



AFASES 2023

SCIENTIFIC RESEARCH AND EDUCATION IN THE AIR FORCE

ISSN, ISSN-L: 2247-3173
DOI:10.19062/2247-3173.2023.24

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www.afahc.ro/ro/editura/editura.html

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Mathematics and
Engineering Sciences in the
Age of Virtual Reality

A METHOD FOR SYNTHESIS OF FAMILIES OF SETS OF PHASE MANIPULATED SIGNALS WITH OPTIMAL CORRELATION PROPERTIES

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DOI: 10.19062/2247-3173.2023.24.1

***Abstract:** In the paper a method for synthesis of families of sets of phase manipulated signals with optimal correlation properties is substantiated. The method could be used in the development of new radar sensor networks, which exploit effectively the electromagnetic spectrum and can operate practically without self-interferences and multiaccess interferences.*

***Keywords:** radio communication system, signal processing, synthesis of phase manipulated signals.*

1. INTRODUCTION

Recent years have seen a steady increase in the number and type of wireless devices used in all areas of the society. For example, industrial networks, where reliability requirements are very high, are constantly being upgraded with control and monitoring applications as well as new sensor and smart networks are being implemented [1], [2]. The military [3] and civilian [4] consumer wireless, cellular and satellite networks are also in rapid progress.

The analysis of these examples show that the importance of different types of wireless electronic communication services increases with relatively equal opportunities to provide the limited natural resource - electromagnetic spectrum. Accounting this situation in the paper a method for synthesis of families of phase manipulated (PM) signals with optimal correlation properties is proposed. The method could be used in the development of new radar sensor networks, in which deleterious effect of the self-interferences (SIs) and multiaccess interferences (MAIs), caused by the multipath radio waves propagation and by the simultaneous use of the communication channel by many users respectively, is minimal [3], [5], [6].

The paper is organized as follows. First, the basics of the signal processing in the receivers of the radar systems are recalled. After that the properties, which the PM signals ought to possess in order to minimize SIs and MAIs, are systematized. On this base a method for synthesis of families of PM signals with optimal correlation properties is developed. At the end, the applications of the proposed method are analysed.

2. BASICS OF THE SIGNAL PROCESSING IN THE RECEIVERS OF THE RADAR SYSTEMS

In the general theory of communication systems it is proved that the communication receivers must be a filter, matched to the signal, which have to be detected. This conclusion ensues from the following circumstances.

First, most often in communication systems the signals must be detected in the presence of the so-called additive white Gaussian noise (AWGN).

Second, the receiver construction as a matched filter (MF) maximizes the signal-to-noise ratio (SNR) in the receiver output, when the signals are influenced by AWGN.

Third, the situation, when the background noise is AWGN, is considered as one of the worst cases of signal reception. In other words, if the receiver is a MF, but the background noise is not AWGN, then the performance of the receiver most probably is better.

Due to the above conclusion, most often, the digital signal processing in the receiver of a radar can be described by the following polynomial model [5], [6]:

$$[\sum_{i=0}^{N-1} \mu(i)x^i][\sum_{i=0}^{N-1} \mu^*(i)x^{-i}] = \sum_{r=-N+1}^{N-1} P_{\mu\mu}(r)x^r . \quad (1)$$

In (1) the following notations are used.

First, the digital signal

$$\{\mu(i)\}_{i=0}^{N-1} = \{\mu(0), \mu(1), \dots, \mu(N-1)\} \quad (2)$$

consists of the samples of the digitalized echo-signal. As the echo-signal is produced by reflection of the probe signal from the surface of some object, the echo-signal is a diminished copy of the probe signal of the radar transmitter [3], [5], [6]. Due to this reason, the samples (2) are complex numbers, presenting the complex envelopes of the elementary phase symbols (or chips) with duration τ_{ch} , forming the probe signal.

Analogously, the sequences of complex numbers

$$\{\mu^*(i)\}_{i=0}^{N-1} = \{\mu^*(0), \mu^*(1), \dots, \mu^*(N-1)\}, \quad (3)$$

$$\{P_{\mu\mu}(r)\}_{r=-N+1}^{N-1} = \{P_{\mu\mu}(-N+1), \dots, P_{\mu\mu}(-1), P_{\mu\mu}(0), \dots, P_{\mu\mu}(N-1)\}, \quad (4)$$

are the samples of the finite response matched filter (MF), used in the radar receiver, and the autocorrelation function (ACF) of the digital signal (2) respectively.

In (3) the symbol “*” stands for “complex conjugation”.

Second,

$$F_{\mu}(x) = \sum_{i=0}^{N-1} \mu(i)x^i \quad (5)$$

is the so-called generating function or Hall polynomial, associated with the digital signal (2).

It should be pointed out that the powers of the variable x^{-i} , x^i denote “overtaking or delay at i time-clocks with duration τ_{ch} during the signal processing” respectively.

Analogously, the generating functions (Hall polynomials) of the digital signals (3) and (4) are

$$F_{\mu}^*(x^{-1}) = \sum_{i=0}^{N-1} \mu^*(i)x^{-i}, \quad (6)$$

$$F_{P_{\mu\mu}}(x) = \sum_{r=-N+1}^{N-1} P_{\mu\mu}(r)x^r . \quad (7)$$

Now it should be taken in consideration, that performance quality of the radar sensor networks is worsened mainly by the SIs and MAIs [3], [4], [5], [6].

The SIs can be explained as follows. The most often in the radar receiver an input mix of echo signals, reflected by different objects, is present. In such situations, the ACF side-lobes of echo-signals of more huge objects can mask the ACF main lobes of echo-signals of smaller objects, which may be more important.

The MAIs are result of the simultaneous work of many radar sensors and other radio electronic devices in a common frequency band.

Accounting the deleterious effects of SIs and MAIs, the rest part of the paper is focused on the development of method for synthesis of families of sets of PM signals with optimal correlation properties.

The theoretical and practical importance of this problem ensues from the following advantages of these families of signals.

First, the PM signals can be generated by simple, reliable and cost-effective digital devices.

Second, the sets of PM signals are wideband as they exploit sets of $M, M \geq 2$ carrier frequencies. As a result, the spectral density of signals can be very small, which provide electromagnetic compatibility with other radio communication systems as well as possibility of reuse of the frequency resources.

Third, the aggregated ACF of every set as well as the aggregated cross-correlation function (CCF) of every pair of sets of PM signals resemble a delta-pulse, i.e. their side-lobes are small or are completely absent.

3. A METHOD FOR SYNTHESIS OF FAMILIES OF SETS OF PHASE MANIPULATED SIGNALS WITH OPTIMAL CORRELATION PROPERTIES

Let the matrices G and H

$$G = \begin{bmatrix} g_{11} & g_{12} & \dots & g_{1M} \\ g_{21} & g_{22} & \dots & g_{2M} \\ \dots & \dots & \dots & \dots \\ g_{M1} & g_{M2} & \dots & g_{MM} \end{bmatrix}, H = \begin{bmatrix} h_{11} & h_{12} & \dots & h_{1M} \\ h_{21} & h_{22} & \dots & h_{2M} \\ \dots & \dots & \dots & \dots \\ h_{M1} & h_{M2} & \dots & h_{MM} \end{bmatrix} \quad (8)$$

be two (not necessarily different) unitary orthogonal matrices, which sizes are $M, M \geq 2$. This means that all entries of G and H have unit magnitude and their columns and their rows are orthogonal, i.e.:

$$\begin{bmatrix} g_{1n_1} \\ g_{2n_1} \\ \dots \\ g_{Mn_1} \end{bmatrix} \otimes \begin{bmatrix} g_{1n_2}^* \\ g_{2n_2}^* \\ \dots \\ g_{Mn_2}^* \end{bmatrix} = C_{gn_1} \otimes C_{gn_2}^* = \sum_{m=0}^{M-1} g_{mn_1} g_{mn_2}^* = \begin{cases} M, n_1 = n_2, \\ 0, n_1 \neq n_2, \end{cases} \quad (9)$$

$$\begin{bmatrix} h_{1n_1} \\ h_{2n_1} \\ \dots \\ h_{Mn_1} \end{bmatrix} \otimes \begin{bmatrix} h_{1n_2}^* \\ h_{2n_2}^* \\ \dots \\ h_{Mn_2}^* \end{bmatrix} = C_{hn_1} \otimes C_{hn_2}^* = \sum_{m=0}^{M-1} h_{mn_1} h_{mn_2}^* = \begin{cases} M, n_1 = n_2, \\ 0, n_1 \neq n_2. \end{cases} \quad (10)$$

In (9) and (10) the symbol “ \otimes ” stands for the ordinary scalar product of vectors. Besides, C_{gn_1} , $C_{gn_2}^*$, and C_{hn_1} , $C_{hn_2}^*$ are the n_1 -th column and the complex conjugate of the n_2 -th column of the orthogonal matrices G and H respectively.

Analogous property possess the rows of the orthogonal matrices G and H .

Here it should be noted that in general theory of matrices several methods have been developed, by the means of which unitary orthogonal matrices with arbitrary sizes can be synthesized [6].

From the orthogonal matrices G and H a family of M derivative matrices can be obtained when the columns of the matrix G are multiplied consecutively by the rows of the matrix H . The general form of the derivative matrices, forming the matrix family, is

$$D_m = \begin{bmatrix} h_{m1}g_{11} & h_{m2}g_{12} & \dots & h_{mM}g_{1M} \\ h_{m1}g_{21} & h_{m2}g_{22} & \dots & h_{mM}g_{2M} \\ \dots & \dots & \dots & \dots \\ h_{m1}g_{M1} & h_{m2}g_{M2} & \dots & h_{mM}g_{MM} \end{bmatrix}, m = 1, 2, \dots, M \quad (11)$$

As seen, in (11) $\{h_{m1}, h_{m2}, \dots, h_{mM}\}$ is the m -th row of the matrix H .

Proposition: Let the family of matrices $\{D_m\}_{m=1}^M$ is generated, according to (11), and let $\{\mu(i)\}_{i=0}^{N-1}$ be an arbitrary PM signal. Then the family of M sets of PM signals

$$\begin{bmatrix} h_{m1}g_{11}\{\mu(i)\}_{i=0}^{N-1} \odot h_{m2}g_{12}\{\mu(i)\}_{i=0}^{N-1} \odot \dots \odot h_{mM}g_{1M}\{\mu(i)\}_{i=0}^{N-1} \\ h_{m1}g_{21}\{\mu(i)\}_{i=0}^{N-1} \odot h_{m2}g_{22}\{\mu(i)\}_{i=0}^{N-1} \odot \dots \odot h_{mM}g_{2M}\{\mu(i)\}_{i=0}^{N-1} \\ \dots \\ h_{m1}g_{M1}\{\mu(i)\}_{i=0}^{N-1} \odot h_{m2}g_{M2}\{\mu(i)\}_{i=0}^{N-1} \odot \dots \odot h_{mM}g_{MM}\{\mu(i)\}_{i=0}^{N-1} \end{bmatrix}, \quad (12)$$

where $m = 1, 2, \dots, M$ and the symbol “ \odot ” means concatenation, possesses optimal correlation properties.

Proof: According to (5), the generating function (the Hall polynomial), associated with the set of PM signals (12), is

$$F_m(x) = \sum_{k=1}^M F_\mu(x) \begin{bmatrix} h_{mk}g_{1k} \\ h_{mk}g_{2k} \\ \dots \\ h_{mk}g_{Mk} \end{bmatrix} x^{(k-1)N} = F_\mu(x) [\sum_{k=1}^M h_{mk} C_{gk} x^{(k-1)N}], \quad (13)$$

where $F_\mu(x)$ and C_{gk} are defined by (5) and (9) respectively.

After taking in consideration (1) and (13), it can be concluded that the CCF of the m -th and n -th sets of PM signals (12) is associated with the following generating function

$$F_m(x)F_n^*(x^{-1}) = F_\mu(x) [\sum_{k=1}^M h_{mk} C_{gk} x^{(k-1)N}] \times \\ \times F_\mu^*(x^{-1}) [\sum_{k=1}^M h_{nk}^* C_{gk}^* x^{-(k-1)N}] = F_\mu(x)F_\mu^*(x^{-1}) \sum_{r=-M+1}^{M-1} P_{mn}(r) x^{rN}. \quad (14)$$

In (14) $P_{mn}(r)$, $r = -M + 1, -M + 2, \dots, -1, 0, 1, 2, \dots, M - 1$ are the samples of the aggregated CCF of rows of m -th and n -th matrices (11), i.e.:

$$P_{mn}(r) = \begin{cases} \sum_{k=1}^{M-|r|} h_{m(k+|r|)} h_{nk}^* C_{g(k+|r|)} \otimes C_{gk}^*, \\ \sum_{k=1}^{M-r} h_{mk} h_{n(k+r)}^* C_{gk} \otimes C_{g(k+r)}^*. \end{cases} \quad (15)$$

In (15) the first row treats the case $-M + 1 \leq r \leq 0$, and the second row treats the case $0 < r \leq M - 1$.

Now it should be seen, that all products in (15)

$$\begin{aligned} [h_{mk} h_{n(k+r)}^*] [C_{gk} \otimes C_{g(k+r)}^*] &= 0, \\ [h_{mk} h_{n(k+r)}^*] [C_{gk} \otimes C_{g(k+r)}^*] &= 0, \end{aligned} \quad (17)$$

are zeros as $C_{gk} \otimes C_{g(k+r)}^* = 0, C_{gk} \otimes C_{g(k+r)}^* = 0$ for the cases $r \neq 0 \cap m \neq n$, according to (9).

When $r = 0$ (15) becomes the form

$$P_{mn}(r) = \sum_{k=1}^M h_{mk} h_{nk}^* C_{gk} \otimes C_{gk}^* = M \sum_{k=1}^M h_{mk} h_{nk}^* = \begin{cases} 0, m \neq n, \\ M^2, m = n, \end{cases} \quad (18)$$

because

$$\sum_{k=1}^M h_{mk} h_{nk}^* = \begin{cases} 0, m \neq n, \\ M, m = n, \end{cases} \quad (19)$$

according to (10) (more precisely, an analogue to relation (10) is valid for the rows of the unitary orthogonal matrix H).

From (17) and (18) the following conclusions can be made.

C 1) The m -th and n -th radar sensor, which exploit m -th and n -th sets of PM signals (12) by the means of a common system of carrier frequencies

$$\{f_1, f_2, \dots, f_M\} \quad (20)$$

can work simultaneously (i.e. to use simultaneously the system of carrier frequencies (16) for transmission/reception of PM signals, put in the rows of the sets (12)) without any MAIs.

C 2) The aggregated ACF of every set (12) of PM signals is defined by the generating function

$$F_m(x)F_m^*(x^{-1}) = M^2 F_\mu(x)F_\mu^*(x^{-1}). \quad (14)$$

Here, according to (1), $F_\mu(x)F_\mu^*(x^{-1})$ is the generating function, associated with the ACF of the PM signal (2). Due to this reason, in the aggregated ACF of every set (12) of PM signals only $2N - 1$ side-lobes can be non-zero, whereas all others ($2MN - 1 - (2N - 1)$ side-lobes are zeros.

The above conclusions prove the proposition.

4. CONCLUSIONS

In the paper a method for synthesis of families of sets of phase manipulated signals with optimal correlation properties is substantiated. The method allow beginning with a practically arbitrary PM signal derivative wideband PM signals with arbitrary large lengths, very high energy and very low spectral density to be created recursively.

The method could be used in the development of new radar sensor networks, which exploit effectively the electromagnetic spectrum and can operate practically without self-interferences and multi-access interferences.

ACKNOWLEDGMENT

This paper is supported by the National Scientific Program “Security and Defense”, approved with Decision № 171/21.10.2021 of the Ministry Council of Republic of Bulgaria.

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IMPLEMENTATION OF DIGITIZATION ELEMENTS AS A SOLUTION OF RISK MANAGEMENT IN MAINTENANCE OF RADIOLOCATION SYSTEMS

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DOI: 10.19062/2247-3173.2023.24.2

Abstract: *We increasingly identify in our lives the presence of devices equipped with recording cameras, as well as facial recognition to unlock devices. At the same time, we notice the increasing presence of technologies capable of identifying different objects, manoeuvres or actions, as well as detecting actions performed in error. This article highlights how these digital devices can be integrated to improve the quality of maintenance and to achieve effective risk management in this sensitive segment of military RaDaR technology and equipment. The data acquisition elements (CWB/AR) can produce records that can be uploaded to a secure government cloud, which can be accessed by teams of appropriately skilled and qualified technicians. An IA structure can be adequately trained to notice, highlight and alert in case of deviations from the maintenance protocol, thus achieving quality management of the monitored equipment.*

Keywords: *government cloud , BodyCam, AR, AI, technical audit, radiolocation systems maintenance*

1. INTRODUCTION

In everyday life and especially in the professional environment, the concept of Double L (Lessons Learned) and also that of Good Practices is increasingly used. Since in the maintenance of radiolocation systems, the working environment involves the interaction of man with / on the technical component, in what is defined as Complex Socio-Technical System (CSTC).

Since 2017, military use has been assigned to policemen in territorial units **MOTOROLA** audio-video devices, type Body Worn Camera (BWC) (Figure 1). The purpose of implementing the project for equipping policemen with BWC was based on 3 important objectives:

- Making the evidentiary material for the deviations from the law found by the policeman;
- Realization of the evidentiary material in the situation of the offense of outrage;
- Carrying out the protection of the policeman in relation to false accusations of abusive conduct.



FIG. 1 Motorola BWC equipment from romanian MAI policeman

Technical features BWC, Motorola, VB400 series:

- resolution 1920x1080P@30fps, HD 1080p (2mp);
- WiFi 802.11 a/b/g/n (2.4GHz & 5GHz);
- storage capacity 64GB;
- Bluetooth monitoring sensor;
- audio: dual microphone.
- built-in GPS sensor;
- Li-Pol battery - up to 12 hours of operation;
- dimensions 68mm x 89mm x 26.6mm;
- weight 162g.

2. PURPOSE AND OBJECTIVES OF THE PROPOSED PROJECT

In order to achieve the desideratum of the research theme, I propose the implementation of an IRMRSM (Improving Risk Management in Radiolocation Systems Maintenance) project containing and using BWC systems similar to those used by the MAI policemen. A practical and up-to-date, but more expensive, alternative is the use of AR glasses. The major purpose of the proposed project is to identify the factors in the radiolocation maintenance that have an impact on the operational availability. In other words, the project aims to minimize the occurrence rate of failures that can remove radars from operational availability within the national airspace surveillance system. This is based on the following important objectives:

- carrying out maintenance operations in time, qualitatively and in full volume;
- ensuring the collection of data by the system by categories of radars and subsystems;
- setting up a database (like a black box – maintenance log) available to be technically audited in real time or later;
- storage of audio-video material on each system / equipment separately to keep clear records of operations on the system / equipment;
- protecting the personnel involved in carrying out maintenance in relation to the technical audit staff that could invoke before the use of the platform, inconsistencies between the planning and execution of maintenance operations;
- identification of risk elements by omission / commission by the personnel involved in carrying out the maintenance of radiolocation systems;
- improving the didactic base for the training of technical staff in educational institutions / specialization courses by using sequences;
- making a map that highlights the critical failures of the equipment / subassemblies / installations that lead to the operational unavailability of the radar systems;

- the establishment of remedial packages for critical elements within radar systems;
- making intuitive decisions related to risk management by the decision-maker.

3. THE PRECEDING PHASE

For the efficient development of the project, it is necessary to go through successively the proposed phases. This phase involves the collection of data from the territory, the categorization of the equipment by the degree of interest and importance as an operative availability, the categorization of the maintenance personnel on the level of training, the realization of the IT application, the organizational chart of the system and the establishment of the attributes of the personnel involved in the project, the writing of the project, the simulation of the project run, the realization of the feedback loops with specialized personnel, the correction of the identified gaps, the finding of the identified gaps, the finding of the variants of project financing, proposal and support of the project to the beneficiary for approval and implementation.

Table 1. Correspondence between the degree of complexity of the operation and the level of qualification of the maintenance staff

Degree of complexity of the operation	Qualification level of maintenance staff	The need for remote auditing	Restrictions
Very complex – operations provided by the manufacturer	N0 - operators designated by the manufacturer	Optional at the decision of the field team	Operators N3 and N2
Complex–	N1 – operators certified by the manufacturer	Optional by the manufacturer's support team YES in the case of operators lower level N2	N3 Operators
Medium	N2 – operators trained and certified by the op. N1	Optional by specialists technical audit level N1 or N0 YES for N3 operators	
Easy – current operations	N3 – operators trained and certified by the op. N2	Upon request by specialists higher technical audit level N2	

A. Implementation phase

This phase is carried out in parallel in several directions:

a. Setting up the specialized technical commission for drawing the directions for project implementation and categorizing the maintenance operations according to the type of equipment and responsibilities of the staff;

b. The realization of the material base involves the purchase of BWC devices / AR glasses (Figure 2), the labeling of the work areas (preferably with QR codes) based on the categorization of the specialized technical commission;

c. Training of the maintenance staff in order to correctly use the BWC devices, to register the essential data in the platform (the person performing the operation, the subassembly subjected to maintenance, the types of materials used, the time allocated) and to save the recording of the executed maintenance operation;

d. Realization, by the designated IT support team, of the platform with files and files, hosted by the Government Authority specialized in the cloud area with the possibility of accessing depending on the level of access of users and administrators.



FIG. 2 AR gloves – HoloLens2 (left), capture from op.maintenance using HL2 (right)

B. Scrolling phase

This phase of the project involves the audio-video recording of maintenance operations. The maintenance staff must additionally follow a series of activities such as: starting the BWC device, logging into the system and starting the recording on the device. From this moment on all the data will be recorded at the device level in the storage space (requiring to be loaded into the platform later) or if the operation with a higher degree of complexity requires real-time technical auditing, live transmission can be performed using the Wifi feature of the device.

The operator designated for the execution of the maintenance operation is authenticated on the IRMRSM platform. with the unique data and starts the maintenance works according to the schedule and the standard sheet. Based on the GPS data and authentication data, as well as the QR code of the respective equipment of the standard maintenance sheet, the identification of the system to which the intervention is performed is carried out, the planned operation is certified and also recorded in the log of the equipment maintenance. Live technical auditing is carried out in fortuitous cases and has the role of carrying out the remote assistance of the technical staff who have a training of a lower level than the operation to be performed.

C. Technical audit phase

This phase is designed to meet the requirements in several plans, two of which are essential. The way to choose the audited operations can be:

- ❑ Pareto model, by identifying the most common 20% of events;
- ❑ Following a predetermined schedule;
- ❑ randomly (random function);
- ❑ upon notification of the activity of an operator;
- ❑ by category of systems.

