped with a maintenance control panel, static currents most often occur when the staff touch any metal element in the workplace. Manufacturing equipment have to be constructed in such a way as to prevent the accumulation of static electricity in an amount that is dangerous for the worker - there are use humidifiers and the floor has an antistatic linoleum.

Increased level of electromagnetic fields – working devices generate some types of radiation: X-ray, ultraviolet, radio frequency, etc. The humans' body reaction on the electromagnetic acts, take place on cellular level, systemic level and the body as whole. The most critical are: nervous system, immune system, endocrine system, etc. The greatest influence on the electromagnetic environment of any building in the industrial frequency range of 50 Hz has electrical equipment, namely: cable lines that supply electricity and other consumers of the building's life support system. Personal protective equipment is used only in cases where other protective measures cannot be applied or they are not effective enough:

- when passing through zones of increased radiation intensity,
- during repair and adjustment works in emergency situations,
- during short-term control and when changing the radiation intensity.

Clothing made of metallized fabrics and radio-absorbing materials is used to protect the body. Metallized fabric consists of cotton or nylon threads, spirally wrapped with metal wire. Such a fabric, like a metal mesh (at a distance between the threads of 0.5 mm) attenuates the radiation by at least 20-30 dB. When sewing parts of protective clothing it is necessary to ensure the contacts of insulated conductors. Therefore, electro-sealing of joints is carried out with electrically conductive solutions or adhesives that provide galvanic contact or increase the capacitive connection of wires that do not come into contact.

Increased voltage in the electrical circuit - ignorance safety rules when using electrical appliances, faulty household appliances, and electrical equipment. To prevent the electric shot - minimize the time spent in the danger zone near the devices, working with devices with a voltage of 330 kV, the use of overalls is mandatory. Means of protection against electric shock: use the gloves and mats are dielectric, tools with insulated handles, protective screens, partitions, cameras for protection against current.

Insufficient lighting of the working area - lighting is the use of light energy from the sun and artificial light sources to ensure the visual perception of the environment. Lighting has a favorable psychophysiological effect, affects a person's ability to work and occupational safety. Rational lighting in the shops of industrial enterprises is an indicator of the aesthetics of production and a high level of work culture. Lighting is an important stimulator of the human body, and therefore its insufficient level increases the fatigue of the visual analyzer in the process of work, which contributes to injuries.

5.2 Measures to reduce the impact of harmful and dangerous production factors.

To avoid injuries with static voltage - is necessary to avoid impressions with providing of protective equipment.

To reduce the impact of EMF, it must be take into account such actions as:

- engineering - technical,
- organizational,
- medical - prophylactic.

Sanitary supervisors are carrying out organizational and engineering – technical measures. They carry out the current sanitary supervision of facilities that use radiation sources, carry out organizational and methodological work on training, technical and engineering supervision.

Since it is impossible to avoid exposure, it is necessary to reduce the time of people entering areas with high EMF, to reduce the time they are exposed. The power of the radiation sources have to be keep to a minimum.

Peculiarities of the use of values have engineering and technical methods of protection: collective and individual. Reduce the intensity of the fields, which limits the settlement in many distances. A similar result is given by the corresponding orientation of the pattern, especially high-directional antennas, for example, by increasing the height of the antenna. But a high antenna is more complex, more expensive, less stable. In addition, the effectiveness of such protection decreases with distance.

When protecting the screen from radiation, the attenuation of the wave when passing through the screen (for example, through a forest strip) must be taken into account. Vegetation can be used for screening. Special screens in the form of reflective and radio-absorbing panels are expensive, inefficient and are rarely used.

Engineering and technical means of protection also include:

- constructive ability to work at reduced power in the process of adjustment, regulation and prevention;
- work for the debug equivalent;
- remote control.

For personnel who operate radio equipment and are located at a short distance, reliable protection must be provided by shielding the equipment. In addition to reflectors, screens made of materials that absorb radiation are widely used.