We have previously defined that the data is recorded and saved in such a way that the operation can be identified at the IRMRSM platform level, both as an operation in succession at the level of equipment and as a specific operation of a subassembly. Thus, at the level of the platform, an analysis can be made that identifies several aspects:

a. On the one hand, based on the general analysis of the system, when identifying the failure of a critical subassembly to a radar system, the technical audit committee has at its disposal the records of maintenance operations from all systems in a designated category. This allows the causes and their nature to be identified (e.g. it is possible to identify whether the operations in full volume or with the appropriate tools or materials are carried out at the level of that subassembly, so errors of omission or commission can be identified). As a result of this type of technical audits, conclusions can be drawn and decisions can be taken:

- to improve the standard maintenance sheet at the level of that subassembly;
- specific training of personnel strictly on that operation;
- of categorization of the operation to another level.

b. On the other hand, a second scenario is the critical failure of a radar system with its removal from the state of operational availability and in order to identify the causes of the failure, the chain of maintenance operations performed on the system is monitored (like the black box investigation of aircraft). The conclusions of the report of the technical audit committee may constitute a package of measures for the other radars of that type in operation.

An extremely important aspect of this audit phase is the realization of the feedback loop, with a defining role in the development of the IRMRSM platform. and implicitly its resilience.

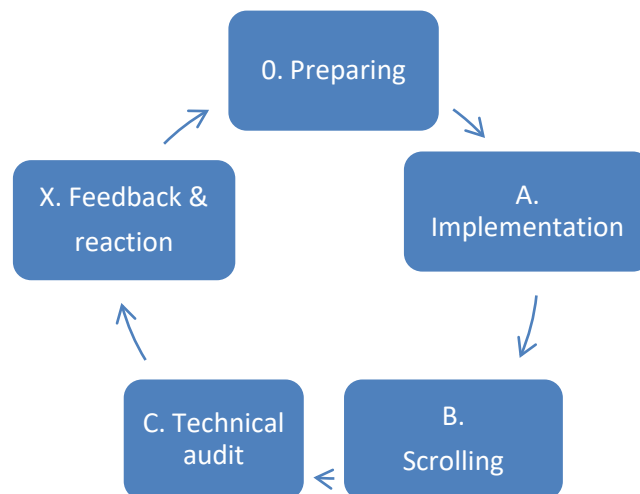


FIG. 3 Stages of the IRMRSM project.

4. ADVANTAGES AND DISADVANTAGES OF IRMRSM PROJECT

The advantages of the platform relate to:

- real-time identification of risks that may arise due to human errors of omission or commission, using reduced staff in audit committees
- protection of the personnel involved in carrying out the maintenance in relation to the technical audit staff that could invoke before the use of the platform, inconsistencies between the planning and execution of the maintenance operations
- achieving a correct norming of the maintenance operations with visible effects on the working climate of the staff, which will lead to the reduction of the probability of producing the risks caused by the human factor
- the awareness by the maintenance staff of the importance of observing all the steps in the standard maintenance sheet

- the realization of the overall picture with the malfunctions that may imminently cause the removal from the operative availability of a system with adverse influences on the national air surveillance system;
- the establishment of a robust database to identify deficiencies in the maintenance of radar systems, which properly exploited, can make recommendations for the system manufacturer.

Disadvantages of the platform:

- Project implementation costs
- Resistance to the new from the staff involved in the project, motivating the occurrence of additional operations.

5. CHALLENGES AND FUTURE DIRECTIONS: THE BET WITH THE FUTURE – THE INTEGRATION OF ARTIFICIAL INTELLIGENCE IN RISK MANAGEMENT IN THE MAINTENANCE OF RADAR SYSTEMS

To understand what AI can change in our lives, Professors Yolanda GIL and Bart SELMAN mapped out the AI development directions map for the next 20 years. The authors anticipate that AI will reduce health care costs, personalize education, accelerate scientific breakthroughs, help the national defense system, and more.

In the section dedicated to digitization and the identification of obstacles in the implementation of AI, we concluded that AI, although so publicized, is to a small extent integrated at the level of companies and society. This last proposed solution is at the moment ideational and represents **a bet with the future**. At this point AI is only able to relate to text and incipient voice databases. The evolution of AI, however, is spectacular. It is estimated that in the not too distant future, based on an analogy with the STEM cell sampling model, the video recordings of the operations in the technological systems will represent the database, already collected, necessary for the development of an AI engine dedicated to the maintenance of the radiolocation systems and implicitly to the management of their risks. Establishment of a digital register in which each element involved in maintenance is classified for human reliability analysis.

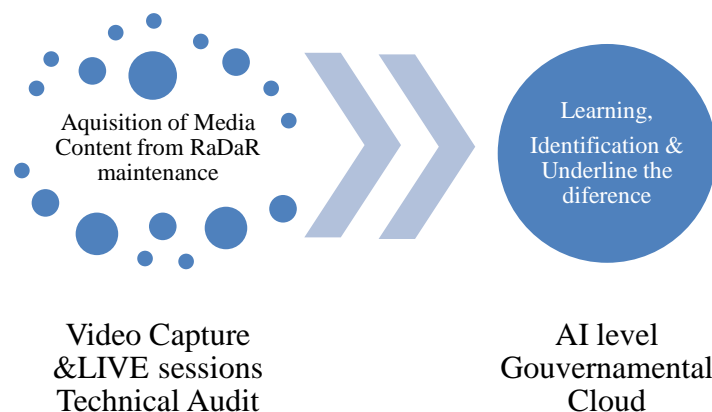


FIG. 4 Basic Structure of AI Technical Audit from media recording from RaDaR Maintenance

CONCLUSIONS

It is obvious that digital equipment can be integrated to improve the quality of maintenance and to achieve effective risk management in this sensitive segment of military RaDaR equipment and technology.

The data acquisition elements (CWB/AR) can produce records that can be uploaded to a secure government cloud, which can be accessed by teams of appropriately trained and qualified technicians. An AI structure can be adequately trained to notice, highlight and alert in case of deviations from the maintenance protocol, thus achieving quality management of the monitored equipment.

The model can also be applied to other areas of activity, with the final beneficiary being responsible for the appropriate learning of IA through the experience gained by specialists in the operational environment.

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THE STUDY OF THE THERMOELECTRIC GENERATOR DEPENDING ON THE LIGHTING LEVELS

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DOI: 10.19062/2247-3173.2023.24.3

Abstract: Whereas in the 20th century, scientists were concerned with the production of energy in huge quantities, regardless of the consequences, their interest later switched to the production of green energy from renewable sources. Nowadays, the interest has been directed towards increasing the efficiency of existent energy systems and finding other energy sources. A way to achieve these is to harvest energy from sources that generate small amounts of energy, but sufficient to power low-power devices, as well as to valorize residual energy (especially heat) that would otherwise be dissipated and lost. Since thermoelectric generators convert heat into electrical energy based on the Seebeck effect, this paper analyzes the important parameters of the TEC1-12706 thermoelectric generator, such as short circuit current, open circuit voltage, maximum power, and internal resistance in laboratory and natural conditions in function of different levels of irradiance. The performance of the thermoelectric generator is lower in real condition than under artificial light.

Keywords: thermoelectric generator (TEG), irradiance, comparison

1. INTRODUCTION

Energy harvesting by thermoelectric generators plays an important role in environmental protection as a result of the possibility to recover the waste energy from automotive, furnaces, and photovoltaic panels. Moreover, by using the energy generated by them, the lifetime of the batteries used for powering the sensors, control the circuits, devices for data communications, and wearable technologies can be prolonged [1]. In this case, fewer batteries will have to be recycled. Two thirds of the energy produced by automotive is wasted in the environment [2], the photovoltaic panels convert between 10 and 24% in electric energy and the rest is the loss in thermal energy [3]. The thermoelectric generators can convert a part of this into electric energy and the quantity can be huge [2].

Bi_2Te_3 is the most widely used thermoelectric generator. It works at a low temperature and is the best for applications where the hot side temperature reaches a maximum of 250-300°C. In case of applications where the hot side can reach a higher temperature CoSb_3 -based skutterudite product by Shanghai Institute of Ceramics can be used [1], or PbTe, Tegna skutterudite [4], TEG-HH-8 from Evident Thermoelectrics company [5]. For all, the values of the temperature of the hot side must be kept under 600°C.

The thermoelectric generators based on oxide can be used for temperatures higher than 800°C on the hot side. The representative modules are those from Calcium/Manganese oxide and Silicon/ Germanium. Cascade thermoelectric modules, such as Calcium/Manganese oxides, Bi₂Te₃ and BiTe–PbTe can be used to increase the performance and area of application.

In security, military and chemical applications, especially for systems that work in severe conditions and generate a lot of heat that is dissipated, self-powering is a very good opportunity and this can be assured by the thermoelectric generators [2]. Because the thermoelectric generator harvests the waste heat and converts it into electricity, it can be used successfully due to its advantages to power the low power sensors, the smart network sensors and others.

For applications such as monitoring, following, and controlling, which use smart sensors or intelligent sensor networks, it is important to have power sources that have almost the same lifetime. Some devices which use thermoelectric generators as power supplies have been developed. Micropelt developed some systems to monitor the temperature and others to control electro-valves from a distance [6]. The systems have a Micropelt MPG-D751 thermoelectric generator module as power supply. This module can generate 1mW maximum power and 1V open circuit voltage if the temperature difference is 10°C and a maximum power of 10mW and 3.7V open circuit voltage if the temperature difference is 30°C [1].

The performance of the thermoelectric generators is studied in different conditions. Cotfas et al. studied the operation of Bi₂Te₃ thermoelectric module considering the difference of temperature between the hot side and cold side and also the effect of this on the Seebeck coefficient [7]. The maximum power generated varies parabolically with the temperature difference between the hot and cold side of the thermoelectric generator. Also, a linear dependence between the open circuit voltage, V_{oc} , and the temperature difference was found. The efficiency of the Bi₂Te₃ thermoelectric module is low [7]. Cotfas et al. studied the response of thermoelectric generators to Bi₂Te₃ and Zn₄Sb₃ under different levels of solar radiation and dimensions, as well as the influence on the maximum power of adding a graphite layer on the hot side of the solar thermoelectric generator STEG (solar thermoelectric generator) [9]. The result shows that by adding a graphite layer on the thermoelectric generator, the power generated and the efficiency of the STEG increase significantly, around 2.5 times. In the case of a higher solar concentration ratio, STEG by Bi₂Te₃ had lower performances than Zn₄Sb₃, but the figure of merit of the STEG by the Bi₂Te₃ is higher; also, the power performance of both STEGs is improved if the length of the semiconductors is increased [9].

In order to increase the performance of thermoelectric generators, scientists have studied the effects of doping on the thermoelectric properties of Bi₂Te₃ with different materials such as Se_{0.3}, Sb [12], Sr [13] or Cu [14].

There are also some studies that investigated the position of TEG in a thermoelectric module (TEM) in order to offer every TEG the possibility of having almost the same temperature gradient and to minimize mismatch power loss. [10][11]

The contributions of this paper are:

- Comparison of the TEC1-12706 thermoelectric generator performance in laboratory and natural conditions in function of different levels of irradiance.
- Analysing the important parameters of the thermoelectric generator, such as short circuit current, open circuit voltage, maximum power, internal resistance and efficiency

The paper is structured as follows: the thermoelectric generator model is presented in the second section, the experimental setup is described in the third, the results in the fourth one, and the conclusions and the future work are presented in section five.

2. THE THERMOELECTRIC GENERATOR MODEL

The thermoelectric generator is composed from a number n of thermoelectric elements, which are connected electrically in series and thermally in parallel [7].

The thermoelectric element contains of a pair of P and N type thermoelements, also known as legs. These are positioned between two ceramic plates manufactured from Al_2O_3 . The Seebeck coefficient is negative for the N leg, whereas for the P leg it is positive. The legs are interconnected using a thin copper plate. The load resistance, noted R_L is connected in series with the TEG, Fig. 1 [8].

The functionality of the TEG is given by the conversion of thermal energy into electrical energy when there is a temperature difference between the hot end the cold sides (Seebeck effect).

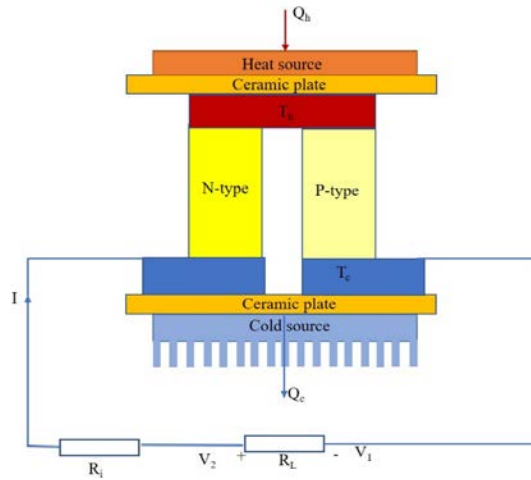


FIG. 1 The structure of TEG with a single thermoelectric element

The circuit voltage is calculated using the following relation:

$$V = \alpha(T_h - T_c) - IR_i \quad (1)$$

where α is the Seebeck effect, T_h is the temperature of the thermoelectric element's hot side, T_c is the temperature of the thermoelectric element's cold side, I is the current in the circuit, R_i is the internal resistance of TEG.

The circuit current is given by equation 2:

$$I = \frac{\alpha(T_h - T_c)}{R_i + R_L} \quad (2)$$

where R_L is the load resistance.

The power generated by the TEG is given by equation 3:

$$P = IV = R_L \frac{\alpha^2(T_h - T_c)^2}{(R_i + R_L)^2} \quad (3)$$

3. THE EXPERIMENTAL SETUP

The goal of this study is to analyze the performance of the thermoelectric generator TEC1-12706, in the laboratory, under artificial light and in natural sunlight conditions, in function of different levels of irradiance.

TEC1-12706 thermoelectric generator is based on Bi_2Te_3 , with 40 mm x 40 mm x 3.8 mm sizes. A graphite sheet is stuck on the hot side of the thermoelectric generator.

The illumination system for the laboratory consists of nine bulbs powered by a programmable power supply and an actuator that allows varying the distance between the bulbs and the thermoelectric generator. The actuator assembly has 20 memory positions. This allows that once the system was calibrated in irradiance, it can be used whenever needed, Fig. 2a. A tripod with manual sun tracker was used for the measurements in sunlight. The same pyranometer which was used for the calibration of the illumination system from the laboratory is placed in the same plane with the thermoelectric generator to measure the sunlight intensity.

The cold side of the thermoelectric generator is placed on the cooling system which consists of a copper parallelepiped with milled channels cooled with water.

The measurement system is created using a cRIO NI platform. The current voltage characteristic is measured using a system developed by the authors using the capacitor technique [15]. Five K thermocouples are used to measure the temperature, two of them of the hot side, and the other three of the cold side. The thermal grease is used between the cold side and the cooling system to keep the temperature of the cold side at quasi constant temperature.

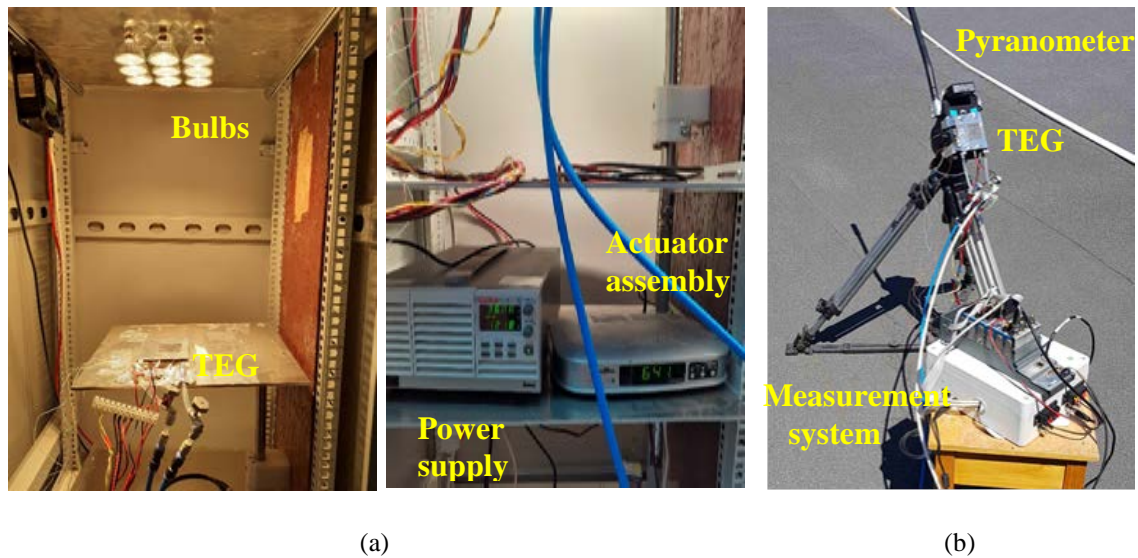


FIG. 2 Experimental setup a) TEG under artificial illumination; b) TEG under sunlight illumination

4. RESULTS AND DISCUSSIONS

In case of the laboratory, the measurements are made at different levels of radiation, from 600 W/m^2 to 1280 W/m^2 . The first goal is to determine the necessary time for the TEG to reach a steady state which according to the analysis of the measurements is 5 minutes. After that, there are some minor variations. They are higher for the higher level of irradiance considered. This behavior is caused by the fact that the hot side of the thermoelectric generator reaches a high temperature and then due to the effects which are in TEG, the temperature difference decreases.

The behavior of the maximum power generated by the TEG on 14 minutes duration is presented in Fig. 3.

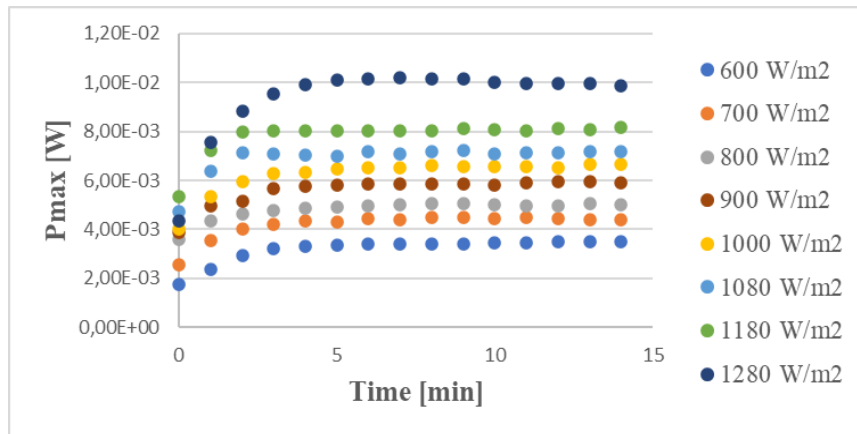


FIG. 3 Behavior of the maximum power in function of time in lab

The average of maximum power generated by TEG considered after five minutes depends linearly on the irradiance, less for the 1280 W/m², Fig. 4.

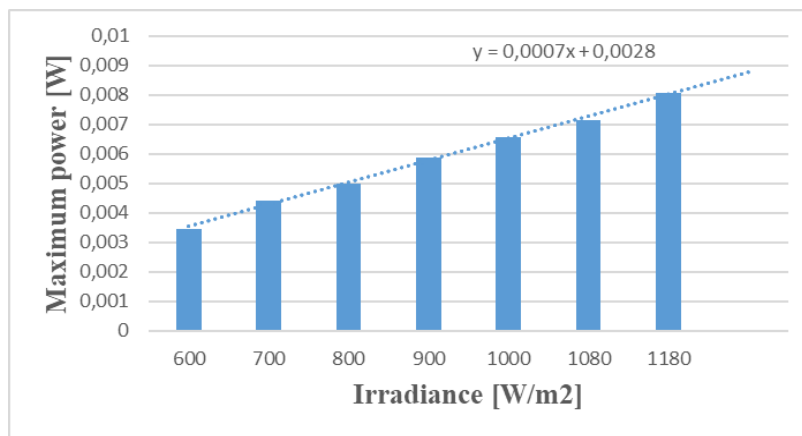


FIG. 4 Maximum power in function of the level of illumination in lab

In case of the sunlight, the measurements are made for three levels of radiation, 800, 900 and 950 W/m². The necessary time as the TEG reaches the steady state regime in sunlight conditions is the same with the one for TEG in the lab. The behavior of the maximum power generated by the TEG in sunlight condition on 14 minutes duration is presented in Fig. 5.

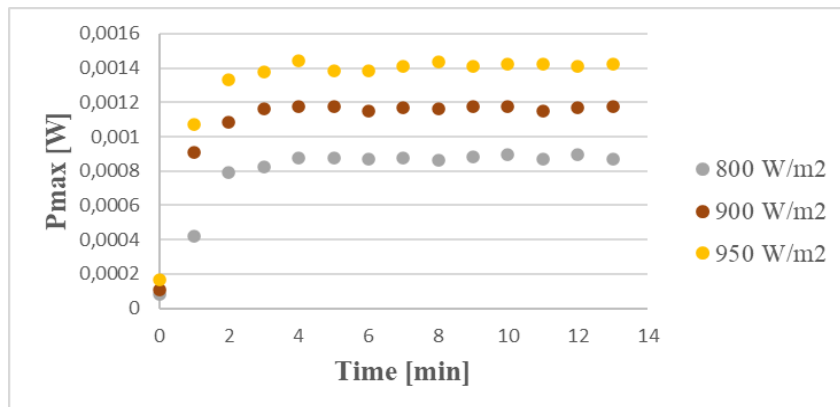


FIG. 5 Behavior of the maximum power in function of time in sunlight conditions

Table 1 presents the values for the parameters of the thermoelectric generator, such as: maximum power P_{max} , short circuit current I_{sc} , open circuit voltage V_{oc} , and internal resistance R_i , in both conditions, lab and sunlight conditions.

Table 1. Example of table

Irradiance [W/m ²]	P_{max} [mW]		I_{sc} [A]		V_{oc} [V]		R_i [Ω]	
	Lab	Sun	Lab	Sun	Lab	Sun	Lab	Sun
600	3.346	-	0.104	-	0.132	-	1.264	-
700	4.434	-	0.119	-	0.149	-	1.250	-
800	5.006	0.878	0.126	0.056	0.158	0.064	1.248	1.349
900	5.881	1.167	0.138	0.061	0.170	0.076	1.245	1.336
1000/950	6.564	1.413	0.145	0.064	0.181	0.089	1.240	1.320

There are notable differences between the maximum power generated under artificial light in the laboratory and under sunlight at the same level of illumination. The TEG generates around five times more under artificial than natural light. This difference decreases when the irradiance increases, at 800 W/m² it is 5.7 and decreases at around 4.3 for 1000 W/m² if the slope of the decrease is considered. The same behavior is observed for the short circuit current and the open circuit voltage. This high difference can be explained by the fact that halogen bulbs have more infrared radiation than sunlight and there are differences between the measurement conditions. The ambient temperature is lower than the temperature in the laboratory and the wind can reduce the temperature of the hot side of the thermoelectric measurements. At 900 the difference in temperature between the hot and cold sides of the thermoelectric generator is 6°C for laboratory conditions and 4°C under sunlight.

5. CONCLUSIONS

TEC1-12706 thermoelectric generator, based on Bi₂Te₃, is studied under artificial light in the laboratory and in natural conditions. The study was made for different levels of illumination. The following parameters were extracted using the measured current voltage characteristic: maximum power, short circuit current, open circuit voltage, and internal resistance.

The maximum power depends linearly on the irradiance. The linearity is kept up to 1200 W/m².

The comparison between the parameters studied under artificial light and under sunlight shows a better response for the first method of illumination. This conclusion shows that thermoelectric generators need to be tested under natural conditions before they are used to generate energy for different systems.

AKNOWLEDGMENT

This work was supported by a grant from the Ministry of Research, Innovation and Digitization, CNCS-UEFISCDI, project number PN-III-P4-PCE-2021-1020 (PCE87), within PNCDI III.

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EW SYSTEMS MANAGEMENT. A CRITICAL REVIEW IN THE ACTUAL CONTEXT OF MULTIPLE CRISIS AND TURBULENCES

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DOI: 10.19062/2247-3173.2023.24.4

***Abstract:** The paper refers to the management of electronic warfare systems and the latest approaches in this field. Also, some important main historical milestones and new development trends in the field of EW (Electronic Warfare) are being discussed. Finally, after identifying the relationship between ECM (electronic counter measures) and ES (electronic support) and the gaps in the current research of electronic warfare systems, it has been shown how is this domain influenced in the current context of multiple turbulences and crises.*

***Keywords:** Electronic Warfare, systems management*

1. INTRODUCTION

For this article we have formulated the following research questions:

- What are the main historical milestones and new development trends in the field of EW (electronic warfare)?
- What are the latest approaches in the management of electronic warfare systems and the relationship between ECM (electronic counter measures) and ES (electronic support)?
- What are the gaps in the current research of electronic warfare systems?
- How is the EW domain influenced in the current context of multiple turbulences and crises?

To answer the study questions formulated, we applied a widely used methodology to conduct a systematic review of the literature based on the preferred reporting elements for systematic reviews and meta-analyses (PRISMA 2020) [1]. We conducted a search in scientific databases that include important journals and conferences in the field studied such as IEEE Xplore, the ACM digital library, ScienceDirect, SAGE Journals Online and Springer Link, to discover relevant articles in the field of electronic warfare. We used the following search string to discover the publications and papers relevant to this research: ("Electronic Warfare" OR "Electronic Surveillance") in the fields of electrical engineering, applied physics, telecommunications, defense, and information systems, for the last six years (2018-2023). In total, we have gathered a set of about 7500 potentially relevant publications, except for gray literature and preprints.

I further analyzed the titles, keywords, and summaries of publications to find documents and articles that fit my area of interest, and I selected a total of eighty-nine relevant publications. We have also studied the bibliographic resources of the selected publications with the aim of expanding our own database.

2. HISTORICAL LANDMARKS AND NEW DEVELOPMENT TRENDS IN THE FIELD OF EW

In the conflicts conducted after the Second World War, all known means and methods of electronic warfare are referring to electronic jamming to the destruction with fire of the opponent's electronic means.

The means of neutralization by electronic jamming arranged on board the means of air attack are for the creation of jamming against the electronic missile and anti-aircraft artillery control systems, the fighter aviation and for preventing the work or misleading the electronic means of radiolocation research from the equipment of the anti-aircraft defense forces. For this purpose, the military used electronic means of attack installed on impactors and aircraft specially designed for electronic warfare, false radar targets and infrared traps. The Air forces launched bombs and air-to-ground guided missiles against the radar stations and the positions of the anti-aircraft missile control stations.

The tactical procedures of electronic warfare execution have changed and have evaluated as the characteristics of the armaments and the technique of electronic surveillance and attack evolved.

In the Korean War, the U.S. Air Force used B-26 aircraft equipped with electronic attack means that usually evolved before the strike group.

In the Vietnam War, the electronic research was executed by the USA with strategic bombing aircrafts of type B-52 and research planes RF-101 A that operated from heights of up to 11000 m, constituted in formations of 16-20 aircrafts, in the composition of the hit groups or outside them, with the evolution in one direction. The RF-101 A research aircrafts were taking pictures of the terrain, with an accuracy of 0.5 m, after which the pilots received the photos to prepare for the execution of the radar jamming and the air attack, after about 15 minutes from the landing of the research planes. To create false aerial situations on the screens of the radiolocation stations, metallic cardboard reflectors launched with a parachute were used, as well as special anti-radiation cartridges that were fired in the anterior hemisphere of the planes' flight direction. There were also used trap missiles (of type MQM-74 A) equipped with equipment for creating active and passive jamming and ground jamming transmitters arranged on dominant heights close to the contact line.

In the 1967 conflict between Israel, on the one hand, and Egypt, Syria and Jordan, on the other hand, electronic warfare was carried out by all categories of armed forces, with the aim of disorganizing the radio links of troop management and neutralizing the electronic means of discovering the means of air attack and of directing anti-aircraft missiles and fighter aviation. During the execution of the first strike, Israeli forces disorganized by jamming the radio connections of the opponents, neutralized the radar stations of the anti-aircraft defense and on board the planes. The execution of electronic warfare measures and disinformation have negatively affected the conduct and coordination of electronic warfare actions of the ground forces, aviation and anti-aircraft defense means of Arab countries.

In the War in the Middle East since 1973, electronic warfare has been used based on experience gained in previous wars in Vietnam and the Near East. On the one hand, it was aimed at neutralizing the electronic means and systems of aviation, anti-aircraft defense, tank units and subunits of the adversary and on the other hand, on the protection of own forces. About 30% of the Israeli strikers were equipped with electronic jamming means, of American origin, and some of them with anti-radar missiles of SHRIKE type. The electronic jamming means were installed on fighter-bomber aircrafts of type F-4 E "PHANTON- II", A-4 E "SKYHAWK" and MIRAGE-III-C, on unmanned aircrafts and

on other special jamming creation installations. The F-4 E and A-4 E aircrafts had snapped containers with radar irradiation equipment of the aircraft (RWR) and active jamming stations of type AN/ALQ-71 (87) and AN/ALQ -19 (55, 100) respectively. Passive jamming made using AN/ALE-29 systems (on A-4E aircrafts) equipped with thirty-two cartridges with dipole reflectors, as well as aviation bombs with dipole reflectors, was also used.

The Arab Israeli conflict in Lebanon since 1982 it has been distinguished by the scale of electronic warfare actions. Active and passive jamming was widely used, which led to air targets being discovered extremely late by Syrian air defense systems.

Before the air attacks were carried out, Israeli forces acted on the Syrian anti-aircraft defense system, with unmanned aircraft and missiles that created clouds of dipole reflectors above the anti-aircraft defense system and mimicked a large number of targets, resulting in the complete "flooding" of the radiolocation station screens, on which it was very difficult to distinguish the real targets from the false ones. For the diversion of infrared-guided missiles, the Israeli air force effectively used overheated balloons for the first time.

In the Anglo-Argentine conflict concerning the Malvin Islands (Falkland), the electronic countermeasures of the English consisted in the use of passive and active jamming in naval warfare. The success of the EXOCET-type missiles used by the Argentine forces was 50% (three out of six missiles hit the targets), and that of the ground-ship ones was 25% (one missile out of four hit the targets). To repel the attack of the aerial means provided with modern anti-ship missiles, the English used the unguided missile projectiles KORVUS, SEAFAN, STOCKADE, loaded with antiradar dipole made of metallized glass wool, aluminum foils and other materials. Due to the opportune use of passive jamming, but also of the active one, no SEA HARRIER aircraft was hit by missiles with radar self-routing heads, launched from the ground.

In the Gulf War , electronic research began intensively as early as August 1990 with Key Hales 11, 12, Lacrosse, TRDS, SDS satellites to obtain the data and information necessary to conduct military operations. The data obtained was entered in the memoirs of cruise missiles Cruise and Tomahawk from ships and submarines. Subsequently, the distant electronic research aircraft AWACS, U-2 and TR-1 were used. The laser marking of some targets (the SCUD Iraqi missile launch facilities), in the depth of Iraqi territory by diversionary scouts, was constituted in support measures for further e-warfare actions. 24 hours before the conflict began, the Allies used SKY SHADOW systems to execute ECM against Iraqi systems. Electronic countermeasures were executed against radar, radio, radio navigation and radio relay means. The "electronic shield" has designated all electronic protection measures used by the Allies. Ef-111 aircraft flew in front of the hit formations and executed active barrage jamming and target imitation (with AN/ALQ-99E systems). In all the air raids conducted, the formations of aircraft had in their composition electronic warplanes: EA-6B, F-4G, Wild Weasel, for group protection, which determined that the reaction of the Iraqi anti-aircraft defense to be weak, conducted with classical means of fire. "STEALTH" planes were also used.

The factors that contributed to the victory in this conflict are:

- the application of electronic warfare measures in the preparation and conduct of military actions had a primary role in achieving success;
- the rapid obtaining of the air and maritime supremacy allowed the combat aircrafts equipped with the most modern air-to-air, air-to-ground missile systems, laser, or video guided bombs, to execute unbroken bombings, these being intensified during the offensive of the ground forces;

- the use of state-of-the-art weapons at that time, with a high impact accuracy (cruise missiles, anti-radar missiles, anti-aircraft missiles, laser-directed artillery shells, research-impact systems, helicopters equipped with guided anti-tank missiles, airplanes equipped with "STEALTH" technology)

- the rapid achievement of victory by the infantry troops, permanently supported by "APACHE" helicopters carrying directed anti-tank missiles and armored aircrafts of the "A-10" type, equipped with projectiles capable of penetrating the armor of the Iraqi tanks;

- logistical organization and coordination throughout the operation;
- high morale of allied forces.

In the events of December 1989 in Romania, through electronic diversion, the aim was to achieve a large consumption of aviation resources and ammunition of artillery and anti-aircraft missiles. At the same time with the imitated aerial targets, in the Romanian airspace, real targets also evolved, which flew under the protection of a strong active radiolocation jamming.

In the events of the former Yugoslavia (90s), the actions of electronic warfare supported an intense confrontation in the electromagnetic environment between the Serbian anti-aircraft defense troops and the Air Force of the Alliance.

3. APPROACHES TO ELECTRONIC WARFARE SYSTEMS MANAGEMENT

3.1 Intelligence Push Technology

The advantages of information superiority exceed those of technological superiority.

Informational superiority generates advantage in the decision-making process in a dynamic space, permanently changing but especially in an armed confrontation, a fact recently demonstrated including in the war in Ukraine. The process of its own "intelligence" (processing and analyzing data and information obtained in diverse ways) must always be doubled by the prohibition of the same process executed by the adversary.

Among the technologies still used, we list the "distribution "on request" to combatants of the information processed that raises the following issues:

- lack of radar data about air targets at any given time;
- the low level of scalability of the collaborative filtering algorithms of this data;
- currently, the collection, processing and analysis of radar data is conducted manually;
- the information technology does not consider the type/need for information requested;
- the personalization of the transmitted information is strictly based on the subjective requirements of the military and does not consider the combat environment;
- "Information overload" - too much information received at a time, or "information lack" - total lack of information.

The modern technologies currently used are:

- IPT ("Intelligence Push Technology"): which involves the generation of three models: user model, Intel model (type of information) and model "Push" (mode of transmission of information), selected with the support of artificial intelligence. This eliminates the flow of information on demand and automates the transfer of information. Information resources become dynamic, are transmitted in real time and information needs are automatically changed according to the transformations in the battle space [2];

- "Service discovery": automatic identification of services and devices in a computer network;

- „Information mining;”

- HUMINT (Human Intelligence): information provision services (obtained by human operators) adapted to the needs of combatants;
- Machine Learning, managing "Big data" and the widespread use of artificial intelligence.

3.2 Agent-Principal theory

The application of the problem Main agent involves the designation of the radar system in the role of "Principal", that is, the owner of the company, the role of the "agent" (manager hired on the basis of a contract) being the responsibility of the equipment with which the jamming is performed (jammer or ECM system- electronic counter measures) [3].

Between the two there is a clear information asymmetry, as follows:

- The objectives of the main (radar) are to discover as many air targets as possible, with the best possible accuracy, to identify the destructive ECM actions of the agent (jamming) and to apply countermeasures – ECCM against it, allowing it to continue the basic mission – airspace surveillance;
- The agent seeks to decrease the accuracy with which the principal discovers air targets, or even missing some of them by applying the ECM. The jamming applied has certain costs and, to increase efficiency, it should be continuous.

This creates an ECM-ECCM covariance, the independent variable being the air target.

The subject untreated in the literature involves the reversal of roles: the main one to be a system or an assembly of mobile terrestrial RE systems and the agent – the radar system on board the opponent's aviation.

Information asymmetry in this situation it is explained as follows:

- The main (offensive electronic warfare system) aims to affect as many opposing on-board radars as possible, with the means at their disposal, to hinder or prevent the actions of the opponent. The aim is to limit the operating costs and to avoid discovering the location of the RE technique in order not to be destroyed;
- The agent aims to discover with the best possible accuracy the elements to be destroyed on the Earth's surface by reducing the effects of the soil jamming performed by the principal.

An ECM-ECCM covariance is also created here, the independent variable being the terrestrial objective to be destroyed by the adversary.

On the other hand, a direction of research involves the designation of many "agents" with several distinct roles and redefining the objectives pursued by the "principal".

3.3. Game theory

The strategy of dynamic allocation of jamming resources simultaneously on-air targets (air raid) can be approached through Game Theory. The novelty is the simulation of dynamic scenarios because approaches with static scenarios have been conducted in the past.

The final stable solution of the stated problem involves identifying the "Nash equilibrium" (NE – Nash Equilibrium) and subsequently choosing the most effective algorithm for learning the response.

It is obvious that the role of the RE executed by one's own forces involves collecting information about the opponent and influencing his actions. The means of jamming are always limited, and this directly influences the effectiveness of one's own jamming actions.

To date, various methods have been identified to optimize the allocation of jamming resources, for example: "Genetically Adapted Immune Allocation Algorithm", "Simulated Annealing Algorithm" [6] or "Hungarian Algorithm" [7].

The formulation of the problem of dynamic allocation of jamming resources simultaneously, on several targets, using Game Theory, starts from the initial assumption that in this case we are talking about a potential game, with at least one Nash balance. It aims to identify a final solution / stable strategy with a reduced complexity of processing input data.

The initial data are as follows:

The letter M denotes the number of jamming systems and N, the number of targets to be combated at a given time. It follows that:

M = set of jamming systems, N = set of targets

$M = \{1,2,\dots, M\}$, $N = \{1,2,\dots, N\}$

According to [9], because there is a certain distance between targets, a jamming signal is considered to cover/hit a single aircraft.

It is known that the opponent is moving information, using a "COMAO" type of force pack (Combined Air Operation) intended for the execution of a specific mission consisting of between eight and over one hundred aircraft of diverse types. [10]

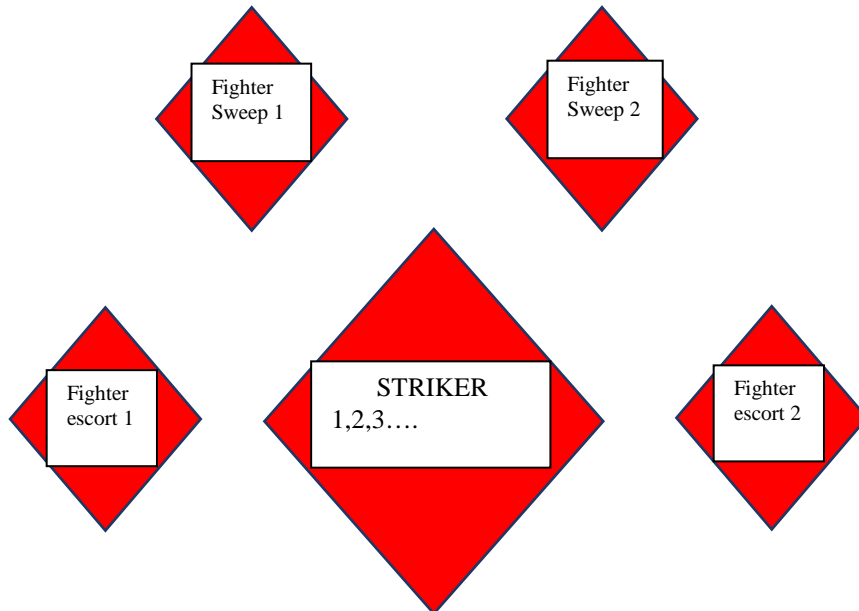


FIG. 3 Diagram of a COMAO package

Denoted by $C_m = \{C_{m1}, C_{m2}, \dots, C_{mN}\}$ jamming strategy and as follows:

If $C_{mn} = 1$ it follows that the system "m" is assigned to jam the target "n"

If $C_{mn} = 0$ it follows that the system "m" does not perform jamming on the target "n".

The following assumptions are made below:

1. When a target is detected, it can be jammed by any jamming system and each target is enough to be jammed by a single jamming system (It happens differently)
2. The jamming signal covers the work lane of the targets and can jam all types of radar signal modulation on board the air target; the effectiveness of the action depends on the strength of the jamming signal received by the target.
3. There are no attenuations in the transmitting antenna.
4. Since $M < N$ (the number of N targets is greater than the number of M jamming systems), when one target changes its strategy, automatically another does the same.

The problem identified here is that we will have a limited set of jamming avoidance strategies borrowed from one target to another. A target can independently change its strategy, or several targets can change their strategies simultaneously, or a different strategy change may be the "exit from the game" (decoupling the radio locator, changing the way of working or the frequencies used).

For the development of electronic warfare systems, it is aimed at:

- improvement of the characteristics of unmanned aerial offensive aircraft and electronic research;
- ensuring the distant discovery by radar with the help of aerostats and airships, as well as using dispersed radiolocation stations and systems;
- increasing the sensitivity of radiolocation research equipment and the accuracy of measurements;
- increasing the power of jamming transmitters and expanding the working range;
- creating jamming with rapid re-tuning on several frequencies by using several magnetrons to generate jamming;
- elaboration of combined jamming systems and simultaneous launch of different undirected reactive projectiles (passive jamming with dipole reflectors, infrared traps, and active jamming transmitters with a sole use);
- making self-guided heads of missiles to be able to distinguish the real target that usually moves in a horizontal direction from the trap created with a dipole reflector cloud that is stationary or moves vertically;
- achieving electromagnetic compatibility of land, air, and naval electronic systems;
- upgrading and modernization of methods of training users of electronic warfare systems, including VR (virtual reality) and AR (augmented reality) [11].

CONCLUSIONS

Based on the analysis and experience gained in conducting electronic warfare actions in previous conflicts, the following conclusions can be drawn:

- the role of electronic warfare has become increasingly important, for all categories of armed forces, but especially for the air force;
- there are increasing use of state-of-the-art electronic surveillance and electronic attack systems, electronic countermeasures (thermal traps and electromagnetic dipoles), aerial research and unmanned combat aircraft, as well as active jamming transmitters with a sole use, car missiles directed on the electromagnetic beam of the opponent's electronic means;
- support with information about the adversary (especially about aviation and air defense) in real time has a primary role in achieving success in the operation;
- while the placement of noise jamming transmitters aboard combat aircraft proved ineffective, the use of "stealth" technology contributed decisively to the success of the operation.

By analyzing the elements in the field of EW present in the war triggered by the Russian Federation on Ukraine, a number of conclusions can be drawn:

- the high technological level of the Russian EW technique unsupported by an optimal level of training of the operators of those systems did not bring significant benefits to the Russian Federation;
- electronic attack systems against GPS systems and satellite communications with a range of up to one hundred kilometers are increasingly used;
- the means of electronic surveillance are used to identify future "jamming targets" or to accurately locate these targets and destroy them with artillery and missile systems;

- with the widespread use in this conflict of UAVs, including combat ones, a counter-weapon has also been developed – anti-drone systems, which jam GPS signals (for example, the Russian production system "Repellent-1");

- the Ukrainian ground forces use portable radio stations with frequency jump broadcasting, with encrypted transmission with over 2000 channels of work, "SINCGARS" (NATO Single-Channel Ground and Airborne Radio System), difficult to intercept by the adversary; however, in the event that SINCGARS stations are unavailable, mobile phones or classic radio stations with unprotected, vulnerable transmissions shall be used alternatively.

Innovative technologies create new risks that affect the armed forces entirely, or punctually, on the operators of the new combat systems. It is precisely this operator that represents the first threshold of defense against threats in cyberspace, a solution in its support being the use of encrypted data transmissions and the implementation of an efficient information management system that does not allow the interception by the adversary of sensitive information [12].

In the current macroeconomic context marked by multiple turbulences and crises, the field of electronic warfare is also significantly influenced. On the one hand, we are considering the increase in inflation amid a global energy crisis, the negative effects being doubled in SCM (supply chain management) through the semiconductor crisis.

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ALGORITHM FOR APPLICATION OF INFORMATION FOR MANAGEMENT OF USERS SPATIAL DISPOSITION IN THE PROCESS OF AUTOMATED SOFTWARE-DEFINED RADIO COMMUNICATION NETWORK IMPLEMENTED BY ORTHOGONAL FREQUENCY DIVISION AND MULTIPLEXING

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DOI: 10.19062/2247-3173.2023.24.5

Abstract: A software-defined radio (SDR) system is a radio communication system which uses software for the modulation and demodulation of radio signals. An SDR performs significant amounts of signal processing in a general purpose computer, or a reconfigurable piece of digital electronics. SDR can talk and listen to multiple channels at the same time, also it can be quickly and easily upgraded with enhanced features. In fact, the upgrade could be delivered over-the-air. In the long run, SDR is expected to become the dominant technology in radio communications.

Keywords: software-defined radio, communication system, signal processing, management of users, communication network.

1. INTRODUCTION

In this research, an algorithm for building radio communication networks (RCN) implementing the concept of SDR through OFDM is proposed.