Radio-absorbing materials are both homogeneous and composite, which consist of heterogeneous dielectric and magnetic substances. In order to increase the efficiency of the absorber, the surface of the screen is made rough, ribbed or in the form of spikes.
Radio-absorbing materials can be used to protect the environment from EMF generated by a source located in a shielded object.
Personal protective equipment is used only in cases where other protective measures cannot be applied or they are not effective enough:

- when passing through zones of increased radiation intensity,
- during repair and adjustment works in emergency situations,
- during short-term control and when changing the radiation intensity.

Clothing made of metallized fabrics and radio-absorbing materials is used to protect the body. Metallized fabric consists of cotton or nylon threads, spirally wrapped with metal wire. Such a fabric, like a metal mesh (at a distance between the threads of 0.5 mm) attenuates the radiation by at least 20-30 dB. When sewing parts of protective clothing it is necessary to ensure the contacts of insulated conductors. Therefore, electro-sealing of joints is carried out with electrically conductive solutions or adhesives that provide galvanic contact or increase the capacitive connection of wires that do not come into contact.

Evaluation and rationing of EMF is carried out by the value of energy exposure (EE). EMF energy exposure is defined as the product of the square of the electric or magnetic field strength at the time of exposure to a person.

Energy exposure in the frequency range 30 kHz - 300 MHz is determined by formulas (1) and (2) as follows:

$$\mathrm{EE_E} = \mathrm{E}^2 \cdot \mathrm{T} \quad (5.1)$$

$$\mathrm{EE_H} = \mathrm{H}^2 \cdot \mathrm{T} \quad (5.2)$$

$$\mathrm{EE}_E = 42 \cdot 5 = 80 \text{ (V/m)}$$

$$\mathrm{EE}_H = 0{,}152 \cdot 5 = 0{,}1125 \text{ (A/m)}$$

Where: E = 4 V/m - electric field strength;

H = 0,15 A/m - magnetic field strength;

T = 5 hours - exposure time in the workplace per shift.

Energy exposure by energy flux density in the frequency range 300 MHz - 300 GHz is determined by the formula:

$$\mathrm{EE}_{EFD} = EFD \cdot \mathrm{T} \quad (5.3)$$

$$\mathrm{EE}_{EFD} = 700 \cdot 5 = 3500 \text{ (mkVt/}sm^2\text{)}$$

Where: EFD = 700 (mkVt/sm^2) - energy flux density.

The maximum permissible level of EMF for communications and television broadcasting is determined by the formula:

$$\mathrm{E}_E = 21 \cdot f^{-0.37} \quad (5.4)$$

$$\mathrm{E}_E = 21 \cdot 175 \text{ -0,37} = 3{,}1 \text{ (V/m)}$$

Where: E_E - the value of the maximum allowable level of electric field strength, V / m;

f - frequency, MHz.

The maximum permissible EMF level in the frequency range 30 kHz - 300 GHz for the population should not exceed 3 V / m = 300 (mkVt/sm^2).

The maximum allowable energy flux density when irradiating persons from antennas operating in the mode of circular inspection or scanning with a frequency of not more than 1 kHz and a duty cycle of not less than 20 is determined by the formula:

$$EFD_E = \text{К} \cdot \left(\frac{\text{EE}_{EFD_E}}{\text{T}}\right) \quad (5.5)$$

EFD_E = 10 · (200/5) = 400 (mkVt/sm^2) = 4 (Vt / m^2),

Where: K - the attenuation coefficient of the biological activity of intermittent influences, equal to 10.

The maximum allowable value of EMF intensity in the range of 60 kHz - 300 MHz (E_E , EFD_E) depending on the time of exposure during the working day (work shift) is determined by formulas:

$$\text{E}_E = \left(\frac{\text{EE}_{\text{E}_E}}{\text{T}}\right)^{1/2} \quad (5.6)$$

In this case:

E_E = (20 000/5) 1/2 = 63,2 (V/m), so (63,2> 63)

63,2 <800

$$EFD_E = \frac{\text{EE}_{EFD_E}}{\text{T}} \quad (5.7)$$

EFD_E = 2/5 = 0,40 (Vt/m^2)

Where: E_E i EFD_E - maximum permissible levels of electric and magnetic field strength and energy flux density;