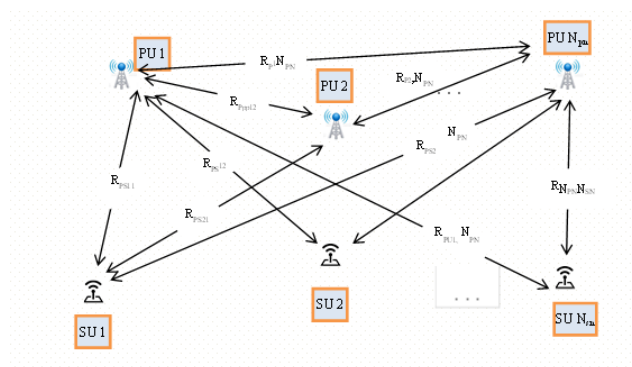


FIG. 1 General geometric structure of the positions of the users of the primary and the secondary SDR - RCN

The users (primary users) of the existing PNs (primary networks - PN) are $PU 1, PU 2, \dots, PU N_{PN}$, and the users (secondary users) of SDR PNs (secondary network - SN) implemented in the physical layer using OFDM technology, are $SU 1, SU 2, \dots, SU N_{SN}$ (Fig. 1).

Also, considering the frequency resource tracking and detection technologies in SDR - RCN and the basic principles of OFDM - RCN the following assumptions can be made.

A1) The frequency band ΔF of the secondary SDR- RCN covers the frequency bands of all primary RCNs (Fig. 2a).

A2) The frequency band ΔF of the secondary SDR - RCN, implemented at the physical level using OFDM technology, is divided into N frequency subchannels of width $\Delta f = 1/T_c$, where T_c is the duration of the symbol interval. Therefore, $\Delta F = N\Delta f = N/T_c$ (Fig. 2b).

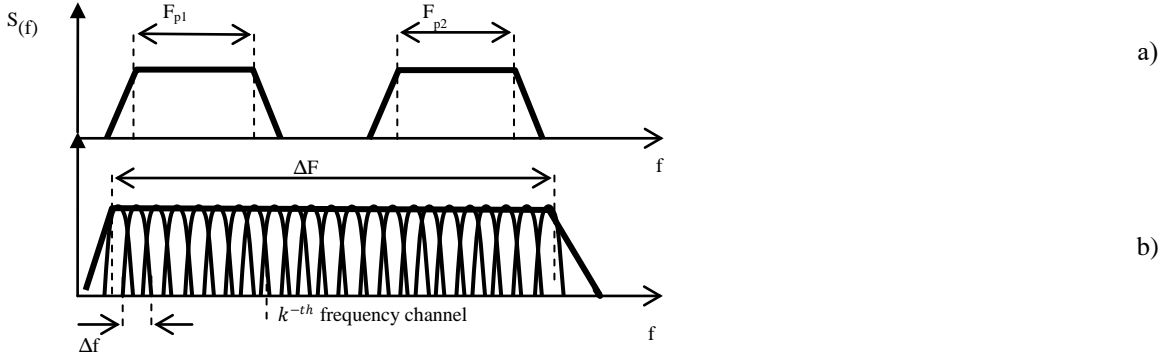


FIG. 2 Frequency bands of the primary (a) and the secondary SDR - RCN implemented at the physical level using OFDM technology (b)

A3) In the current time frame, using specialized measuring equipment and artificial intelligence methods for information processing, the following parameters have been measured and/or determined with sufficient accuracy:

P1) Geographical location of each of the users $PU 1, PU 2, \dots, PU N_p$ and $SU 1, SU 2, \dots, SU N_s$ of the primary and secondary RCN;

P2) Power of the signals $P_{P_i,k} [W], i = 1, 2, \dots, N_p, k = 1, 2, \dots, N$, emitted by the transmitter of the user $PU i, i = 1, 2, \dots, N_p$ in the k^{th} frequency subband (k^{th} channel), $k = 1, 2, \dots, N$, of the secondary SDR PCN;

P3) Information reception rate $I_r(k)_i \left[\frac{b}{s} \right]$ by the user $PU i, i = 1, 2, \dots, N_p$ in the k^{th} frequency subband (k^{th} channel $k = 1, 2, \dots, N$, of the secondary SDR - RCN;

P4) Spectral density $P(k)_{n_0} \left[\frac{W}{Hz} \right]$ of the noises in the k^{th} frequency subband (k^{th} channel), $k = 1, 2, \dots, N$, of the secondary SDR - RCN.

Regarding the determination of the parameters P2 and P3, it is necessary to make the following clarification: The power of the used signals $P_{PU} [W]$ and the information transmission rate $I_{r_{PU}} \left[\frac{b}{s} \right]$ are known from the technical documentation of the corresponding primary RCN. Most often, however, the frequency band F_p used by the primary RCN spans several frequency subbands (frequency channels) of the secondary OFDM - RCN, whose width $\Delta f = 1/T_s$ is determined by the duration of the symbol interval T_s . That is why in the most general situation it is fulfilled:

$$\frac{F_p}{\Delta f} = K_{ol} > 1 \quad (1)$$

It follows from (1) that the parameters P2 and P3 should be calculated using the formulas:

Obviously:

$$N_p \geq N_{p1}, N_{p2}, \dots, N_{pk}, \dots, N_{pN} \quad (5)$$

Step 2: Determining the distances between users of the primary RCN and users of the secondary SDR – RCN.

The geographic location information of each user $PU 1, PU 2, \dots, PU N_p$ and $SU 1, SU 2, \dots, SU N_s$ of the primary and secondary RCN (P1) makes it possible to calculate the elements of the following sets:

2.1) Multiple distances between users of the secondary SDR - RCN:

$$Cs = \{R_{s11}, R_{s12}, \dots, R_{slm}, \dots, R_{sN_s-1N_s}\} \quad (6)$$

2.2) Multiplicity of distances between the users of the secondary SDR - RCN and the users of the primary RCN:

$$Csp = \{R_{11}, R_{12}, \dots, R_{lm}, \dots, R_{N_s N_p}\} \quad (7)$$

In (7) R_{lm} is the distance between the l -th user $SU l$ of the secondary SDR - RCN $l = 1, 2, \dots, N_s$ and the m -th user $PU m$ of the primary RCMs $m = 1, 2, \dots, N_p$.

Step 3: Calculation of the additional noise powers created by the operation of the transmitters of the users of the secondary SDR - RCN at the inputs of the receivers of the users of the primary RCN.

As is known, when non-directional antennas are used, the maximum powers of the signals from the k -th subband (k -th frequency channel) of the users of the secondary SDR - RCN at the inputs of the receivers of the users of the primary RCN are:

$$Psp(k)_{lm} = \begin{cases} \frac{Ps(k)_l}{4\pi R_{lm}^2}, \\ 0, \end{cases} \quad (8)$$

$$k = 1, 2, \dots, N, \quad l = 1, 2, \dots, N_s, \quad m = 1, 2, \dots, N_p, \quad l \neq m.$$

In (8) the following notations are used:

– $Psp(k)_{lm}$ is the signal power of the user $SU l, l = 1, 2, \dots, N_s$ in the k -th frequency subband (k -th channel) received at the input of the user's receiver $PU m, m = 1, 2, \dots, N_p$;

– $Ps(k)_l$ is the user's transmitter power $SU l, l = 1, 2, \dots, N_s$ in the k -th frequency subband (k -th channel) which is determined at stage 2, Step 6 of the operation of the SDR PCN management server (i.e. at the stage of frequency OFDM channel allocation among users of the secondary SDR - RCN);

– R_{lm} is the distance between the user determined in Step 2 $SU l, l = 1, 2, \dots, N_s$ and user $PU m, m = 1, 2, \dots, N_p$;

The values $Psp(k)_{lm} = 0$ refer to the cases when in the current time frame (time frame) the user $PU m$ does not receive signals via primary RCN in the k -th frequency subband (k -th channel).

Step 4: Calculation of the signal powers of the inputs of the receivers of the users of the primary RCNs.

Analogously to (5), the maximum powers of the signals from the k -th subband (k -th frequency channel) at the inputs of the receivers of the users of the primary RCNs are:

$$Pp(k)_{uv} = \begin{cases} \frac{Pp(k)_u}{4\pi R(k)_{puv}^2}, \\ 0, \end{cases} \quad (9)$$

$$k = 1, 2, \dots, N, \quad u = 1, 2, \dots, N_p, \quad v = 1, 2, \dots, N_p, \quad u \neq v.$$

In (9) the following notations are used:

– $Pp(k)_{uv}$ is the signal power of the user $PU u, u = 1, 2, \dots, N_p$ in the k^{-th} frequency subband (k -th channel) received at the input of the user's receiver $PU v, v = 1, 2, \dots, N_p$;

– $Pp(k)_u$ is the user's transmitter power $PU u, u = 1, 2, \dots, N_p$ in the k^{-th} frequency subband (k^{-th} channel), which is calculated according to (2);

– $R(k)_{puv}$ is the distance between users determined in Step 1 $PU u, u = 1, 2, \dots, N_p$ and $PU v, v = 1, 2, \dots, N_p$, using the k th frequency subband (k^{-th} channel) (i.e. $R(k)_{puv} \in Cp_k$);

the values $Pp(k)_{uv} = 0$ refer to the cases when in the current time frame (time frame) the user PUv does not receive signals via primary RCN in the k^{-th} frequency subband (k^{-th} channel) from the user PUu (i.e. user PUu does not emit signals or its signals are shielded by hills or buildings).

Step 5: Calculation of the maximum permissible signal powers of the transmitters of the users of the secondary SDR – RCN.

According to the Shannon-Hartley Theorem [1], and [2], the possible maximum rate of information transmission on the k^{-th} frequency subband from the user PUu to the user PUm (i.e. the capacity $Imax(k)_m$ of the k^{-th} frequency channel, evaluated from the point of view of the user PUm) is determined by the formula:

$$Imax(k)_{um} = \Delta f \log_2 \left(1 + \frac{Pp(k)_{um}}{\Delta f P(k)_{n_0}} \right) \quad (10)$$

In (10) $\Delta f P(k)_{n_0}$ is the noise power in the k th frequency channel.

If $Imax(k)_{um} > Ir(k)_m > 0$ (i.e. if the possible maximum speed of information transmission on the k^{-th} frequency channel to the user PUm is greater than the actually used speed), then the users of the secondary SDR - RCN can use the k^{-th} frequency channel without interfering of the user PUm if the powers of their signals $Psp(k)_{lm}$ ensure the fulfillment of equality:

$$Imax(k)_{um} = \Delta f \log_2 \left(1 + \frac{Pp(k)_{um}}{\Delta f P(k)_{n_0}} \right) \quad (11)$$

Accordingly:

$$\begin{aligned} Ir(k)_m &= \Delta f \log_2 \left(1 + \frac{Pp(k)_{um}}{\Delta f P(k)_{n_0} + Ps(k)_{lm}} \right) \Rightarrow \\ \Rightarrow \frac{Ir(k)_m}{\Delta f} &= \log_2 \left(1 + \frac{Pp(k)_{um}}{\Delta f P(k)_{n_0} + Ps(k)_{lm}} \right) \Rightarrow \\ \Rightarrow 2^{\frac{Ir(k)_m}{\Delta f}} &= 1 + \frac{Pp(k)_{um}}{\Delta f P(k)_{n_0} + Ps(k)_{lm}} \Rightarrow \\ \Rightarrow \Delta f P(k)_{n_0} + Ps(k)_{lm} &= \frac{Pp(k)_{um}}{2^{\frac{Ir(k)_m}{\Delta f}} - 1} \Rightarrow \\ \Rightarrow Ps(k)_{lm} &= \frac{Pp(k)_{um}}{2^{\frac{Ir(k)_m}{\Delta f}} - 1} - \Delta f P(k)_{n_0}. \end{aligned} \quad (12)$$

Once accounted for (12) in (7) it's found that in the k^{-th} frequency channel the permissible powers of the signals of the users of the secondary SDR - RCN (i.e. the powers at which the rate of transmission of information to the user $PU m$ does not falls below the nominal speed as a result of the simultaneous use of the k^{-th} frequency channel and by the user $PU l$), are:

$$P_s(k)_l = \left(\frac{P_p(k)_{um}}{I_r(k)_m} - \Delta f P(k)_{n_0} \right) 4\pi R_{lm}^2, \quad (13)$$

$k = 1, 2, \dots, N, \quad l = 1, 2, \dots, N_S, \quad m = 1, 2, \dots, N_P.$

If $I_r(k)_m = 0$ (i.e. if no information is transmitted on the k^{-th} frequency channel to the user $PU m$), then the users of the secondary SDR - RCN can use the k^{-th} frequency channel without interfering with the user $PU m$, even if the powers of their signals $P_{sp}(k)_{lm}$ are maximally possible, according to the technical characteristics of the secondary SDR - RCN, i.e.:

$$P_s(k)_l = P_{max} s(k)_l, \quad (14)$$

$k = 1, 2, \dots, N, \quad l = 1, 2, \dots, N_S.$

Stage 2: Allocation of OFDM channels among users of the secondary SDR - RCN, maximizing the rate of information transmission in the secondary SDR - RCN subject to the constraints established in the previous stage.

Step 6: Calculation of the maximum possible rates of information transmission by users of the secondary SDR – RCN.

Based on the set C_s (step 2, formula (6)) of the distances between the users of the secondary SDR - RCN and the set of maximum permissible signal powers of their transmitters (calculated at step 5, formulas (8) and (9)), the power of the signals at the inputs of the receivers of the users of the secondary SDR - RCN is calculated by the formula:

$$P_s(k)_{lw} = \frac{P_s(k)_l}{4\pi R_{slw}^2}, \quad (15)$$

$k = 1, 2, \dots, N, \quad l = 1, 2, \dots, N_S, \quad w = 1, 2, \dots, N_S, \quad l \neq w.$

In (15) the following notations are used:

- $P_s(k)_{lw}$ is the signal power of the user $SU l, l = 1, 2, \dots, N_S$ in the k^{-th} frequency subband (k^{-th} channel) received at the input of the user's receiver $SU w, w = 1, 2, \dots, N_S$;
- $P_s(k)_l$ is the user's transmitter power $SU l, l = 1, 2, \dots, N_S$ in the k^{-th} frequency subband (k^{-th} channel), which was calculated in the previous step according to (8) or (9);
- $R(k)_{slw}$ is the distance between users determined in Step 2 $U l, l = 1, 2, \dots, N_S$ and $SU w, w = 1, 2, \dots, N_S$, when using the k^{-th} frequency subband (k^{-th} channel).

Analogous to (11), the information transmission rates that can be achieved by the users of the secondary SDR - RCN at the current moment in time are calculated by the formula:

$$I_r(k)_{lw/u} = \Delta f \log_2 \left(1 + \frac{P_s(k)_{lw}}{\Delta f P(k)_{n_0} + P_{ps}(k)_{uw}} \right), \quad (16)$$

$k = 1, 2, \dots, N, \quad l, w = 1, 2, \dots, N_S, \quad m, u = 1, 2, \dots, N_P, \quad l \neq w, \quad u \neq m.$

In (16) the following notations are used:

- $I_r(k)_{lw/u}$ is the maximum possible speed of transmission of information by the user $SU l$ to user $SU w$ to $SU w$ on k^{-th} the frequency subband (k^{-th} channel) when using (by the user $SU l$) signals with permissible power;

– $P_s(k)_{lw}$ is the signal power of the user $SU l, l = 1, 2, \dots, N_S$ in the k^{-th} frequency subband (k^{-th} channel) available at the user's receiver input $SU w, w = 1, 2, \dots, N_S$ according (15);

- $\Delta f P(k)_{n_0}$ is the noise power in the k^{-th} frequency channel;
- $Pps(k)_{uw}$ is the power of the signal of the user $PU u, u = 1, 2, \dots, N_p$ in k^{-th} frequency subband (k^{-th} channel) available at the user's receiver input $SU w, w = 1, 2, \dots, N_s$ which is calculated analogously to (8) by the formula:

$$Pps(k)_{uw} = \frac{Pp(k)_u}{4\pi R_{uw}^2} \quad (17)$$

$k = 1, 2, \dots, N, u = 1, 2, \dots, N_p, w = 1, 2, \dots, N_s.$

In (17) the following notations are used:

- $Pp(k)_u$ is the user's transmitter power $PU u, u = 1, 2, \dots, N_p$ in the k^{-th} frequency subband (k^{-th} channel), which is calculated according to (8);
- $R(k)_{lw}$ is determined by step 2 and this is the distance between the users $PU u, u = 1, 2, \dots, N_p$ и $SU w, w = 1, 2, \dots, N_s.$

Step 7: Allocation of OFDM channels among users of the secondary SDR - RCN, maximizing the information transmission rate in the secondary SDR – RCN.

The purpose of this step is to find the one-way communication links (lines) “passing information from the user $SU l, l = 1, 2, \dots, N_s$ receiving information from the user $SU w, w = 1, 2, \dots, N_s$ for which the information transmission rate is maximum for each frequency channel. To achieve this goal, $N \times N_s$ number of two-dimensional arrays are constructed, each of which can be represented by a table of the following type.

Table 1 Maximum possible speeds of information transmission by a user $SU l$ to user $SU w, w = 1, 2, \dots, N_s$ on the k^{-th} frequency channel in case of interference by a user $PU u, u = 1, 2, \dots, N_p$

		User $SU w$					
		1	2	...	w	...	N_s
User $PU u$	1	$Ir(k)_{l1/1}$	$Ir(k)_{l2/1}$	...	$Ir(k)_{lw/1}$	...	$Ir(k)_{lN_s/1}$
	2	$Ir(k)_{l1/2}$	$Ir(k)_{l2/2}$	...	$Ir(k)_{lw/2}$	...	$Ir(k)_{lN_s/2}$

	u	$Ir(k)_{l1/u}$	$Ir(k)_{l2/u}$	...	$Ir(k)_{lw/u}$	...	$Ir(k)_{lN_s/u}$

	N_p	$Ir(k)_{l1/N_p}$	$Ir(k)_{l2/N_p}$	...	$Ir(k)_{lw/N_p}$	...	$Ir(k)_{lN_s/N_p}$
Min. element in the column		$Ir(k)_{l1}$	$Ir(k)_{l2}$		$Ir(k)_{lw}$		$Ir(k)_{lN_s}$

The analysis of the w^{-th} of the table. 1 shows that if on the k^{-th} frequency channel information is transmitted from user $SU l$ to user $SU w$, then the speed of information transmission is determined by the user $SU u$, which disturbs the indicated connection to the greatest extent. For this reason, the rate of transmission of information from user $SU l$ to user $SU w, w = 1, 2, \dots, N_s$ to k^{-th} frequency channel is:

$$Ir(k)_{lw} = \min_{u = 1, 2, \dots, N_p} \{Ir(k)_{lw/1}, Ir(k)_{lw/2}, \dots, Ir(k)_{lw/N_p}\} \quad (18)$$

The rates of information transmission for all w determined by (18) are presented in the last row of the table. 1.

Since, in principle, a user $SU l$ can transmit information to any user, $SU w, w = 1, 2, \dots, N_s$, the rate of information transmission is maximal for that user $SU w_0$ for which:

$$Ir(k)_{lw_0} = \max_{w = 1, 2, \dots, N_s} \{Ir(k)_{l1}, Ir(k)_{l2}, \dots, Ir(k)_{lN_s}\} \quad (19)$$

According (19), it can be summarized that the communication connection "transmission of information from the user $SU l$ - reception of information from the user $SU w_0$, in which the speed of information transmission on the k^{-th} frequency channel is the highest, is determined by the maximum element in the last row of the table 1.

After applying the described procedure for each user $SU l, l = 1, 2, \dots, N_S$ and for each frequency channel, the one-way communication connections (lines) "transmission of information from the user $SU l, l = 1, 2, \dots, N_S$ - receiving information from the user $SU w, w = 1, 2, \dots, N_S$, maximizing the speed of information transmission in the secondary SDR - RCN.

3. CONCLUSIONS

In conclusion of this paper, it is necessary to note the following circumstances in particular:

- First, the criterion "maximum information transmission rate" for allocation of OFDM channels among users of the secondary SDR - RCN is suitable for many cases, but it is not universal. Therefore, in situations where there are specific requirements for the operation of the secondary SDR - RCN, then some combination of the approaches should be used at the stage of allocation of OFDM channels between users.

- Second, in cases where the secondary SDR - RCN is used for the needs of the police, army, civil defense, etc., the main problem of ensuring maximally noise-protected and secure communication comes to the fore.

ACKNOWLEDGMENT

This publication was prepared in fulfillment of Project BG05M2OP001-2.016-0003, "Modernization of Vasil Levski National Military University and Sofia University "St. Kliment Ohridski" - Sofia, in professional direction 5.3 Computer and communication equipment", financed by Operational program "Science and education for smart growth", co-financed by European union by European structural and investment funds.

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CYBERSECURITY RECOMMENDATIONS AND BEST PRACTICES FOR DIGITAL EDUCATION

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DOI: 10.19062/2247-3173.2023.24.6

***Abstract:** In light of Covid-19, there has been an increasing trend over the past few years to use e-learning platforms more frequently. Hackers use various methods to play with the human mind of the learner or instructor, using their unexperienced internet habits. The article examines the risks and benefits of using augmented, mixed, and virtual reality applications in e-learning. Good practices for cyber risk assessment and measures to improve cyber security are shown.*

***Keywords:** digital education, cybersecurity risk, network security*

1. DISTANCE LEARNING

With the development of modern computer and communication technologies and Internet connectivity, it becomes possible to create digital learning content by simulating different types of activities, such as driving a robot, car, plane, etc. At the same time, computer-aided technologies for training, design and training are getting a big boost in development.

It is apparent that information and communication technologies (ICT) must be used in education. The "e-Europe" program aims to successfully integrate ICT systems into educational institutions. It can benefit all stakeholders and solve difficulties of a different kind, such the issue of traditional classrooms' time and space constraints [1]. Additionally, students and teachers have access to a wealth of current and varied information through the use of ICT and related software and hardware, which can help students learn and teachers create lesson plans. The dynamic nature of information technology development has led to the rapid development of learning approaches, upgrading from classrooms to providing learning materials on flash/CD and moving into the world of e-learning and cloud technologies.

Electronic learning (e-learning) is a course in which the delivery of learning content is in an electronic format. Communication between users and knowledge control is done with the help of computer technology.

The flexibility and cost of online education are its two main benefits. Students who have more flexibility can access lectures whenever they want, making it easier for them to balance their family obligations, career commitments, and course loads. The cost-effectiveness of online education is another major draw; classes there are far less expensive than those at regular colleges. A student can acquire an education at a fair price regardless of background thanks to the extensive reach of online learning. Their improved standard of living is a result of this education [6]. E-learning can be divided into several types:

- CBT – Computer-based training);
- TBT - Technology-Based Training – technologies are used in training. It usually takes place outside the "classroom";
- Web-based training – self-study using the resources of a Web browser;
- Distance learning.

2. RISKS AND BENEFITS OF USING VIRTUAL, MIXED AND REALITY APPLICATIONS

In many cases, a combination of several types is used in the implementation of e-learning, and in the last 10 years, in addition to entertainment, virtual, augmented and mixed reality technologies have been widely used as a supplement to technology-based learning and allow the combination of high technologies and traditional learning approaches.

- ↪ VR - virtual reality is a computer-generated reality with a 3D image and in most cases with sound.
- ↪ AR - augmented reality refers to computer-aided perception or representation that augments the real world with virtual objects. With integrated cameras in mobile devices, additional objects or information can be included in the current image of the real world.
- ↪ MR - in mixed reality, either augmented reality (Augmented Reality), which requires AR-glasses, or augmented virtuality in the sense of connecting with reality is expanded.

The benefits of using such technologies are time-proven and can include:

- Education independent of time and place, but only of hardware and software connectivity;
- Personalized and flexible training;
- Learning through experience - acquired information is perceived as experience;
- Ability to judge environment and extract context;
- Ability to standardize a certain environment and study the behavior of learners;
- Ability to analyze and review the actions that led to one or another scenario;
- Introduction of uniform evaluation criteria;
- Ability to introduce policies for mandatory and recommended activities to be performed;
- Ability to simulate dangerous experimental situations, in order to carry out experiments without the participants being physically endangered;
- Ability to quickly and easily switch from one virtual environment to another virtual environment.

Some of the disadvantages include vertigo, loss of spatial orientation, nervousness, addiction but also vulnerability to malicious attacks – denial of service, voice theft, fingerprinting, eye tracking, malware use, hacking attacks, ransomware and denial of service attacks, spoofing, fraud and data theft, privacy and data integrity issues, etc. [6]

Online classes are more vulnerable to cyber-attacks than computer-based learning, especially from the point of view of end-user security. Cyber risks that can threaten [3] the safety of online learners include [8]:

- Deliberate software attacks (viruses, worms);
- Software bugs and errors - problems of a technical nature at the physical and channel level;

- Human errors due to ignorance or mistakes;
- Intentional unauthorized access, espionage or intrusion to collect data);
- Sabotage/vandalism damage to information or system);
- Equipment damage;
- Intentional theft (unlawful taking of equipment or information);
- Theft of intellectual property;
- Deviations in the quality of service due to outdated technologies;
- Extortion to disclose information.

Given the observed increase in the use of virtual/augmented reality technology, potential cyber vulnerabilities and threats must be considered. Cyber-attack scenarios [5] related to VR/AR can include:

- Illegal recording and data theft of user behavior – Hackers record user behavior in their VR/AR environment and threaten to publicly release the recording unless a ransom is paid
- Inserting information or data into VR/AR to mislead or entice users to select items that exfiltrate personal information
- Sabotaging the availability of VR/AR devices to disrupt important workplace meetings
- Using fake VR/AR apps that steal personal information or exfiltrate behavioral data
- Replacing educational or training content with malicious content or taking over the VR/AR ecosystem and demanding a ransom.

3. MEASURES TO REDUCE CYBER RISK

In order to apply adequate measures to a specific distance learning system, it is necessary to conduct a test and analysis/evaluation of the e-learning system.

Nevertheless, to have a secure environment for use, a cybersecurity requirements must be met, the following elements [2] must necessarily be included:

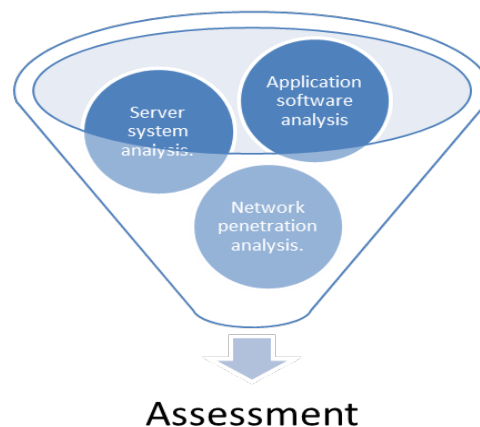


FIG.1 Assessment of e-learning system

An example methodology for assessing the cyber security of an electronic learning platform is shown in Table 1.

Table 1: Cybersecurity e-learning platform methodology [2]

№	Activity / Test phase	Instruments	Expected Output
1.	Information Gathering (Reconnaissance)	<ul style="list-style-type: none"> - Netdiscover; - Nmap/ZenMap; - Dnesenum; - DNSMap. 	<ul style="list-style-type: none"> - IPs; - Network topologies; - Active services; - Used applications
2.	Vulnerability Scan (Scanning phase)	<ul style="list-style-type: none"> - OpenVas; - Nessus Scanner; - Nmap; - BED 	<ul style="list-style-type: none"> - Network Vulnerabilities; - OS Vulnerabilities - Web Vulnerabilities; - DB Vulnerabilities
3.	Network Security Assessment: (Testing the network services and components)	<ul style="list-style-type: none"> - Cisco torch; - Cisco Auditing Tool; - Cisco Global Exploiter; - Aircrack-ng; - Fluxion; - Ghost Phisher; - Nmap 	<ul style="list-style-type: none"> - users, passwords; - firmware vulns. exploits - misconfigurations; - Authentication Control; - Traffic encryption
4.	OS Security Assessment	<ul style="list-style-type: none"> - OpenVas Scanner; - Nessus Scanner; - Metasploit - Core Impact; - Searchsploit. 	<ul style="list-style-type: none"> - users, passwords; - OS vulns. Exploits; - Configuration check; - Security Update Status
5.	Web Security Assessment (Web App check)	<ul style="list-style-type: none"> - Burpsuite; - Webscarab; - Owaspzap; - Nikto; - Metasploit 	<ul style="list-style-type: none"> - XSS; - SQLi; - webApp (apache, nginx) vulnerabilities; - Update status; - Denail of Service; - URL manipulation
6.	DB Security Assessment	<ul style="list-style-type: none"> - Sqlmap; - Sqlninja; - Oscanner; 	<ul style="list-style-type: none"> - users, passwords; - SQLi; - Privilege and role grants; - Data encryption; - Authorization Control; - Configuration Checking; - Update Status.
7.	Final Penetration testing report (detailed pentesting process overview)		<ul style="list-style-type: none"> - Assessment Overview; - Found Vulnerabilities; - Risk Factors; - Tools used; - Summary of Findings; - Evidence - Remediation and patching; - References
8.	Cybersecurity requirements definition	<ul style="list-style-type: none"> - Using Penetration testing report as a detailed cyberhealth estimation overview of the target network/system. 	<ul style="list-style-type: none"> - Personalized cybersecurity policy; - Personalized cybersecurity recommendations

Network security is a responsibility for the whole institution. Network administrators and protectors can maintain up-to-date knowledge of threats and counter measures through exchange of information with peers, government and others. The contribution of users cannot be underestimated in the security of any network and related information. [3]

Cybersecurity policy and requirements for e-learning platforms includes: Requirements for System (server) administrators; Account policy; Permissions and Access policy; Network Security Policy Data Loss Prevention frontend web application and backend DBMS security policy; Update and Patch Policy;

Requirements for e-learning software (front-end, application) administrators: Requirements for users – teachers and instructors; Safety and security rules; General password requirements; Requirements for users – students and learners; Safety and security rules; **Error! Bookmark not defined.** Anti-Malware Policy; General password requirements

Measures to improve cyber security of VR/AR systems: [5]

- Using secure messaging between VR/AR devices and a centralized content system
- Encrypting incoming and outgoing connections to and from VR/AR devices and a centralized content system
- Use appropriate identity and authentication mechanisms and a centralized ecosystem to manage agent communications with the master server
- Protecting the applications and firmware that are installed on the devices
- Installing anti-tampering software on user firmware
- Storing the key by applying security concepts – such as encryption or data masking
- Protection against device and identity impersonation
- Force authentication of communication between VR/AR devices
- Monitoring for unusual behavior of the VR/AR device, application and ecosystem.

4. CONCLUSION

To maintain a high degree of common cyber hygiene and cyber resilience, all personnel must adhere to the established standards and the cybersecurity policy. A platform that is based on the internet can never be completely safe because it allows network access and hacker assaults are always evolving. Administrators must be knowledgeable and qualified in order to respond effectively to emerging trends and threads. The systems and software are kept up to date, cybersecurity awareness training is given to all users, and social engineering is still a successful attack vector.

ACKNOWLEDGEMENT

The creation of this paper was possible by the active support of the participants in National Science Program "Security and Defense" financed by the Ministry of Education and Science (MES) of the Republic of Bulgaria.

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SYSTEMS WITH ARTIFICIAL INTELLIGENCE FOR DEFENSE AND SECURITY

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DOI: 10.19062/2247-3173.2023.24.7

***Abstract:** To date, artificial intelligence systems are predicted to rapidly enter the defense and security sector. The importance of such automation systems is still under research, in order the qualitative and quantitative indicators for decision making to be improved. In such researches, real-time data analysis tools have to be used and their data exchanged. Common examples are surveillance drones, large amount of sensors and the connection to cloud computing. In the field of cybersecurity AI algorithms undergo continuous revolution. By the use of Artificial intelligence algorithms predictions are the key results for adequate and correct decisions. Huge amounts of data processing define the possibility to make right decisions in non-deterministic environments. In this review report an overview of the already used systems is made and benefits and risks of using artificial intelligence systems in defense and security is examined.*

***Keywords:** Artificial intelligence, defense and security, military weapons*

1. INTRODUCTION

AI technology in military science is applied in four primary domains, namely logistics, reconnaissance, the cyber domain, and electronic warfare. Advanced AI applications have already been implemented or are currently undergoing testing in the logistics, reconnaissance, and cyber domains [1]. In wartime, through the implementation of computational agents and artificial intelligence, the aim is to reduce the costs of servicing the army. Artificial Intelligence (AI) systems can be used in a variety of ways in the military and can provide significant advantages. Here are some of the examples of AI systems in the armed forces:

1) Threat detection: AI algorithms can be used to analyze large amounts of data in real-time, such as satellite imagery, radiolocation ISAR images [16] and social media data, to provide early warning of potential threats and identify patterns that may not be easily recognizable to humans.

2) Logistics and supply chain management: AI systems can be used to optimize logistical operations by predicting the best routes and supply schedules, and by automating tasks like inventory management and maintenance.

3) Remote operations: AI systems can be used to control unmanned vehicles, such as drones and ground robots, to perform a wide range of functions such as reconnaissance, surveillance, targeted strikes and logistics.

4) Cybersecurity: AI-powered cybersecurity systems can detect and respond to threats in real-time, protecting sensitive military data and networks from cyberattacks.

5) Training and simulations: AI can be used to create realistic virtual simulations that help soldiers train for different battle scenarios in a safe and controlled environment.

- 6) Smart weapons that use AI to increase accuracy and targeting capabilities.
- 7) Autonomous ground vehicles (AGVs), like unmanned vehicles, can perform a variety of tasks, some of which are: logistics and transportation, search and rescue.
- 8) Predictive analytics programs that use AI to analyze large amounts of data to identify patterns and make predictions about future events.

Artificial intelligence machines and agents in particular are programmed to assist soldiers both in an attack and in the event of insecurity (Fig.1) [2]. AI agents are influenced by paralinguistic, demographic, visual and physiological factors. Through acoustic (paralinguistic) improvements to the robots, it is aimed to accurately and clearly convey the information that is necessary for the successful completion of military operations. The interaction between agents and people is determined by demographic factors. Through physical characteristics such as gender and age, the smart agents assess the soldier's reaction and make a decision how they can cooperate with it. By using computer vision, agents recognize patterns, but the information provided is not the most accurate and correct due to various circumstances on the battlefield, such as noise disturbances caused by explosions and gunfire (visual factors). Training the machine with AI allows monitoring the emotional state of the soldier and, if necessary, taking the actions needed, while physiological factors play an important role.

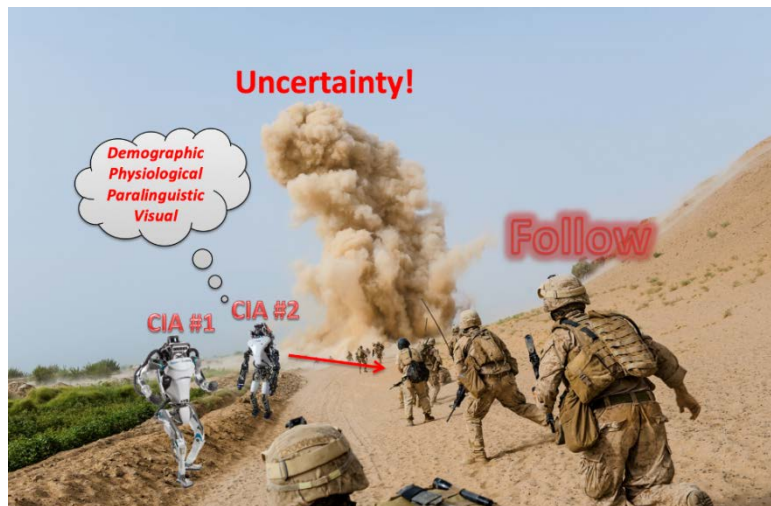


Fig. 1 A theoretical agent reacting to uncertainty in a soldier-agent mission [2]

2. WEAPON SYSTEMS WITH AI IN THE ARMY

Regarding autonomous, weapon systems can be broadly categorized into three tiers:

- 1) Partially automated weapon systems (human in the loop).

A weapon system, once activated, is designed with the sole purpose of engaging individual targets or specific target groups that have been deliberately selected by a human operator [7]. Some of them are: Black Hornet, Samsung SGR-1, LRASM.

- 2) Human-monitored intelligent weapon systems (human on the loop).

The term “autonomous” is commonly utilized by engineers to denote systems that operate independently without direct human intervention. In the military, some of the systems are highly automated, but are not yet classified as fully autonomous as they operate under the supervision and direct control of humans. Additionally, even though equipped with weaponry that possesses certain automated functionalities, such as laser-guided missiles and GPS-guided bombs, these systems still depend on human operators to directly control and make all decisions regarding targeting and firing [8].

Examples of weapon systems that fall into the “human in the loop” category include Israel's Carmel tanks and Aegis combat system, as well as missile defense systems such as the Patriot and Iron Dome systems.

3) Weapon systems that operate fully autonomously, without the need for human intervention or oversight (removing humans from the decision-making process).

As of now, no military utilizes fully autonomous weapons systems. The concept of a fully autonomous war is currently only a dystopian vision within the realm of AI-assisted warfare. [1].

There are a number of AI systems successfully integrated into the military. Some of them are:

Black Hornet Nano – it is a small unmanned aerial vehicle created by Prox Dynamics AS in Norway. It is utilized by the armed forces of multiple countries including Norway, the United States, France, the United Kingdom, Germany, Ireland, Australia, the Netherlands, Poland, New Zealand, India, Turkey, South Africa, and Algeria. The drones have dimensions of approximately 16×2.5 cm and offer ground troops with immediate situational awareness in their immediate surroundings. They are compact enough to be held in one hand and weigh 18 g with batteries. The UAV is outfitted with a camera that provides the operator with both video footage and still images [3]. Drones have proven to be highly valuable assets in Ukraine, particularly in reconnaissance missions and the gathering of data for artillery purposes [4].

Samsung SGR-1 – It is a semi-autonomous weapon system that patrols the border between North and South Korea. SGR-1 detect and target but requires a human operator to approve the kill shot [9]. The Samsung SGR-1 incorporates advanced heat and motion detection technology, enabling it to identify potential targets at distances exceeding 2 miles. Equipped with a 5.5 mm machine gun and a 40 mm grenade launcher, the SGR-1 is capable of engaging and neutralizing these identified targets effectively [10].

LRASM – A mobile missile launcher whose targets are selected, modeled and programmed before launch by human operators. LRASM (Long Range Anti-Ship Missile) is specifically engineered to detect and eliminate high-priority targets present within groups of ships, even in challenging electronic warfare jamming conditions. It possesses the capability to engage and neutralize these targets from extended distances. The LRASM is directed at enemy ships up to 200 nautical miles from its launch aircraft. This missile system receives new information through a data link and on-board sensors.

Israel's Carmel tanks are equipped with smartphone-sized AI. The Carmel is a manned vehicle that incorporates a significant level of automation, utilizing Artificial Intelligence to oversee numerous functions of the tank. Weighing thirty-five tons and equipped with tracks, the Carmel requires a crew of two to operate effectively [6]. Carmel collects data from infrared and radar sensors and uses them to determine the location of enemy fighters located in trenches hidden underground on the battlefield. The data obtained is transmitted to the commanding officer and under his control, it is processed in order to prepare a battle plan using the best methods of attacking each of the targets.

Aegis Combat System (ACS) – AEGIS is an advanced system that detects, tracks and destroys enemy targets through advanced radars, automatic detection and tracking, a versatile multifunctional radar system with a phased array antenna and powerful computers. Through specialized radars, the system tracks more than 100 concurrent objectives. The central component of the Aegis combat system is the automated directive and choice module. This interface empowers the Aegis combat system to execute concurrent operations against various threats involving multiple missions, encompassing air defense, surface attack, and submarine defense [12].

Patriot is a surface-to-air missile (SAM) system that include a command center, a phased array radar station, power generation equipment, computers and up to eight launchers, each containing four ready-to-fire missiles [14]. The Patriot system covers an area of around 68 kilometers. Its radar can track up to 50 targets and engage five of them at once. Depending on the version in use, the interceptor missiles can reach an altitude of more than 24 kilometers and hit targets up to 160 kilometers away. Each unit requires about 90 troops to operate [13], with only three soldiers sufficient during combat.

Iron Dome weapon systems detect, evaluate and intercept a variety of short-range targets such as: missiles, artillery and mortars. These systems are designed for utilization round the clock and irrespective of atmospheric conditions. The Iron Dome features a multi-purpose launcher designed to fire a variety of interceptor missiles. Iron Dome's Tamir missile takes down incoming threats fired from ranges of 4-70 km. Tamir missiles have electro-optical sensors and guidance vanes with high-explosive warheads [15].

3. BENEFITS AND RISKS OF USING ARTIFICIAL INTELLIGENCE IN DEFENSE AND SECURITY

There are several benefits of using artificial intelligence in defense and security, including:

1)Enhanced surveillance: AI can help in monitoring and analyzing vast amounts of data coming from various sources such as satellites, drones, and surveillance cameras. This can help identify potential security threats and predict criminal activities.

2)Improved threat detection: AI algorithms can be trained to detect an array of threats such as unauthorized access, malware, and other cyberattacks, which can be tough for traditional security systems to detect.

3)Real-time decision-making: With AI, commanders can get real-time insights and situational awareness that enables them to make informed decisions faster.

4)Cost savings: By automating certain tasks and reducing manual labor, AI can help reduce the operating costs of a security system.

5)Enhanced defense capabilities: AI can help in the development of advanced weapons systems and technologies such as autonomous vehicles and drones, making defense and response more efficient and effective.

As with any technology, there are also potential risks of using artificial intelligence in defense and security. These risks include:

1)Dependence on technology: There is a risk of over-reliance on AI, resulting in potentially catastrophic consequences if the technology fails, or produces incorrect results.

2)Bias and discrimination: AI systems are trained based on data, and if that data contains bias, the system may produce biased results. This could contribute to, for example, discrimination in the selection of potential security threats.

3)Increased vulnerability: AI systems can become targets for attacks from hackers and cybercriminals, who may exploit flaws in the system's design or programming to conduct their activities.

4)Lack of transparency: Numerous AI systems exhibit intricacy and opaqueness, making it challenging to comprehend their result-generation mechanisms. This absence of clarity can have detrimental consequences as it creates a breeding ground for errors and malicious activities to go unnoticed.

5) Ethical considerations: The use of AI in defense and security raises ethical considerations, such as the potential for autonomous weapons, which raises concerns about accountability and the need for human control.

CONCLUSIONS

AI is a powerful tool in defense and security, providing improved situational awareness and threat detection capabilities with the ultimate goal of improving the country's national security. Although AI has enormous potential in defense and security, it is necessary to consider both the benefits and risks when developing and deploying these systems. Adequate oversight and transparency are needed to minimize AI risks in defense and security. AI has significant potential benefits in military applications, as well as several considerations for ethical and legal use of AI in the military, including accountability and oversight for autonomous systems, potential for bias, and ensuring compliance with international laws of warfare, and lastly – own security risk precised. The battlefield is an extremely dangerous place, and AI can mitigate some of the threats that the military personnel faces. A prime example of how AI keeps soldiers safer during combat is identifying hazards more quickly, and providing soldiers' guidance on how to deal with potential hazards. Today's ground vehicles and military aircrafts have intelligent sensors, radars and advanced computing, which is of great benefit to the military as it reduces the risk to human life, but future algorithms development is inevitable for evolution proceeding.

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Management and Socio-Humanities

THE ROLE PLAYED BY WOMEN IN THE SECURITY SYSTEM: FROM UN RESOLUTION 1325 TO DIRECT ACTIONS

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DOI: 10.19062/2247-3173.2023.24.8

***Abstract:** The role of women in the security and defense system has become increasingly visible in recent decades. Since the adoption of Resolution 1325 Women, peace and security of the Security Council of the United Nations Organization, on October 31st, 2000, member countries of this international organization, including our country, have taken steps to assume and implement new policies in the field of conflict resolution, peacekeeping, humanitarian assistance, which actively involves women. On the other hand, the intrinsic importance of women in the leadership and management of military structures, makes all legislative approaches related to this subject take concrete consistency.*

***Keywords:** female leader, gender, equality, legislative measures, leadership.*

1. INTRODUCTION

Gender equality is a concept that is frequently discussed in various environments, a subject as sensitive as it is complex, encompassing a number of elements that arouse controversy. This implies the existence of equality between women and men, both in terms of their rights and opportunities, with the help of tools to eliminate psychological and social barriers that could jeopardize their achievement.

Nowadays, topics such as gender equality and equal opportunities between women and men are present in all social spheres, including security and defense, both at the national level and within international organizations such as the UN, NATO, EU, OSCE.

The United Nations presents gender equality as one of the global issues that it manages, but which still does not have a deeply visible solution at the level of all states. Respect for human rights is closely connected with equality between women and men, with a human aspect at its heart. This equality does not mean only equal access to resources or equal control over them, but also equal implication in decision-making and implementation and access to key, leadership positions.

In this sense, the provisions of Resolution 1325 of the UN Security Council on Women, Peace and Security are applied or in the process of being applied at the level of many states and international organizations, which are developing the legal and application framework to encourage the participation of women in missions and international peacekeeping operations, but also for their increased representativeness within the leadership systems at the level of public authorities or within the security and defense system.