5.3 Safety instructions when using the maintenance laptop.

General requirements:

1. Persons over the age of 18 who have been trained in safe work methods and on-the-job training are allowed to work independently on laptops (receiving and entering correction information, reading from the screen).
2. A worker` laptop must have at least I-II qualification group in electrical safety.
3. Laptop must have factory-provided protection against electric shock.
4. Laptop location:
    - exclude the possibility of direct illumination of the screen by a source of natural light;
    - the surface of the screen should be at a distance of 400-700 mm from the user's eyes;
    - the height of the working surface of the table should be 680-800 mm, width - not less than 500 mm;
    - the chair must have a height of 280-320 mm, width - not less than 380 mm;
    - there must be a stable footrest at least 300 mm in wide.
5. Persons working on computers are prohibited from:
    - touch broken and bare electrical wires;
    - use damaged sockets and plugs;
    - work on laptops whose monitors are located opposite each other within the room (premises).
6. When working with text, information, it is recommended to work on a light (white) background with black signs.
7. When working with a computer, dangerous and harmful production factors can occur:
    - electromagnetic fields (radio frequencies);
    - insufficient lighting;
    - electrostatic field;
    - psycho-emotional stress during prolonged work with the video monitor screen.
8. People who work on a laptop must follow the following mode of operation:

- when entering data, reading information from the screen, the continuous duration of work should not exceed 4 hours with an 8-hour working day;
- use breaks for visual and physical unloading:
- after every hour of work it is necessary to take a break for 5-10 minutes, and in 2 hours. - 15 minutes;

a) standing or sitting shaking his head left and right (fast pace);
b) massage the forehead, lightly stroking it, as well as stroking the areas above the eyebrows towards the temples;
c) non-compliance with the requirements of the current instruction is a violation of labor discipline, which may entail liability under applicable rules and regulations.
d) standing or sitting to tilt the head back and forth (moderate pace);
e) standing or sitting perform self-massage of the neck and nape, stroking the back of the head and neck towards the torso;

CONCLUSION TO PART 5

Labor protection during using of the Built-In Operational Damage Recognition System is very important. And if workers and employers follow all the rules and recommendations every one health will be in the safe. And don't forget about the rules before starting work it is necessary to check:

- the presence of the provided protective screens.
- to provide illumination of a workplace so that reflections from the keyboard and the screen of the video monitor in the direction of eyes of the worker were not formed;
- placement of laptop components (mouse, printer, and other units);
- The monitor should be positioned so that the angle of view on the monitor screen is 10-15 degrees and the distance to the screen is 400-800 mm.
- integrity of connecting cables.
- Connect the laptop components according to the wiring diagram.
- the presence and condition of protective covers. Prepare your laptop for disconnected operation.
- if it is impossible to provide - apply special protective nets, filters.

6 ENVIRONMENTAL PROTECTION DURING USE OF THE BUILT-IN OPERATIONAL DAMAGE RECOGNITION SYSTEM

6.1 Analysis of the impact on the environment during manufacture and operation of the Built-in Operational Damage Recognition System.

Environmental activity is now an integral part of any sphere of human activity - agriculture and forestry, transport, energy, industrial production, research, culture, etc. All decisions related to the use of human and natural resources must be made taking into account its consequential impact.

Today, electronics are actively used in all spheres of human life and activity. And it has all the positive and negative effects on the environment.

Various aspects influence to the ecology: how and from what materials the devices are made; noise, vibration and electromagnetic pollution. Electronics carriers also have a great influence - in this case, it is the plane itself during operation.

Electronics are made of a wide variety of materials, such as polymers, metal, plastic and others.

Consider the impact on the environment in the production of electronics:

- Polymers. They exist in both crystalline and amorphous states. In crystalline polymers, the emergence of various supramolecular structures (fibrils, spherulites, single crystals, the type of which largely determines the properties of the polymeric material. molecular weight distribution, degree of branching and flexibility of macromolecules, stereo regularity, etc. The properties of polymers significantly depend on these characteristics. [18]

They are poisonous substances and can provoke a large number of diseases in humans and the central nervous system and individual organs. In some cases, there may be complications that cause disability or lead to death. Most polymers are very cheap to make, so manufacturers use them to endanger people's health.