2. THE ROLE OF SECURITY COUNCIL RESOLUTION 1325 IN TODAY'S WORLD

„United Nations Security Council Resolution 1325 Women, peace and security, adopted on 31 October 2000, affirms the important role of women in conflict prevention and resolution, peace negotiations, peacebuilding, peacekeeping, humanitarian response and post-conflict reconstruction and emphasizes the importance of the full participation and involvement of women in all efforts to ensure and promote peace and security.”[1]

There are 4 pillars on which Resolution 1325 rests, namely: **participation, prevention, protection and relief and recovery**. These pillars refer, on the one hand, to the involvement of women in the decision-making process at the national and international level, within the conflict resolution mechanisms, but also their participation in international peacekeeping missions under the auspices of the UN and the undertaking of measures to avoid violence against women during and after conflict and on the other hand to protect women against any type of sexual violence, including in the situation where they are in refugee camps and to support women by addressing their needs including in refugee camps.

By adopting Resolution 1325, the UN Security Council emphasized the fact that all conflicts involving the civilian population have a particularly strong impact on women and children, and at the same time, highlighted the idea that women have a particularly important role in achieving peace, maintaining it, but also in the post-conflict reconstruction period. This resolution has legal force and applies to all UN member states. In order to apply and implement the document, the UN Security Council supported the governments of all member states, but also civil entities, academic communities and other entities interested in developing and implementing action plans for the introduction of the gender perspective in the field of security and defense, by encouraging women to actively participate in peacekeeping missions, but also in post-conflict reconstruction missions.

At an international level, there is an Agenda on this topic, since its adoption eight more resolutions on this topic have been adopted, as follows:

- Resolution 1820/2008, which focuses on sexual violence as a war tactic;
- Resolution 1888/2009, which emphasizes the importance of UN maintenance missions of peace in the system of support and protection of women and children in conflict situations;
- Resolution 1889/2009, requesting the UN Secretary-General to bring to the attention a series of indicators for the application of the provisions of resolution 1325;
- Resolution 1960/2010, which calls for the creation of lists of people who commit violence against women;
- Resolution 2108/2013, which requests that the UN member states get involved in the application of the provisions of the Security Council resolutions on Women, Peace and Security;
- Resolution 2122/2013, which elaborates measures to encourage and support the involvement of women in the resolution of conflicts at the UN level and beyond, and calls for the reduction of any impediments to this endeavor;
- Resolution 2242/2015, which focuses on new elements that have an important impact in this field: climate change, violent extremism, the increasing number of refugees and internally displaced persons;
- Resolution 2467/2019, which emphasizes the importance of eliminating sexual violence in conflict, elaborating measures to eliminate it.

Considering the importance of the mentioned theme in the contemporary security environment, the implementation of the Women, Peace and Security Agenda had and has echoes within other international organizations as well. At NATO this was achieved through the BISC Directive 40-1 Integration of UNSCR 1325 and the gender perspective in the NATO command structure, including protection measures during armed conflicts. The NATO document is an action plan that addresses the gender perspective, both at the level of NATO forces and in the plan of operations and missions that take place under the auspices of NATO. In the view of the North Atlantic Organization, the inclusion of the gender perspective must be carried out both in the planning stage, but also at all operational and management and evaluation levels. Deep awareness of this tool is the starting point for its implementation, at least at the organization level.

At the level of the European Union, the Women, Peace and Security Agenda is the mechanism by which equal opportunities between women and men are managed, as well as aspects related to violence and security, both inside and outside its borders. The overall vision of the Global FPS Agenda aims to achieve gender equality, peace and security.

In 2018, the EU Foreign Affairs Council adopted the Conclusions on Women, Peace and Security (WPS) and the EU Strategic Approach to WPS, which wish to underline the full implementation of the WPS Agenda and the UN Strategy on Gender Equality, Peace and security.

The EU Council underlines the political importance of the WPS Agenda and welcomes its integration into various EU policies and action plans since the adoption of the Council conclusions in 2018. In this regard, the European Commission adopted the EU Gender Equality Strategy 2020-2025 and the EU Gender Equality Action (GAP) III "An Ambitious Agenda for Gender Equality and Women's Empowerment in EU External Actions" 2021-2025, welcomed by the Presidency conclusions of 16 December 2020. *"The Council invites the High Representative and the Commission to report with on actions taken and lessons learned in the implementation of WPS commitments in reporting on the various policies and action plans and draw operational conclusions to accelerate actions in this regard."* [2]

The Council also notes that the implementation of the entire FPS Agenda remains a key priority for the EU-UN strategic partnership on peacekeeping and crisis management, as endorsed in its conclusions of 24 January 2022, as and for partnerships with other international and regional organizations such as the OSCE, NATO and the African Union. It calls for stepped-up efforts to accelerate the operationalization of the joint EU-UN engagement on FPS, with particular attention to the protection of human rights defenders and women involved in peacebuilding against reprisals, threats and violence. *„The Council encourages the EU and its Member States to systematically adopt a gender-sensitive approach and integrate a gender perspective and analysis, as well as the participation of women in all EU external actions, including all CFSP/ CSDP, civilian and military, as well as to political dialogues, human rights dialogues and international partnerships."* [3]

Therefore, as concerns the two previously mentioned international organizations, NATO and the EU, the WPS Agenda is assimilated and integrated into their action plans and policies, being an important tool for managing the issue of integrating women into various management teams and encouraging women's participation in construction and peacekeeping operations and missions in areas marked by conflicts, but also in areas requiring reconstruction.

3. THE ROLE OF WOMEN IN THE SECURITY SECTOR IN ROMANIA

In the last 50 years, society has gone through multiple periods marked by economic or social transformation, which determined the implementation of new social roles related to women, some of which belong to the field of security. Despite this aspect, the social image of the woman is still connected with the household, raising children, and that of the man with the idea of supporting the family financially, the social perception towards the roles of each gender has not improved to a satisfactory level.

3.1 Gender equality at the national level

At a national level, Romania has a legislative framework that refers to gender equality and combating discrimination, which was based on the Convention on the Elimination of All Forms of Discrimination against Women, concluded in New York on December 19, 1979 and ratified by the Decree State Council no. 342/1981, which refers to the social, economic and political rights of women, being a first approach to equal opportunities between women and men, in all social sectors.

Subsequently, a series of subsequent documents related to this subject were issued, which regulate the promotion of equal opportunities between women and men, in order to eliminate direct and indirect discrimination based on sex, in all spheres of public life in Romania.

„Due to the awareness of the importance of UNSCR 1325 (2000), but especially the specific activities carried out, in 2014 the Implementation Plan was developed at the level of the Ministry of National Defense of UN Security Council Resolution 1325/2000 "Women, peace and security" and related resolutions, as well as the complementary documents approved at the level of various international organizations, of which Romania is a member - 2014-2024.”[4]

In our country, the Ministry of National Defense is the structure responsible for the integration of the National Action Plan.

The Ministry of National Defense is staffed by female personnel, both military and civilian personnel, who are employed in executive and management positions, at all hierarchical levels. From the point of view of the positions that can be occupied by women, in the Ministry of National Defense there are no regulations that prevent women from accessing certain positions, military or civilian, obviously in compliance with the general regulations corresponding to weapons and military specialties.

„Beginning in 2001, the Romanian Ministry of National Defence resumed a female recruitment and selection programme aimed at developing, utilizing and promoting women according to their genuine professional skills and potential.”[5]

Moreover, with our country's accession to NATO, the Romanian Army went through an extensive modernization process, which consisted of revisions on multiple levels, including: human resources field, and womens' access to the army that became unrestricted.

However, in 2005, at the level of Ministry of National Defense, it was decided that the number of women admitted to military institutions should be limited. The reason was the number of women who were admitted to the army in the period 2001-2005, was more than 50% of the total number of candidates to the military profession.

Nevertheless, as of 2017, this limitation has been removed, and the number of vacancies for access in military institutions was not restricted by gender.

3.2 Female leadership in national defense

At the military institutional level, the leadership is the most important segment that ensures the survival and the development of the organization.

Regardless of the resources, policies and strategies at their disposal, organizations cannot function without strong leadership and without decision-makers able to make correct, firm and timely decisions.

In the military field, as I mentioned before, the presence of women in military institutions is a relatively recent one. Also, „*at the level of NATO member states, the average number of military women present in armies is approximately 12%, an increase compared to 2015, when it was recorded only 10.8%.*”[6]

Despite these low numbers and all the stereotypes existing in the collective mind, in our country, women successfully occupy leadership positions in the military field, proving that they can be effective leaders in an organization that until recently was exclusively dedicated to the male side. Moreover, the way in which women led certain military structures or microstructures revealed that they possess remarkable leadership skills, and certain characteristics of them highlighted the importance and essential role they hold in the organization.

In military organizations, leadership is a complex of actions and activities that involve the ability to lead people and the organization itself, to establish and achieve the goals and missions related to the organization, to adopt decisions in a very short time, sometimes in crisis situations, to inspire, motivate, influence, encourage subordinates to perform at the highest level. These aspects can be put into practice by female military personnel, having the same effectiveness or even surpassing the level of effectiveness of male military personnel.

Addressing all aspects of the military leadership process requires a wide range of skills, cultures and a broad vision to make decisions with lasting impact. Increasing institutional performance, risk management, human resource management, solving crises that can arise in a very short time frame are just a few key areas that require answers filtered through a wide range of skills and talents of leaders. In the situation when we analyze the management of these issues from a gender perspective, we will find that the approach of female leaders can be different from that of male leaders.

In what follows, we will conduct a brief analysis based on empirical data of the attributes of military women in leadership positions that help them to establish a more constructive leadership relationship than men in similar situations.

First of all, by their nature, women possess both well-developed emotional and social intelligence, which makes it extraordinarily easy for them to interact with subordinates. The military environment is one in which teamwork, close cooperation between members of the organization is the key to solve many situations or even some crises. In this sense, the leader is the one who constitutes the link between individuals, being the facilitator of social relations.

Second of all, female leaders are highly organized, serious, and details-oriented. Regardless of the nature of the mission they have to perform, women focus deeply on accomplishing all the related tasks, sticking to the time and organizing the work in great detail. They focus on work results, but at the same time pays close attention to the needs of team members. These two aspects merge, and in this way, the effectiveness of female leadership increases.

In terms of communication style, the manner of conveying information, unlike men in management positions, who prefer to be as neutral as possible in communication, women in the same positions communicate with greater ease, using empathy, tending to help team members with their expertise to complete some challenging tasks for the team.

Moreover, an extremely important aspect specific to women leaders is the intuition.

This is „an immediate and irrational understanding of reality, a direct perception of spontaneously organized elements in a determined whole, or even "a kind of instantaneous and unpredictable illumination" that allow us to immediately understand the essence of a being or the solution of a problem.”[7] Intuition, along with big-picture thinking and emotional intelligence, are the foundation of a mid-term and long-term vision that any effective leader must have. Now, more than ever, the military organizational environment needs visionary leaders who have the ability to look into the future and to be able to easily adapt to future transformations. Women leaders in the military possess these important characteristics and they certainly help them in the process of leading troops.

CONCLUSIONS

United Nations Security Council Resolution 1325 Women, peace and security, adopted on October 31, 2000 and all subsequent resolutions and documents were the pillars on which the human resources policies were developed regarding the integration of the gender perspective in the Romanian Army. This organization needs strong, trained, professionally competent leaders who are able to make decisions in any type of situation in a complex, volatile, uncertain and ambiguous operational environment.

Despite the preconceived ideals about the military profession, intended until recently for men, despite all the existing prejudices and stereotypes, in the international environment, women demonstrate that they can perform the same missions and perform the same functions, based on the same standards and conditions, as men.

Leadership has no gender, and leaders should not be selected using this metric. In leadership, both female leaders and male leaders must pursue efficiency and achievement of objectives, and the natural, biological differences between the male and female profiles must be used in favor of achieving results beneficial to the military organization.

As such, the society as a whole owes it to give up prejudices or destructive mentalities, to become open to new aspects, to accept the idea that women can lead any organization, and the leadership positions in the Romanian Army are not only dedicated to the male gender, but these they must be filled by truly competent people with genuine leadership qualities.

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A HYBRID SECURITY THREAT

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DOI: 10.19062/2247-3173.2023.24.9

Abstract: According with NATO Capstone Concept for the Military Contribution to Countering Hybrid Threats and EU Joint Framework to Counter Hybrid Threats, approved a new Military Strategy that will help set out NATO's military priorities and approach to current and future challenges, including cyber and hybrid threats, instability across the Middle East and North Africa, and a more assertive Russia.[1]Hybrid conflict is defined as a dynamic interaction between elements of hard power (consolidation of military forces, deployment of military forces and capabilities in conflict zones, financing of separatist movements, activities to destabilize and undermine the security of a state or regions) and soft power (maintaining an economic or energy dependence, applying economic sanctions, conducting propaganda, disinformation and influence campaigns, conducting cyber attacks, etc.)[2]. Hybrid warfare encompasses a vast area of hostile actions in which military force is only a small part of a flexible strategy with long-term objectives, complemented by political, economic and informational methods.

Keynotes: hard power, soft power, hybrid war, hybrid threats

1. INTRODUCTION

Hybrid threats combine military and non-military as well as covert and overt means, including disinformation, cyber attacks, economic pressure, deployment of irregular armed groups and use of regular forces. Hybrid methods are used to blur the lines between war and peace, and attempt to sow doubt in the minds of target populations. They aim to destabilise and undermine societies. [3] Features of Hybrid War can be multidimensional and on the multilateral parts on society:

- exploits national vulnerabilities in political, military, economic, social, informational and infrastructural terms;
- can be initiated and carried out by both states and non-state structures;
- may use means of organized crime (corruption, blackmail, etc.) and terrorist actions, assassinations, crimes, other acts committed for the purpose of serious disturbance of public order;
- uses less visible attacks to be difficult to detect and often relies on digital information dissemination technology [4].

Hybrid threats present certain characteristics such as: "complexity, low vulnerability, difficulty to counter them, adaptability, increased lethality, use of nuclear, biological and chemical means, development of cybernetic war capabilities and damage to command and control systems through the use of anti-satellite programs".[5]

2. THE CONCEPT OF THREAT

The threat defines the totality of hostile actions, facts, intentions or strategies aimed at intimidation, potentially endangering the interests, values and national and international security objectives, affecting the normal activity of the institutions of the security structures, as well as those in the civil field. In the military literature, the threat is seen as the restriction and analysis of all information related to potential activities that may endanger state security. There are different approaches to the concept of threat, starting from a wide range of techniques and procedures of persuasion and manipulation, it can have references to the action of disadvantage and coercion, even reaching a psychic action carried out with the aim of influencing the victim to fulfill the established wishes of the aggressor.[6]

Military aggression of the Russian Federation on Ukraine led to the fact that in 2014 the system of international and regional security as well as the system was distorted international law. Virtually all international security guarantees of Ukraine (including the one in the Budapest Memorandum) can be considered unreal, given that the main aggressor pronounces himself as main guarantor – Russian Federation. "Hybrid war", from a structural and functional point of view, is unique: in form it is "hybrid", and as "asymmetrical" content. The character of the new hybrid war can be seen in the process of annexation in the spring of 2014 by The Russian Federation of Crimea, and later also in supporting separatist elements in the east Ukraine. Thus, analyzing each element of "hybrid warfare", is worth noting the fact that some elements have been used and in the classic wars of the past. The innovative character of this phenomenon resides in element correlation, dynamics and ability of their use, as well as increasing the role of the informational factor. Thus, the informational factor in some cases becomes independently, no less important as the military one. Although many researchers and polemicists point to the "hybrid" character of this war, however the conceptualization of this phenomenon remains incomplete.

Hybrid warfare "incorporates a wide range of means used in warfare, including conventional capabilities, irregular tactics and formations, terrorist acts, undifferentiated violence and coercion, as well as legislative confusions (gaps). These multimodal activities can be carried out by separate units or even by the same unit, but are generally operationally and tactically directed and coordinated in the central battle space to achieve synergistic effects".[7]

"Hybrid warfare" includes a wide spectrum of actions, in which the military component has an insignificant role. The main means of attacking the opponent are the political ones, informational, psychological and economic. These methods make it possible to achieve the necessary results - they cause political, economic and territorial damage to the opponent, disorder of the state and administrative system, demoralize society.[8]

Building the definition of hybrid warfare and hybrid threats firstly we can point out that they coexist with the conventional warfare. Actually, they are the sum of conventional and unconventional strategies as a whole, which will be explained further on this dissertation, and on a parallel line it is the mixed combination of all the types of warfare together. [9]

On the new paradigm of war Frank van Kappen states: "Hybrid warfare is a fusion of classical warfare with the use of new elements. The state that leads a "hybrid war", concludes agreements with non-state executors - fighters, groups of the local population, organizations, with which the connection is totally denied. These executors can perform actions that he himself the state would not allow them.

All actions non-state formations execute them dirty. Thus, the Russian Federation, through classic scenarios of maintaining frozen conflicts such as the Transnistrian one in the Republic of Moldova, Ossetian and Abkhaz in Georgia currently also uses energy resources as elements of "hybrid warfare"¹.

3. CYBER SECURITY - COMPONENT OF THE SECURITY ENVIRONMENT AND PART OF THE HYBRID WAR

Security is a state, as researchers in the field would say, it is influenced by the environment in which we live, the influences of international actors on it and the level of protection attributed to it, the security environment represents the totality of the influences of the system of international relations the evolutions of these relations, the changes in the balance of power, the strategic trends, the reaffirmation of certain states and all the registered changes that can affect the balance. 'Cyber-conflict' and 'cyber-war' serve as examples of the use of new technologies within the scope of hybrid threats. Cyber-war basically refers to a sustained computer-based cyber-attack by a state (or NSA) against the IT infrastructure of a target state. [10],[11]

The evolution of the technological field and technology is the main factor that allows us to use the virtual environment, along with its evolution, vulnerabilities and threats to it have also developed, and its security has become a priority both for the state and public institutions, as well as for organizations international organizations that outlined the protection of cyberspace as a priority, this priority gradually developing into a responsibility of the entire society and becoming an aspect of strategic importance. Opportunities to develop and implement interconnectivity in this environment offer new possibilities for economic, social, cultural growth and can develop a stable and strong security environment, but this can only be achieved if the level of protection is high and attention is given increased that is needed.[12]

The first step of defense against an asymmetric threat is the use of information, an advanced detection of threats is connected with the need to test the vulnerabilities of systems and remediate deficiencies, relevant training in real situations, development and enforcement of security policies are as critical as the level of development of technology. While standard defense technologies are always needed against standard hackers, avoiding an asymmetric attack requires advanced intelligence and analytics to effectively identify and address attacks.[13]

4. ASYMMETRY CONCEPT IN HYBRID THREAT WAR

Asymmetry "consists in refusing the rules of combat imposed by opponent, thus doing any unpredictable operations". [14] The asymmetric threat can be defined as "the wide range and unpredictability of military, paramilitary and information operations, led by nations, bodies, individuals or indigenous forces or by placing under their command, which specifically targets weaknesses and vulnerabilities in an enemy government or armed force"[15]. As a rule, conventional forces engage in war symmetrically, because asymmetric threats do not allow them to demonstrate the ability to destroy a relative, invisible enemy.

¹ The original publication of the interview with Frank van Kappen, 26 April 2014, in Russian, is available at <http://svoboda.org/content/article/25362031.html/>, accessed on 30.04.2023 on <https://www.svoboda.org/content/article/>

In the plus, asymmetric actors choose places like the jungle as their battlefield, the mountains and even the urban environment, where they attack and disappear, diminishing the advantage of the powerful, of the security and military forces of the states. In addition, asymmetric actors use the power of psychology to a cover the material inconveniences against the belligerents strong. In this regard, for example, device attacks improvised explosive devices or suicide bombings heighten the feelings fear of the adversary's military, but also of the population.

Asymmetric threats can be grouped into three broad categories: intelligence operations, weapons of mass destruction and unconventional operations. [16]

- attacks against infrastructures (for example: attacks against computer networks, electronic warfare, physical destruction);
- deception (for example: propaganda operations in the media of public communication, dissemination of false information, etc.);
- psychological operations (for example, taking hostages or distributing pamphlets, broadcasting radio or television shows or using other media to sow fear and discouragement).

Forms such as:

- the use of new tactics and terrain: the use of tactics unorthodox or unconventional terrain (eg urban space) by an asymmetric adversary can facilitate a direct attack on military materiel or operations, maximize the physical and psychological impact of an attack, and complicate possible military or police responses. An armed response in populated areas raises special problems, as the large number of civilians may prevent the attackers from being identified. In addition, a counterattack could further increase the number of civilian casualties;
- civil disobedience: an asymmetric opponent can generate a threats through strikes and riots, demonstrations, the illegal occupation of important points in a locality (communication centers, for example) and the initiation of boycotts in order to destabilize and discredit his opponents or cause them damage.
- This type of unconventional action is increasingly used in failed states (like Somalia) or countries that do not exercise political control over the territory. It should be mentioned that such unconventional actions do not only target the armed forces, but also the civilians in the attack area.
- the use of terror; actions such as intentional targeting a civilian populations in regions far from the main scene a conflict, hostage taking, kidnappings, mutilations, crimes and others criminal activities can lead to the appearance of terror in the heart of the population without the asymmetric attacker exposing himself to high risks.

Hybrid threats are the product of a wide variety of adverse circumstances and existing actions, such as terrorism, migration, piracy, corruption, ethnic conflict and more. Hybrid threats are not exclusively a tool of asymmetrical or non-state actors, but can be applied by state and non-state actors equally. [17]

5. CONCLUSIONS

In conclusion, a state or non-state actor that resorts to hybrid actions can create instability in the internal affairs of another state. Hybrid threats have a direct impact on defense and national security. This is for a number of reasons. First, they are usually generated by non-state actors such as:

- militias, mutant guerrillas, hybrid entities populated by terrorists, fanatics, "patriot bandits" and military deserters;
- orders of dissident generals, seniors of the war, or pure and simple bandits;
- unknown or imperceptible entities, capable of mutations and frightening alliance changes;
- groups with different orientations (religious, ethnic, ideological, political) that ignore international laws and including those that reveal humanitarian respect;
- different illegal organizations living in symbiosis with the economy criminal, in the triangle narcotics - weapons of war - oil. Then, hybrid threats combine, in a relatively random way, conventional and unconventional, symmetric and asymmetric methods and means of action to achieve the objectives established.

"Hybridization" can be found in the entire spectrum of combat actions and profoundly changes the conduct of modern warfare. This makes it very difficult to pinpoint when it started. Additionally, it increases the possibility that an actor using hybrid actions will deal significant damage to their opponent before they can respond or even detect a hybrid attack.

From this point of view, the states that bear the effects of hybrid actions must first of all understand the aggressor's strategy and identify, mitigate and possibly overcome the operational and strategic dilemmas associated with the operational environment.

Given that a "hybrid war" campaign means the conduct and direction of political, conventional, unconventional, asymmetric and cyber warfare, both directly and indirectly, on objectives in all domains and instruments of national power, the aware state that will be affected must prepare countermeasures and effective methods of their implementation.

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POLITICAL-MILITARY DOCTRINE, ITALIAN FASCIST DOCTRINE

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DOI: 10.19062/2247-3173.2023.24.10

Abstract: *Fascism was a political movement founded by Benito Amilcare Andrea Mussolini in 1919, dominating Italy's leadership between 1922-1945. In its various periods, fascism has received many different definitions, obviously based on quite different points of view. Each of them reveals to a greater or lesser extent the political essence of this contradictory and enigmatic phenomenon for the culture of the twentieth century.*

Keywords: *totalitarianism, political system, ideology, repressive attitude, dictatorship.*

1. INTRODUCTION

Ernst Thalmann characterizes fascism as an "armed counter-revolution presented as a mass movement and represented by Hitlerite organizations". In the same period, the Italian historian Delle Plane calls fascism a "preventive counter-revolution" and Luigi Longo qualifies it as "one of the forms of preventive counter-revolution".

Eugen Kox, in his desire to highlight the contradictory nature of fascism and, in particular, the contradiction between its mass social base, between the mass popular movement and the profoundly reactionary program it carries out, calls it a "reactionary revolution."

Wilhelm Reich in *Mass Psychology of Fascism*, without denying the role of the economic factor in the emergence of fascism, tries to explain its entire rise through psychological causes. Fascism constitutes "an affirmation of the irrational structure of man shaped by the mob."

All the definitions and characterizations mentioned above contain a partial truth. They simply reflect certain sides of the real political phenomenon called fascism. But none of them reveal the main basis of fascism, its specific essence. This was expressed relatively fully in the definition given to fascism by the 7th Congress of the Comintern: "an open terrorist dictatorship of the most reactionary, chauvinistic and imperialist elements of finance capital". Because precisely this financial capital is the basis of fascism, determining its program.

Without the presence of finance capital, fascism would have lost its nature, political essence and content. In general, without financial capital, fascism could not have become a movement of the entire nation and could not have seized state power. It is no coincidence that fascism appeared in the age of imperialism, in the conditions of a strong social crisis, which threatened the very existence of the capitalist system.

Fascists support violence, war and militarism as a provider of positive transformation in society, bringing a new spirit, education, instilling a desire to dominate in the character

of the people and creating national camaraderie through military service. Fascists see violence and war as actions, which create national regeneration, spirit and vitality.

2. ITALY AFTER THE TRAUMA OF THE WAR AND ITS ROLE IN THE CRYSTALLIZATION OF FASCIST IDEOLOGY

Fascism, a far-right political regime, appeared after the Great War in Italy as a product of economic and social difficulties such as: increasing financial expenses, tax increases, the crisis in the sale of industrial products, the decrease in purchasing power, the emergence of a labor surplus as a result of the war demobilizations, the accumulation of disappointments among those who linked their high hopes to the consequences of the war, seconded by the success and strengthening of the positions won by the socialist and communist political parties in the local councils and in the Parliament. "It had reached a rejection of everything that was considered to be of bourgeois essence"[1], and everything that had a bourgeois appearance was an object of aggression.

Disappointed in its territorial ambitions, prey to a crisis generating unemployment and often bloody strikes, processed by the socialist extreme left that in March 1919 joined the Third International and demanded the dictatorship of the proletariat, "Italian democracy, collapsed in governmental instability, it seems unable to prevent the civil war and the triumph of Bolshevism. In the face of this danger, fascism seems the only bulwark of order". [2]

The First World War and the economic crisis that followed generated the sociological and psychological conditions necessary for the constitution of the fascist movement, but they did not produce the fascist ideology. The war contributed to the final crystallization of fascist ideology by providing proof of nationalism's ability to mobilize the masses and showcasing the formidable power of the modern state. He highlighted new possibilities for economic planning and mobilizing both the national economy and private property in the service of the state. "The state was seen as an expression of national unity, and its power depended on the spiritual unanimity of the masses, but at the same time it was the guardian of this unity, which it supported by all available means".[3]

The war demonstrated how great the capacity for sacrifice of individuals could be, how superficial the idea of internationalism was and how easily all layers of society could be mobilized in the service of the state. He demonstrated the importance of unity of command, authority and leaders, moral mobilization, mass education and propaganda as instruments of power and, above all, "showed how easily democratic liberties could be suspended and how easily a quasi-dictatorship could be accepted". [3]

3. THE NATIONALIST AND REFORMIST PLATFORM

Against the background of these conditions, Benito Amilcare Andrea Mussolini's initiatives to form the association *Fasci Italiani Di Combattimento* (Italian Combat Fascisms) with a nationalist and reformist platform actually appeared on the Italian political scene.

If we were to characterize Mussolini in a few words, we could say about his character that he was a sum of contradictions, making up a complex personality, the thirst for action, the taste for violence and the ambition to succeed, define him completely. Mussolini was an extrovert, he liked to impress and impose his character. [4]

Under the political aspect, it provided for measures regarding the application of the democratic principles of strictly proportional representation, the right to vote and eligibility for women, lowering the age for electing deputies from 33 to 25, abolishing the

Senate and replacing it with technical councils chosen by professional groups, convening a National Assembly for the purpose of drafting a new fundamental law.

One of the essential features that dominates the structure of the fascist regime is the "primacy of the chief" symbolized by the formula: "Il Duce ha semper ragione!" ("The Duke is always right"). To give applicability to the formula "traditional institutions are emptied of their content or suppressed" [2] as in the case of the Chamber of Deputies replaced in 1928 by the Chamber of fascists and corporations, while all power was concentrated in the hands of the Duke, simultaneously head of government, minister of corporations and the leader of the armies.

Another basic feature of fascism was the "primacy of the party" identified with the state, its essential deliberative body being from December 9, 1928, the Great Council of Fascism which designates the candidates for deputy, being consulted less and less by the Duke.

The social field saw measures such as the regulation by law of the eight-hour working day, the participation of representatives of industrial workers and agricultural workers in the management of specialized enterprises, the concession of public enterprises to workers' organizations that proved capable of taking them over.

The financial policy envisaged the exaggerated taxation of capital, the sequestration of the assets of religious congregations, the removal of fiscal privileges granted to the clergy and especially the ecclesiastical hierarchy, the revision of military supply contracts concluded during the war.

The final objective of fascist-type political action is "justice for all and freedom for all", and the achievement of this objective takes place under the motto: "Harmony, altruism, freedom, discipline, the union of rights and duties, the work of peace".

3.1 Fascist ideology - "ideology of rejection"

"Fascist ideology is made up, above all, of rejections: rejection of democracy, rejection of socialism, rejection of class struggle"[5]. The negations are strongly supported, but the affirmations belong to a rhetoric that, most of the time, comes down to a few completely traditional ideas: the cult of action, of violence, of virility, the cult of the duke and the state.

The fascist ideology is based on the anti-materialist theses of Sorel, who replaced the Hegelian rationalist foundations of Marxism with anti-materialist, voluntarist, vitalist elements. "This form of socialism was a philosophy of action based on intuition, on the cult of energy and momentum, on activism and heroism". In order to mobilize the masses, Sorel believed, we needed not reasonings but myths, systems of images that ignite the imagination. By replacing the proletariat with the great force in the process of being affirmed, the nation as a whole, a socialism for all was arrived at, which embodied a new idea of revolution, a national, moral and psychological revolution, "the only kind of revolution that did not have the characteristics of class struggle ". Thus, during the war, revolutionary trade unionism turned into national trade unionism and then into fascism". [3]

3.2 "The new man" and the "new society"

The fascist concepts of "new man" and "new society" were ideally characterized by the French fascist Marcel Deat: "The total man in the total society, without conflicts, without collapses, without anarchy."

The revolutionary nationalists and syndicalists wanted to replace the mercantile civilization of their time with a civilization of monks and warriors, a virile and heroic warrior civilization" in which the sense of sacrifice would replace bourgeois selfishness. This new world was to be created by an elite aware of its duties, the only one capable of leading the masses, who were nothing more than a herd, into battle". [3]

Fascism cultivated the image of a solitary and reunified people and precisely because of this it emphasized marches, parades and uniforms, on an entire community ceremonial in which the place of deliberation and discussion was taken by songs and torches, by the cult of physical force, violence and brutality.

3.3 Anti-individualism and corporatism

For Mussolini, the fascist state is a conscious entity endowed with its own will. Not only does the existence of the state imply the subordination of individual rights, but the state proclaims its right to be a state that necessarily transforms men, even in their physical aspects. Outside the state there can be no human or spiritual values, no individuals or groups, cultural associations, economic unions or social classes.

A "fascist style" had also taken shape, which gradually took shape trying to copy Mussolini's style, from the shaved head to the furious gaze. In an attempt to define the new style, Mussolini himself states that "life, as conceived by fascism, is serious, austere, religious. Fascism despises the comfortable life. He believes and will continue to believe in holiness and heroism". Mussolini's phrase was often present in Italian newspapers: "It is better to live one day as a lion than one hundred years as a sheep."

"Fascism rejects the materialistic conception of a possible happiness. He therefore denies the equation of well-being and happiness according to which people turn into animals because they only think of one thing: to be fed and fat, that is, to a simply vegetative life". [5]

With all its anti-individualism, fascism is characterized by the cult of a leader who embodied the spirit, will and virtues of the people and who was identified with the nation. "Credere, ubbidire, combattere" ("To believe, to obey, to fight") is the fascist slogan that proves that fascism is an ideology of submission and conquest characterized by a rhetoric of violence and faith, by a mysticism of the leader, of the hierarchy and the state, of an exaltation of nationalism.

In this ideological context, corporatism became "the great theme of propaganda, the great illusion, the great hope, the great alibi". [5]

The fundamental principle of corporatism consists in the subordination of private interests to the general interest, that is, to the national interest and to the subordination of social classes to the collective. As a consequence, there can no longer be conflicts between social classes, these having to collaborate with each other within what is represented by the "state-arbitrator, state-regulator" which organizes social classes.

3.4 The totalitarian state

In 1936 Il Duce stated: "Everything resides in the state, nothing human or spiritual exists outside the state." The fascist conception of the state being all-encompassing and outside of it no human or spiritual values can exist, Mussolini states that "fascism is totalitarian and the fascist state, a synthesis and unity of all values, interprets, develops and potentiates the whole a person's life".

Proposing to create a new civilization, a new type of man and a completely new way of life, fascism could not conceive of any sphere of human activity remaining immune to state intervention. "We are, in other words, a state that controls all the forces acting in nature. We control the political forces, we control the moral forces, we control the economic forces", wrote Mussolini.

4. THE FALL OF THE FASCIST REGIME

The balance sheet of the twenty years of Mussolian despotism is eloquent: over 40,000 civilians and soldiers killed in deportation and 444,523 people officially declared as killed and missing as a result of the war. In 1945, industrial production exceeded only a

quarter of that of 1938, and agricultural production, at least half. Foreign trade had been destroyed by autarky, gold reserves were exhausted, inflation and unemployment had increased, public finances were disorganized.

Mussolini miscalculated his aggressive status on the European scene. He assumed that if he intensified his military force, the opponents would give in to his territorial claims. Mussolini had always talked about the advantages of war and about Italy's willingness to enter the conflict if necessary.

In 1940 Germany launched a lightning attack on France and Mussolini quickly took a stand, showing cowardly arrogance. He entered the war under the impression that it was a matter of weeks before the tension would ease. It didn't happen like that. Mussolini had now become a puppet of the Germans. He supported Hitler in declaring war on Russia in June 1941 and on the United States in December 1941.

And they chose death. Italy was defeated on all its fronts and foreign flags were flying in Sicily in 1943. The war was over and Italy had been humiliated. She turned against her savior. The king ordered his arrest.

A few months later, the Germans rescued him and Mussolini moved to the north of Italy where he founded and led a new fascist party (Republica Salo). In 1945 he was captured by Walter Audisio, an Italian partisan. Realizing that he was fast approaching his own end, Mussolini asked to be shot. The next day, Mussolini's body was hung upside down for all to see.

Italy had finally gotten rid of a demonic figure. Italy was slowly rising from its misery. As expected, fascism had failed in its intention to create a perfect Italian state.

CONCLUSIONS

In conclusion, the fascist totalitarian regime can be considered the definition of statism (theory according to which the role of the state is paramount in the organization and administration of economic and social life): "If liberalism means the individual, fascism means the state", chanted Mussolini.

Therefore, "everything in the state, nothing against the state, nothing outside the state" represents the essence of fascist doctrine.

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WOMEN LEADERS' RIGHTS, BETWEEN ASSUMED COMMITMENT AND MODERN REALITY

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DOI: 10.19062/2247-3173.2023.24.11

Abstract: *Gender issues are an important dimension that is constantly on the international agenda thanks to the benefits of feminism and femininity. The presence of modern women in leadership positions, in key areas that are predominantly male-dominated, is more than a social desideratum, it is a necessity. As a form of humanism, feminism promotes the affirmation of women with their panoply of skills, without discriminating against or discrediting the skills of men, with the aim of harmonising psycho-socio-cultural flows within an organisation or community. The article emphasises a complementary, balanced perspective of engaging female-transformational and male-transactional personalities in potentially performance-enhancing roles. This perspective renders the rights, freedoms, responsibilities, opportunities and challenges of the modern woman who does not aim at a superiority ratio over the strong gender, but a validation, a large-scale recognition of female capabilities in quality management.*

Keywords: *female leadership, gender equality, gender equity, security and defence, women's rights.*

1. INTRODUCTION

In a predominantly patriarchal society, globally, the world faces imbalances of representation in positions of responsibility. Gender equality manifested in all sectors of society is a topic of interest in the social policy sphere and beyond. Occupational equality, as a sub-framework, is built on deepening and understanding diversity, challenging stereotypes, overcoming prejudices and objectively prioritising those in charge in a sector according to ability.

In the methodological path, this article aims to use investigation, reflexive and interpretative research, to analyse data integrating a complex of deductive and inductive reasoning, an explanation, an analysis about quantitative findings. It's very difficult, even impossible to measure leadership, but a qualitative research can offer answers about its traits, about commitments and abilities. It is required because this type of phenomena has to be explored, deconstructed, reconstructed, and interpreted.

The research hypothesis is based on the essentially exploratory question: *What are the leadership differences between women and men?* More than that, regardless of the sector of activity, leaders exercise their authority in order to maximise the efficiency of their initiatives. This raises a secondary question: is it possible to speak of gender-differentiated productivity or efficiency in decision-making processes and institutional processes?

2. FEMALE LEADERSHIP – FROM CONCEPT TO GENDER IDEOLOGY

2.1. The concept and styles of leadership

In the literature, the relationship between *management* and *leadership* is intensely exploited. These two concepts are directly linked to the organic growth of an organisation. Leadership has received numerous definitions, starting from the finest characteristics or perceptions - as a performance or quality improvement practice, as a way out of repetitive patterns, as a social intervention, as a theory of action in exercising control through emotional and social intelligence. *"The practices of leadership become substantially more complex and powerful as they engage the energy and commitment of people in the organization."* [1]

Leadership engages inspiration, energy, skills, emotional and social intelligence, knowledge, assumed commitment. K. Davis *"Leadership is the skill to awaken in collaborators the dream to which they will tend, inspiration in them of the energy necessary to their movement."*[2]

According to Kurt Lewin, an American behaviour psychologist and specialist in interpersonal relations, in the 1930s and 1940s he distinguished three core leadership styles: autocratic (authoritarian), delegative (*laissez faire*) and democratic (participative) leadership. From this research, the models of leadership developed progressively and, our days we can talk about much more types such as strategic, transformational, transactional, bureaucratic, situational leadership.

Later, in 2002, in their book *Primal Leadership: Unleashing the Power of Emotional Intelligence* [3], Daniel Goleman, Richard Boyatzis and Annie McKee proposed six basic styles of leadership:

- Visionary – *Come with me!*
- Coaching – *Try this!*
- Affiliative/ Collaborative – *People come first*
- Democratic - *What do you think?*
- Pacesetting – *Do as I do, now!*
- Commanding – *Do what I tell you!*

Transformational and transactional styles were theorized in the 1980s and 1990s by Bernard M. Bass. The American psychologist developed studies in leadership and organisational behaviour. Two perspectives of analysis are identified. On the one hand, the transformational leader is the visionary able to influence his subordinates through persuasion and moral influence, and the transactional leader is the manager who builds his mission on give and take tasks, on their accomplishment and on predictability. This approach places the two types of leadership in antithesis. [4]

On the other hand, female leadership is associated with transformational leadership, built on inclusion, diversity, digitization, soft skills. At the opposite pole, male leadership is built on transactional leadership. Transformational leadership is considered to derive from transactional leadership and can be more effectively applied nowadays through coaching and mentoring. It involves an idealistic vision, beyond self-interest, focused on process, motivation, group interest, intellectual stimulation and inspiration. Transactional leadership aims a pragmatic change, assumes a certain rigidity, is focused on the end goal and materialises on reward or sanction. [5]

Correlating the two researches, through transitivity, it appears that the traits of the transformational leader coincide with the female profile, while the characteristics of the transactional leader - manager overlap with the male profile.

2.2. General Considerations on Women's Leadership. Ideology and theories

Female leadership is the art of balanced, integrative, empathetic, detail-oriented influencing, changing perceptions, persuading, leading responsibly, effectively, goal-oriented, harmony and people-centred. Female leadership is and has to be resilient, noble and natural at the same time.

Feminist ideology is a doctrine of action that claims the fight against gender inequality, aims to promote the role and rights of women in society. Feminism has evolved from the perspective of a woman inferior to a man, who makes demands of substance in terms of social and psychological specificities, to a modern woman who makes demands of refinement in terms of power relations, objectification, social justice, elimination of stereotypes and prejudices.

In the 1950s, the demands were subtle or timid, like Simone de Beauvoir's structuring of the feminist theme in « *Le deuxième sexe* ». Later, in the 1960s, it was a more courageous, militant period of expression.

Recently, a new feminism movement emphasizes the complementarity men-women and introduce social change. Women do not deny femineity, elegance, aesthetics, accept gender differences, know how to value their uniqueness and procreative vocation and support men. Men and women are becoming interchangeable entities and we can observe that there is a tendency for the woman to place herself superior to the man, due to some assets that make her recognize her own power.

Gender-Role Congruence Theory. Among the leading theories in female leadership, the *Gender-Role Congruence Theory* by Eagly and Karau stands out. According to this theory, there are sectors of activity dominated by men, and women are thus in an incongruent relationship with society's expectations. An example of this is women in the military, who are commonly perceived to be unqualified to occupy such a social and professional role, let alone in a position of authority and leadership. [6]

Theory of Gender Differences. Gender theory highlights that women's qualities are questioned. They argue against the widespread view that they are the weaker sex, trying to appear more distant, more tough. As early as 1977, Rosabeth Kanter was developing the idea of women's differing performance in men. The history of the 1980s set out to contradict their approach, so that cooperative/ participatory leadership was intended to replace authoritarian leadership. Women's transformational leadership built on empathy, trust, responsibility and team spirit overshadowed male leadership. In 1990, Helgesen points out that women act cooperatively, with quality as their main goal, while men are more competitive. [7]

Gender Equality Theory. Studies confirm gender equality from all perspectives: equal opportunities, equal rights, equality between genders in terms of autonomy, social behaviour, self-control, responsibility. [8]

To connect the essence of these theories born from the societal problems of women, McKinsey & Company's 2007 study *Women Matter* shows that the leadership of woman behaviours increase and reinforce the performance within an organization. According to this study, we can observe and the male and female leadership assessing the leadership behaviour for every gender. Analysing 9 behavioural dimensions, we can observe the differences in the frequency. Women apply more people development, expectations and rewards, role model, women apply slightly more inspiration, participative decision making and thus contribute to stronger organizational performance. Men apply more individualistic decision making and control and corrective action. Even if we are looking to a corporate performance, in the military field or in the sphere of international relations, leadership processes and systems are very similar. Female leadership, described as process from this perspective is "a competitive edge for the future". [9]

2.3. Women's rights in international documents and institutions

Immediately after its foundation in 1946, the United Nations Organization showed its commitment to women's rights, so that, from the very beginning of the UN Charter, the "equality of rights of men and women" is stipulated and brought to attention in Article 8 of Chapter III. Subsequently, at its 4213th session on 31 October 2000, the UN Security Council adopted Resolution 1325 (2000). This recalled the commitments of the *Beijing Declaration and Platform for Action* which had at its core equality, gender equity, human rights and the protection of all women participating in the process of maintaining and promoting international peace and security. [10]

The UN Charter, from its preamble, highlights the principle of equality between women and men, and Article 8 of Chapter III mentions equal access of men and women to the main and subsidiary bodies. [11]

Women's rights are also found in the constitutions of states, and their importance is major both at national and international level.

Until now, the United Nations has organized four world conferences on women: in 1975 in Mexico City, in 1980 in Copenhagen, in 1985 in Nairobi and, the last one and the most important, in 1995 in Beijing.

Considered the key global policy document on gender equality, *The Beijing Declaration and the Platform for Action* were adopted unanimously by 189 countries, in an agenda for women's empowerment. There are contained 12 critical areas: *women and poverty, women and health, education and training for women, violence against women, women and armed conflict, women and the economy, women and the media, women in power and decision – making, institutional mechanism for the advancement of women and finally, human rights of women.* [12]

At UN level, gender parity is on an upward trajectory. In 2022, 32% of civilian peacekeepers in the field will be women, up from 28% in 2017. As for military personnel, between 2018-2021, the number of female staff officers increased from 8% to 20%, and female police officers from 20% to 30%. [13]

According to European Union law, equality between women and men is one of the most important objectives. The principle of equal pay for women and men was included in Article 157 of the Treaty on the Functioning of the European Union, a treaty that became enshrined in 1957.

The issue of gender equality between women and men is multidimensional. The topic of equal opportunities between women and men is shifting from the sphere of leadership to the area of discrimination, domestic violence, its prevention and combating.

3. FEMALE LEADERSHIP IN THE INTERNATIONAL FRAMEWORK

3.1. The woman leader - blocking prejudice and disseminating power

There are stereotypical narratives that portray women as constrained. Thus, she is portrayed as incapable of making decisions, with a poor capacity for orientation, deficient in interacting with technology, with a restrained interventionism, incapable of acting, of coordinating, assuming predominantly their second role. In reality, women with leadership skills can take on decision-making roles as negotiators, challenging professions as pilots, technology specialists, military personnel or in management positions. [14]

In the popular, mainstream view, various preconceptions are conveyed that women cannot be dynamic, competent and effective leaders, often inoculating an unintentional discrimination. Women are described as sensitive, cautious, gentle, with an aesthetic

sense, while men are more competitive, risk-taking, domineering, more focused on managing stress and crisis situations better or being imposing,

However, the woman is adaptable, giving, more empathetic, creative, confident, motivated, adopts a democratic style, while the man has an autocratic style, is more aggressive, tends to make decisions on impulse.