In the process of polymer reactions - chemical compounds are released:

Dioxin is a stable chemical poisonous substance without color and odor [19].

Once in the human body, dioxin is stored in it for a long time. Short-term exposure to high levels of dioxin in humans leads to changes in liver function, and prolonged exposure leads to damage to the immune system, nervous system and reproductive functions.

Dioxin enters the body by airborne droplets during combustion and in contact with the skin. It is practically not removed from an organism.

Formaldehyde is a carcinogenic substance that causes deterioration or loss of vision, liver dysfunction and cirrhosis.

Styrene - the most common (is the main raw material in the manufacture of plastic utensils). Being in a gaseous state causes irritation of the mucous membranes, which provokes acute temporary or chronic inflammatory processes in the oral cavity.

Bisphenol A - affects the nervous, endocrine and immune systems. It is used to obtain plastic products, which are used to make plastic packaging for food and beverages, spectacle lenses, etc.

Polyethylene, polystyrene, polyvinyl chloride, polyethylene terephthalate are the main types of compounds used in the manufacture of polymer products.

The most dangerous is polyvinyl chloride (PVC). To increase the resistance of PVC to thermal and light aging, stabilizers are introduced into it. To do this, use compounds of lead, barium, cadmium, tin, organic compounds, amines. For elasticity, plasticizers are added, the most famous of which are esters of phthalic and phosphoric acids.

For the manufacture of electronic components using plastic parts, some components of which can be dangerous for children.

Polymers cause great damage to nature, which is very difficult to calculate. Their disposal creates big problems, because polymeric materials cannot be burned.

Impact on the environment of electronics when working on electricity.

An important aspect in the operation of electronics is electromagnetic radiation and its impact on the environment.

Intensive development of electronics and radio engineering caused pollution of the environment with electromagnetic fields.

- Electromagnetic pollution - a type of physical pollution that occurs due to changes in the electromagnetic properties of the environment caused by exceeding the level of the electromagnetic background. This background is created by electromagnetic oscillations - interdependent oscillations of electric and magnetic fields, which form a single electromagnetic field and propagate in the form of electromagnetic waves [20].

Radio frequency electromagnetic waves are called high frequency (microwave) currents - this radiation has a range of waves from a few kilometers to units of millimeters:

long radio waves (10–3 km),

medium (3 km - 100 m),

short (100–10 m) - according to the purity characteristic they are referred to as high frequencies (HF),

ultrashort (10–1 m) - up to ultrahigh frequency (UHF),

shorter (decimeter 1 m - 10 cm; centimeter 10–1 cm; millimeter 1 cm - 1 mm) - up to ultra-high frequency (UHF).

The propagation of radio frequency electromagnetic waves is associated with the appearance of magnetic and electric fields. In the HF-UHF range, due to the long wavelength, the electric and magnetic field strengths in the work area can be measured separately. In the microwave range, shorter waves form a single electromagnetic field, the intensity of which is estimated by the energy flux density and expressed in watts, milliwatts (1/1000 W) or microwatts (1/1 000 000 W) per 1 cm^2. The frequency range is measured in hertz Hz, kilohertz kHz (1000 Hz) or megahertz MHz (1,000,000 Hz). Sources of electromagnetic fields: with RF radio waves - radio, medicine, industry (heat treatment process), etc .; with UHF radiation - television, radio, medicine; Microwave - radar, radio astronomy, radio control, etc. The literature does not describe the range of wavelengths, but indicates the sources of electromagnetic radiation - power lines, open switchgear, which includes switching devices, protection and automation devices, measuring instruments, as well as radio facilities, television and radar stations, thermal shops , televisions, displays, microwave ovens, refrigerators, cabs of cars, communication, radar and direction finding stations, persons. computers, radar systems, etc.

In everyday life, the sources of electromagnetic fields and radiation are televisions, displays, microwave ovens, and others. devices, and also synthetic carpets, etc. coating (in conditions of low humidity - less than 70%). TV screens and displays as sources of electromagnetic radiation are dangerous to humans at a distance of up to 30 cm.

The maximum allowable level of electric field strength is 25 kV / m. According to the norms of stay in an electric field with voltage up to 5 kV / m is allowed during the working day; the allowable time spent in an electric field with a voltage of 5-20 kV / m can be realized once or several times during the working day; at a voltage of 20–25 kV / m, the time spent by personnel in an electric field should not exceed 5–10 min. The following values of electric field strength are accepted as the maximum permissible levels for settlements: inside residential buildings - 0.5 kV / m; on the territory of residential development - 1 kV / m; in populated areas outside the residential area, ie in the urban area within its long-term development for 10 years, suburban, green, resort. zones, on the lands of urban-type settlements, within the settlement zone of these points, as well as on the territory of gardens and orchards - 5 kV / m; at the intersections of overhead lines with highways of I-IV categories - 10 kV / m; in populated areas.

Consider the effect of noise pollution during UAV operation, regardless of the type of energy.

- Noise is understood as unpleasant and unwanted sounds that interfere with normal work, sound perception, rest. This is one of the forms of physical pollution of the natural environment, to which organisms are unable to adapt. Noise has a very harmful effect on human health, reduces its efficiency, and causes deafness, disease.

Noise is a set of sound waves, ie periodic (oscillating) changes in air pressure, which are measured by such parameters as intensity (or volume), spectrum, time intervals.

Noise intensity is determined by the change in air pressure level (energy characteristic). To determine the noise intensity, a logarithmic scale is established, each degree of which corresponds to a change in noise intensity by 10 times and is called white in honor of the inventor of the telephone A. Bel. In practice, use a more convenient unit - decibels (dB), which is 1/10 white.

Sound is divided into spectra depending on its intensity.

The spectrum of sound is its components, simple harmonics of oscillations that have a certain frequency, phase and amplitude. The human ear perceives sound at a frequency of

16 to 20,000 Hz. Sound waves below 16 Hz are called infrasonic, and higher than 20 kHz are called ultrasonic. Although such sounds are not perceived by the human ear, they are no less, and (at some frequencies and at a certain intensity) even more harmful to the body. Particularly dangerous are inaudible infrasounds, the frequency of which coincides with the resonant frequencies of human internal organs (heart, liver, etc.).

Time intervals of sound are the sum of short pulses of oscillations, characterized by a certain length (time) and amplitude. There are pulsed and continuous sounds.

The sources of noise in the environment are all modes of transport, working machines and mechanisms, industrial facilities, loudspeakers, elevators, televisions and radios, musical instruments, crowds of people and individuals.

Vibrations are also harmful to the human body.

Vibrations are tremors or concussions of the whole body or its individual parts during various works (concrete laying, pneumatic grinding of rocks or road surface, work in mines with a jackhammer, etc.). Prolonged vibrations cause great harm to the body - from severe fatigue to the so-called "vibration disease" of miners, concussions, tissue rupture, cardiac dysfunction, nervous system and more. To reduce vibrations and protect people from it, use various vibration-insulating casings around the mechanisms, elastic bases and supports, vibration-damping gloves, gaskets and mats.

6.2 Calculation of lighting of the workplace of the maintenance laptop during use of the Built-in Operational Damage Recognition System.

Calculation sequence:

1. Check the admissibility of the method.
2. Choose the type of light source and type of lamps, determination of location and number.
3. Determine the level of normalized illumination.
4. Calculate the reflection coefficient of the ceiling and walls.
5. Find the index of the room.
6. Calculate the luminous flux utilization factor according to the reference table.
7. Determine the ratio of stock and minimum illumination.

8. Calculate the required luminous flux of light sources in the lamp.
9. According to the table of the lamp of the chosen type the nearest on a light stream. (If the nearby standard lamps have a luminous flux that differs by more than - 10 + 20%, then choose a lamp with a larger, substitute this value in the calculated expression and determine the relative number of lamps.)
10. Calculate the total power of lighting fixtures. Calculate the luminous flux that must be emitted by each bulb (for a given number of lamps) by the formula:

$$F_l = \frac{kE \cdot S \cdot Z}{n \cdot \eta} \tag{6.1}$$

Where: F_l - luminous flux, lm;

E – illumination by norm, lux;

S – floor area in the room, m^2;

k – stock ratio;

Z – coefficient of uneven illumination;

η – luminous flux utilization factor;

n – number of installed lamps.

The stock factor k takes into account the decrease in illumination due to possible contamination of lamps or fixtures during their operation.

The coefficient k takes into account the absorption of light by fixtures, ceilings and walls. It depends on the type of lamp, the size and shape of the room, the color of the walls and ceiling, as well as the height of the suspension of the lamp above the work plane.

Much less often than the determination of lighting using the coefficient of utilization of light flux, to calculate the lighting of office buildings and premises using the point method. This method is appropriate when calculating localized lighting and when testing calculations of lighting in specific places of the illuminating surface. The point method allows you to accurately take into account the light created by the light flux reflected from the walls and ceiling.

Direct component of lighting:

$$E_l = \Phi' \cdot \mu \cdot \frac{\sum \varepsilon}{1000k} \cdot h \tag{6.2}$$

Where: Φ' – specific luminous flux, lm / m;

ε – relative illumination, ie illumination at 1000 lm / m

The value is usually taken from the graph of linear isoluxes. In the absence of a linear isolux for this lamp (but with a known light distribution of the lamp) determination of conditional horizontal illumination for a light intensity of 100 kD, and then depending on I_a i ε_o find ε. The formulas determine the direct component of illumination, because of which you can find full illumination:

$$E = E_l \cdot \frac{\eta}{\eta_0} = E_l \cdot \mu \tag{6.3}$$

Where: $\mu = \eta/\eta_o$ – a factor that takes into account the effect of reflected light;

η – luminous flux utilization factor for given φ, p_p, p_c, p_r;

η_o – luminous flux utilization factor for a "black" room at $p_p = p_c = p_r > 0$.

The luminous flux of the lamp is found by the formula (6.1)

We select numerical values according to the tables. To determine the coefficient of use of luminous flux, we first calculate the indicator of the room:

$$\varphi = \frac{a \cdot b}{H_c(a+b)} = \frac{6 \cdot 20}{3(6+20)} = 1{,}5 \tag{6.4}$$

We accept that η = 0.44 at maximum reflection walls and ceilings.

Coefficient of uneven lighting (choose a lamp type LSP 2 with perforation and with a lattice) Z = 0,867;

k accept equal 1,5;

E = 100.

Substitute all values for the formula, find

$$E_l = \frac{1.5 \cdot 100 \cdot 100 \cdot 0.687}{14 \cdot 0.44} = 19181.4 \text{ (lm)} \quad (6.5)$$

For lighting, we choose fluorescent lamps like ЛБ40-1.

Calculate the required number of lamps:

$$N = n \cdot 2 \quad (6.6)$$

Where, N - is the number of lamps;

n - is the number of lamps;

$$N = 16 \cdot 2 = 32 \text{ (numb.)} \quad (6.7)$$

Calculate the power consumption of lamps

$$W = W_л \cdot N \quad (6.8)$$

Where, $W_л$ – power of one lamp ЛБ40-1.

$$W = 40 \cdot 32 = 1280 \text{ (Vt)} \quad (6.9)$$

Therefore, calculating the required amount of light for the operator, we can confidently say that the lamp ЛБ40-1 is the best option for maximum illumination with minimal environmental pollution.

6.3 Ways to reduce harmful effects during production and operation of the Built-in Operational Damage Recognition System.

Considering the above factors of the impact of unmanned aerial vehicles on the environment, we can suggest the following ways to reduce the negative impact.

To begin with it is necessary to pay attention to materials from which make the Built-in Operational Damage Recognition System. Among them are many polycarbonates and plastics, which contribute to chemical pollution of the territory for many years, and are quite toxic. To eliminate this problem, plastic should be replaced with modern materials that are non-toxic and do not harm the environment. Particular attention should be paid to the disposal of aircraft that have failed and expired.

The next point is to consider the types of energy resources used in the work the Built-in Operational Damage Recognition System.

Particular attention should be paid to the effects of electromagnetic radiation on the environment, in particular on the protection of the operator of the Built–in Operational Damage Recognition System:

- Electromagnetic fields have a very strong effect on humans. Almost all systems of the human body are negatively affected by the electromagnetic field. Therefore it is necessary to apply methods of protection against their action. The most common of these methods are:
- reducing the energy flux density, if this process or equipment allows;
- time protection (ie limitation of the time spent in the area of the EMF source);
- distance protection;
- shielding of the workplace or source;
- rational workplace planning;
- application of means of the warning alarm system;
- use of personal protective equipment.

To reduce the impact of electromagnetic fields on personnel who are in the area of some electronic devices, a number of protective measures are needed: organizational, engineering and treatment.

Based on the above, there is a need to:

- introduce and improve the environmental management system, use modern energy and resource-saving technologies, energy-efficient production systems aimed at stabilizing or reducing the negative impact on the environment;

- systematically organize and equip the territories of industrial sites, sanitary protection and recreational areas;
- develop partnerships with the public and the authorities to address issues of sustainable development of the gas industry.

It should be noted that even at the design stage, the mutual placement of objects must be ensured in such a way that the radiation intensity is minimal. Care should also be taken in advance to reduce staff time in the exposure area. The power of radiation sources should be the lowest possible.

Thus, the use of methods to protect health from hazards in the workplace with a high electromagnetic background and compliance with state standards of Ukraine will reduce the negative impact on the human body and help maintain the health of staff.

CONCLUSION TO PART 6

After analyzing the process of manufacturing and operation of the Built–in Operational Damage Recognition System, was conclude that it work has a significant negative impact on the environment and harms the Earth's biosphere. Particular attention should be paid to the use of wireless technologies, as they create electromagnetic pollution, which is the most common pollution of the 21st century.

After analysis, we found that electromagnetic pollution is a type of anthropogenic or natural physical pollution that occurs when modifying the electromagnetic properties of the environment (under the action of high voltage power lines, the operation of some industrial plants, natural phenomena - magnetic storms, etc.).

Electromagnetic radiation at the projected object is caused by the use of electrical equipment and, to a greater extent, the use of wireless communication. This type of communication, which uses electromagnetic radiation as a method of data transmission, is one of the most polluting factors.

In conclusion, it should be noted that work on new, modernized systems that will avoid problems with electromagnetic pollution and pollution caused by emissions of harmful gases is very important. The urgency of this issue is determined by the general ecological condition of the biosphere of Ukraine.

GENERAL CONCLUSION

During the implementation of this work, the development of aircraft maintenance was investigated and analyzed, from which it is possible to make assumptions about the further development of this industry. Due to the rapid development of technology, it is safe to say that over time, health monitoring will displace the NDT method. This is due to the cost of using NDT and the speed of the relevant procedures. SHM methods at times speed up the maintenance process. It greatly simplifies the process of predicting the behavior of materials during loads on the relevant parts of the aircraft due to the ability to track and collect indicators without undue effort.

After researching possible ways to use SHM methods, we can conclude that at the moment there is no system that would track the formation of cracks, delamination and corrosion in real time, and give an assessment for further work with these damages.

The first stage in creating the Built-In Operational Damage Recognition System was to study the development of the system as part of an engineering idea. This knowledge gave a clear understanding of the logic of creating and implementing the system in the aircraft, which was calculated in one of the parts above.

The second stage was the development of the logic of the system - data collection, stages of comparing internal data with external data loaded into the system in advance and checking itself for accuracy. Thanks to the wide capabilities of the neural network - to issue final results with information about the location, type and degree of damage prescribes an appropriate procedure to eliminate the damage.

The installation of the Built-In Operational Damage Recognition System must be in accordance with the statistically defined areas that are most frequently damaged during the operation of the aircraft. In this case - on the example of its own developed aircraft.

There are no analogues of this system, which would track the formation of cracks, delamination and corrosion in real time, and give an assessment for working with damage. The development of this system gives impetus to further research and development in this direction.

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