But what qualities should an authentic, reliable and effective leader have? It is important to be honest, dedicated, hard-working, articulate in communicating with his team, organised, punctual, visionary, with adaptive potential, resistant to stress and crisis situations, with an emotional and social intelligence that supports him in decisions and predictions, flexible and firm at the same time.

Before being part of the gender equality paradigm, gender identity establishes gender roles, overlaps different social and cultural influences.

3.2. Prominent female figures in international leadership

Throughout history, female leaders have been found in politics, security and defence, diplomacy, science, technology and business, in professions perceived in the collective mind as compatible with the male profile.

Among the great figures of international female leadership are *Queen Elizabeth II* of Great Britain, American diplomat and Former Secretary of State Madeleine Albright, Former US Secretary of State *Margaret Thatcher* – Former Prime-Minister of United Kingdom, German Chancellor *Angela Merkel*, Former US Secretary of State *Condoleezza Rice*, Former First Lady *Michelle Obama*, Prime Minister of New Zealand *Jacinda Ardern* or *Kamala Harris* – Vice President of the USA.

Who are these leaders and what they did? Every leader has a message that develops new perspectives, inspire and teach us how to be more confident, more open-minded, and powerful. For example, Kamala Harris expressed her faith to „inspire young people to pursue their dreams”, Michelle Obama said that „education ...gave me the confidence to pursue my ambitions and make my voice heard in the world. For me, education was power.” [15]

Other women leaders we admire are mobilizing other different systems: global climate, social protections, COVID-19 crisis, racial discrimination. There are parts of the world where the struggle is for equality, only in the democratic world can we talk about equity in leadership.

Michelle Bachelet, human rights advocate, the first woman President of Chile, and the first Executive Director of UN Women works to protect, defend, and promote the fundamental rights. About the leaders of feminist movements, she said: “Their vision, strength, courage, empathy, and achievements are enormous sources of inspiration and hope for the future.” [16]

Demecia Yat is known as one of 15 women survivors of sexual violence during the internal armed conflict in Guatemala (1954–1996). From 2011 to 2016, the women, respectfully called the *abuelas* (grandmothers) in their small community near the Sepur Zarco outpost, fought their case in the nation’s highest court. Her message is “today’s generation [...] should speak out against any violation of their rights”. [17]

The activist *Malala Yousafzai* was 11 years old when the Taliban announced on the radio that girls could no longer attend school in Pakistan. Yousafzai began speaking up for girls’ right to education, and, very soon, she became a target for the Taliban. In October 2012, Yousafzai was shot as she returned home from school. After surgeries and rehabilitation, she continued to fight for girls’ education, and she became the youngest Nobel laureate at 17 years of age. [18]

The future of leadership is based on consensus, on cooperation, on innovation, on empathy, on powerful and inspiring leaders.

Whether we are talking about military leadership or about politics, international relations, diplomacy, the image of the woman, is still remaining the symbol of force, courage and elegance.

CONCLUSIONS

In the current evolution of organizational management, the role of women is becoming more and more prominent in the labour market and beyond, given their skills, abilities, determination, considerations of excellence in any work environment.

This article is intended to draw the attention of practitioners to the fact that female leadership advances a well-defined common goal in the group's understanding, soft skills, opportunities in professional environments.

The role of the modern female leader is focused on process rather than outcome, denoting a greater attention to detail, quality and a desire for self-development.

Regardless of gender, an authentic leader knows how to use their qualities at the highest level. In the era of the struggle for gender equality, the very spirit of consensus that would maximise productivity and efficiency in the top management of any organisation has been neglected. Although the balance between women and men is stabilising, we are still far from parity. Men's earnings are still even higher than women's, the representativeness being still high in different fields.

Equity in leadership is more than equality in leadership, equity is multidimensional, incorporating elements of *identity*, *power*, *achievement* and *access*. Our leaders has to use their power, compassion, curiosity, creativity, courage, education to change the world beyond difficulties and pressions, social barriers. [19]

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THE GAULLIST POLITICAL IDEOLOGY AND THE EXCEPTIONALISM OF A COMPLETE LEADER

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DOI: 10.19062/2247-3173.2023.24.12

Abstract: Charles de Gaulle, « Le Général », is one of the emblematic figures of our century, an undisputed hero whose impact on the French nation and people was revolutionary, transformational and inspirational. The article proposes a qualitative, correlational meta-analysis, which stimulates reflection on his noble personality, on his visionary spirit, on his qualities as an affable negotiator. His virtues shape his destiny as a leader who worked in the spirit of dialogue, negotiation for modernization and freedom.

Because of his exceptionalism, Charles de Gaulle can be considered a multidimensional leader. Characterised by a total leadership, his figure encompasses transactional, transformational, charismatic, informal, spontaneous leadership. Arguing through a deepening of scientific theories and exemplification of all these frameworks provides an elaborate and carefully researched perspective of a unique figure in French history.

Keywords: persuasion, political systems, strategic management, transactional leadership, transformational leadership.

1. INTRODUCTION

A personality of great complexity, a military, political, social and cultural figure, General de Gaulle managed to gather people of all political persuasions around his architectural idea of France. His political ideology, known as *Gaullism* was pragmatically built on the role of the state, the independence of the nation and the primacy of the national interest. The idea saw France as an independent, powerful nation that was not subordinate to other nations or organisations.

Charles de Gaulle can easily be included in the panoply of complete leaders because of the complexity of his personality. In his case, several types of leadership merge. We find him described as a transactional, strategic, transformational, visionary, charismatic, *great man leader*, a typology associated with the concept of a *complete leader*.

According to a review in *L'Observateur*, French scientist and demographer Alfred Sauvy notes that, following the Second World War, the world is divided into the *First World* - of capitalism, the *Second World* - of Soviet socialism, and the *Third World*, of the ex-colonies. The concept of the *Third World*, which he initiated (1952), changed history, although it was widely criticised and was still used after 1991, even in the context of the fall of the socialist Second World. It referred to demographically, economically and civically-politically underdeveloped countries. At the other end of the spectrum were the *First World* countries, the capitalist states, generally democracies that were consolidated or stable in terms of political institutions. These include the USA, France, Germany, Australia, Japan, with a modern infrastructure that encourages people to pursue their own interests, not just economic ones. [1]

2. SYMBOLS AND REPRESENTATIONS OF A MASTERFUL MAN OF ACTION

2.1. Perspectives on the international context

In terms of unity, the fracturing of Berlin marked the split and consolidation of Europe into two spheres of influence. While in 1945-1948 Stalin created a Soviet sphere in which the Eastern European states threatened the Western ones, in 1949-1956, after the signing of the North Atlantic Treaty on 4th April 1949, the NATO bases were consolidated and the Western European states were integrated. France is one of the 12 founding members of the Organisation. Thus, in addition to the USA and Canada, the United Kingdom, Belgium, Denmark, Iceland, Italy, Luxembourg, Norway, Portugal, Northern Ireland and the Netherlands also joined from Europe. [2]

After the *Cuban missile crisis* [3], the Soviets focused on penetrating developing countries so that Europe experienced '*bipolar stability*', which allowed representatives of Britain (Prime Minister Mcmillan), France (Prime Minister Charles de Gaulle) and the United States (President John F. Kennedy) a period of time to draw up convergent plans on the status of the Alliance, the future of Europe, including nuclear weapons. This was a period when Britain was no longer a world power, but the illustrious Winston Churchill (Prime Minister 1940-1945; 1951-1955) was to pursue an egalitarian policy in diplomatic relations with the US and the Soviet Union, citing Britain's heroic involvement in the Second World War and demonstrating, through his oratorical skills, his power to influence the strategic calculations of the superpowers. Charles de Gaulle himself characterized him as "*made to act, to risk, to play his role very emphatically and unscrupulously, [appearing to be] the great champion of a great society and the great artist of a great History.*" [4]

Subsequently, the *Suez Crisis* of 1956-1957, also known as *Operation Musketeer*, took place during Churchill's successor as Britain's Prime Minister - the peaceful and diplomatic Anthony Eden (1955-1957) who resigned for medical reasons in favour of Harold Macmillan (1957-1963), renowned for his pragmatism. This was a war in which France and Britain attacked Egypt to regain control of the Suez Canal, a Franco-British property nationalised in 1956 following a 1955 British contract to pay Gamal Abdel Nasser's Egypt \$40-60 million in financial aid to use in building the Aswan Dam on the Nile. Israel, on the other hand, demanded an end to attacks on Israeli settlements and civilians and respect for the right to navigate the canal. Hence the name Arab-Israeli conflict. The war ended with a clear defeat for Egypt, but the intervention of the USSR led to the withdrawal of French, British, American and Israeli troops, and treaties were signed to mark the end of Franco-German rule in the Middle East after more than a century.

After Suez, the conclusions of France and Britain were diametrically opposed. Macmillan was aiming for a rapprochement with the US and a strengthening of Anglo-American relations with a view to a shift from power to influence, while de Gaulle was aiming to accelerate the course towards independence, which he believed would strengthen European security, by adopting a dismissive behaviour that would inconvenience and hurt. Macmillan, however, deftly took care to act from the side-lines, leaving the authority of American plans at the centre, thus prompting the US to consult Britain in its decision-making, thus annihilating de Gaulle's defiant intentions. Despite all misleading appearances, de Gaulle was not anti-American in principle during the Cuban missile crisis, himself offering unconditional help to American officials, but he could not accept a possible subservient relationship to the United States. However, France was dependent on American support in avoiding monetary collapse, its security also depended on US protection, and it also received weapons for its soldiers.

2.2. Political systems in France. Overview

France's complex history evokes moments of triumph, but tumultuous ones too. It has experienced different political systems, being in turn a Federal monarchy (481-987), feudal (987-1610), Absolute (1610-1791), Constitutional (1791-1792, *July Monarchy* (1830-1848), Imperial monarchy (I 1804-1814, II 1852-1870) and Republic (I =1792-1804, II =1848-1852, III =1870-1940, IV =1946-1958, V =1958-present), alternating with longer or shorter periods such as the First (1814-1815) and Second Restoration (1815-1830), the 100 days between the return of Napoleon I and the dissolution of the Napoleon II Commission, the executive after his abdication (1815), France Combatant (1940-1943), the French Committee of National Liberation (1943-1944), the Provisional Government (1944-1946).

After the French Revolution (1789), perhaps the turning point in history, there were five great periods, generically known as the *First, Second, Third, Fourth and Fifth Republics*. Throughout these, the relationship between the political and administrative apparatuses was ideally centred on administrative interests.

The Fifth Republic was the most important period in French history. It had prominent representatives who gave a new dynamic to the current European construction, including, chronologically, Charles de Gaulle, George Pompidou, François Mitterrand, Jacques Chirac, Nicolas Sarkozy, François Hollande and finally Emmanuel Macron.

3. LEADERSHIP THEORIES

Charles de Gaulle was Prime Minister of the Fourth Republic from 1958-1959 and President of the Fifth from 1959-1969. With a distinguished military career and a brilliant political career, he gave birth to the political movement that bears his name - *Gaullism*. Moreover, he was a promoter of reform and a revolutionary spirit. As for his social reform, "*when General de Gaulle took power, there were a million television sets in France... When he left, there were ten million...The state is always a show business. But yesterday's state-theatre was something completely different from today's state-TV.*" [5]

Born in Lille (22 November 1890) into a Catholic, nationalist, patriotic family, he opted for a military career as early as 1908. He first experienced the harshness of war as a lieutenant in the First World War, being wounded three times in combat. He married in 1921 and had three children.

He was an open-minded personality, especially as long as cooperation was in the interests of France, and he wanted his nation to always be a reliable ally. Captain de Gaulle began to become involved in the affairs of state, and in 1931 he was appointed adviser to the General Secretariat of National Defence in Paris. In the period between the two world wars he became increasingly concerned with the relationship between the army and politics, and was preoccupied with army reform. In 1937 he became colonel, in 1939 commander.

On 1st June 1940 he is appointed General and a few days later becomes Under-Secretary of State for National Defence and War in the Paul Reynaud government.

After the Normandy landings in June 1944, de Gaulle urged General Eisenhower, commander of the Allied forces, to liberate Paris, which he did on 25 August 1944. As president of the provisional government, he quickly disagreed with the Constituent Assembly on the role of political parties and the concept of the state, and decided to resign in January 1946. Nevertheless, he accomplished the mission for which he was nicknamed '*Liberator*': he liberated the territory, erasing the shame of the years of Marshal Philippe Pétain whose government had lost its legitimacy in 1940, restored the Republic, organised free and democratic elections, and undertook economic and social

modernisation. For his outstanding merits in liberating France from the Second World War, he was awarded the "Grand Master of the Order of Liberation". [6] After 1947 he dreamed of working towards constitutional reform. The Fourth Republic was heading for a deep crisis because of ministerial instability and powerlessness in the face of the Algerian War which had just broken out on 1st November 1954.

On 1st June 1958, de Gaulle becomes the last President of the Council of the Fourth Republic. In a referendum on 28 September 1958, the French vote 79.2% in favour of the Constitution, and on 21st December 1958 they elect him President of the French Republic by indirect universal suffrage. Nowadays, often evoked, it is rarely practiced on a positive note. [7] The Constitution of the Fifth Republic was one of the great reforming victories initiated by the founder de Gaulle in the contemporary era and beyond, which still forms the basis of the French state today. As the General himself said at the press conference on 31st January 1964, "a Constitution is a spirit, institutions, a practice". [8] The spirit refers to the Restoration of the State and, if possible, to the restoration of the parliamentary regime of the Republic.

Over time, leadership theories have set out to analyse and explain a relatively new and very complex concept. In the work Leadership style vs Leadership typology, the authors emphasises four important theoretical perspectives in the field of leadership, in a chronological order: *The Great Man Theory, Trait Theory, Behaviourist Theories, Contingent Theories, Transactional Leadership Theory, and Transformational Leadership Theory*. The first dominates the 19th century, the others are representative of the 20th century. [9]

The Great Man Theory is the most appropriate and comprehensive to capture the greatness of Charles de Gaulle and his decisive impact on history. Popularized by Thomas Carlyle, the theory is based on the idea that such a leader is born, not made. The born leader is described as the man endowed with certain special abilities characteristic of heroes or divinity, incompatible with ordinary people. However, a mention is required, The messianic leader is providential precisely because of his humble character.

Leadership trait theory has focused on analysing mental characteristics, physical and social traits to discover which qualities are common among leaders and which combinations of qualities are responsible for leadership.

Behaviourist theories focus on the behaviour of leaders and not on mental, physical or social characteristics.

Contingent Theories. Leadership effectiveness is dependent. Certain individuals can perform most effectively in certain environments or in partnership with certain people, otherwise performance can be at its lowest.

Transactional leadership theory values the interactive nature between leader and subordinates in a mutually beneficial relationship. The leader offers psychological, economic and political rewards that are positively received by subordinates.

Transformational leadership theory is about cultivating a sense of belonging to the organisation, developing attachment emotional attachment of subordinates to the organization and to the group, the leader inspires, is flexible, empathetic and relaxed. Motivational resources are involved. [10]

4. CHARLES DE GAULLE - THE COMPLETE LEADER

The French Fifth Republic is a semi-presidential republic (concept created by Marcel Duverger) in force since 4 October 1958 until today. The semi-presidential republic is a regime of separation of powers in the state, in addition to the classical models of presidential and parliamentary regimes.

The French Fifth Republic was led by a total, complete leader, as we can characterize Charles de Gaulle, thanks to his ability to rule himself and others with a clear mind and a firm hand. A leader who leads others with diplomacy and tact has intrapersonal and interpersonal skills, is persuasive, a good negotiator, manages teamwork convincingly.

On a visit to Paris in 1959 by President Dwight D. Eisenhower, President Eisenhower approached the French leader with the firmness of one of America's greatest military commanders, but also with falsity, asking, "Why do you doubt that America could identify its destiny with that of Europe?" [11] Politely, de Gaulle did not hesitate to recall the lack of American intervention in the First World War in support of France until three years later, which brought it to the brink of collapse, and the belated involvement in the Second World War when France was already occupied. It highlights the traits of the *spontaneous leader* who naturally, without hesitation, knows how to impose himself emotionally, to maintain a cordial, jovial, but firm and imposing tone of discussion at the same time. In this note of discussion, the transactional leader also stands out, establishing a negotiating, recalibrating relationship that leaves nothing to chance.

In the nuclear age they got involved late once again. In the same discussion, a question also arose on this sensitive issue of how national military forces within the alliance could be integrated into a single military plan.

While for de Gaulle nuclear forces were a political-institutional rather than a technical issue, Eisenhower had in mind strategic options, finding a wartime command structure, not political and diplomatic ones, like his French counterpart. De Gaulle had already answered the question a year earlier, on 14 September 1958, when he proposed the Political Directorate within NATO, presenting the American and British heads of government (Eisenhower himself and Macmillan) with the memorandum containing his ideas on the appropriate structure of the Alliance. [12] By putting forward procedural, bureaucratic schemes designed to dissipate de Gaulle's attention and determination, the two ended up realising that they no longer had before them the ephemeral and indeterminate profile of the French head of state in the Fourth Republic. Thus, in 1966, he acceded to the option of France's complete withdrawal from NATO's integrated military commands, while not questioning the Washington Treaty and still wanting the Atlantic Alliance to exist.

Subsequently, the John F. Kennedy administration proclaimed the *Declaration of Independence* between the United States and a United Europe on 4 July 1962, supporting the integration of all NATO nuclear forces. Within Europe, Franco-German cooperation was the focus of French foreign policy. Gaullist France envisaged a unity based on states, an organised Europe, respecting the borders of Bismarck's Germany.

In his article *Political Rationalities in State Reform: the Case of the Fifth Republic*, Philippe Bezes argues that "the development of state reform policies in the 1960s is a contemporary social fact whose originality must be highlighted." [13]

In his view, since the 1960s autonomous reform programmes have had a strong impact on the relations between the administration and political power, the organisation and division of labour in ministries and offices, the management of material and human resources, the employment systems of public officials, and the whole process of bureaucratisation of the state's administrative systems. All these policies of the administrative system have had a driving and supportive role, but they have also encountered bottlenecks. The decrees of 1964 are directly linked to the emergence of the new Gaullist regime whose prime ministers were first Michel Debré and then Georges Pompidou, the renewal of the civil service in 1989 is due to Prime Minister Michel Rocard, under François Mitterrand, and the general review of public policies is linked to the name of Nicolas Sarkozy. [14]

The Fifth Republic appeared in its history as a fairly simple regime: a President of the Republic was elected every 7 years by the people, supported by a parliamentary majority bound to it by a more or less solid contract, animating political life. Alongside him, ministers with a prime minister at the helm prepared political action. As de Gaulle's Prime Minister, Michel Debré always brought his ideas and ideas to the consultation process for his views on general policy and on the personalities who were to become government collaborators.

De Gaulle was a leader loved by the people for his impetuosity, for his authority, for the high expectations he set for himself and others. His profile was built solidly, gradually, on honesty, dignity, patriotism, unwavering values and principles.

From being elected comes the framing of a new type of leadership - *informal leadership*. [15] In community dynamics, informal leadership is elected, recognisable, respected, honest, credible, cooperative, participatory. His participative attitude is concrete and measurable. From a very young age, he participated in combat operations during World War I, later he led France against Nazi Germany in the Second World War and also fought for the restoration of democracy from 1944 to 1956 as head of the French provisional government. At the opposite pole, the *formal leader* is appointed and imposes his authority with difficulty or not at all, and the organisation loses cohesion.

In the 1980s and 1990s, the American psychologist Bernard M. Bass theorized transformational and transactional leadership styles, both models characterising the prodigious personality of Charles de Gaulle.

4.1. Transactional leader

Transactional leadership focuses on organisation, performance and supervision. It is built on the power of competitive advantage. Gaullism as an embodiment of pragmatic leadership emphasizes stability and consolidation of society, a strong economy, through executive pragmatism.

De Gaulle's qualities as a strategic leader were formed gradually through interaction with members of the groups in which he developed, due to the environment in which he was born and raised. He was born into a conservative family with five children, hence his modesty and predisposition to be popular, open and proactive. In 1912, he graduated from Saint-Cyr Military College. After the participation during World War I and World War II, on June 1940 he emigrated to Great Britain because he refused the armistice with Germany. Before the liberation of France in 1944, Charles de Gaulle was the leader of the government-in-exile.

Characteristic of transactional leadership is also de Gaulle's defiant interventionism towards British Prime Minister Winston Churchill to ensure that French interests were taken into account during the negotiations for World War II. In his June 18 appeal from the BBC studio, de Gaulle demanded: "*Whatever happens, the flame of French resistance must not and will not be extinguished.*" [16]

Charles de Gaulle has a very active leadership style, with clear objectives, focused on negotiation, associated with rewards and sanctions. He is constantly concerned with cultivating the intellect, both for himself and his subordinates. Appreciates interactions based on mutual trust, motivation and collective effort.

4.2. Transformational leader

Transformational leadership is also called *The new leadership*. It incorporates the visionary and charismatic leadership. He is the educated leader whose lines of descent fostered the culture. Going through several generations of the extended family, we can say that he belonged to the aristocracy. His mother, Jeanne Maillot came from industrial entrepreneurs, his father, a professor of French history and literature, in turn, had roots in

the aristocracy of Normandy and Burgundy, his great-grandfather was a prosecutor of the Administration of the Paris Region.

The charismatic leader builds his offensive on one main quality – charisma, a rather rare asset that is undoubtedly corroborated with optimism, constructive enthusiasm and devotion.

Charles de Gaulle was, first of all, a military thinker and a great reformer.

From an action perspective, charismatic leaders can be crisis or visionary leaders. [17] In this regard, he mobilized the French to resistance from London when The Pétain government requested an armistice from Nazi Germany.

4.3. The decline of a leader - caution and reserve

In 1965 he was already 75 years old, he didn't want to run again for fear of falling like Pétain or Churchill, he had become more reserved and cautious. In his political career, he wanted Georges Pompidou as his successor, but the Socialist opposition leader François Mitterrand was a charismatic personality with a good chance of taking power, and he could not afford to risk it. He also ran in the 1965 presidential election, the first direct universal suffrage election for a seven-year term. He won in the second round on 19 December 1965 and was re-elected with 54.49% of the votes cast, and resigned four years later. As history shows, he was succeeded by his protégé Georges Pompidou and later by his declared enemy François Mitterrand. [18]

If Pompidou's popularity was already declining in 1967, it was precisely because of the antagonism between the President of the Republic and his Prime Minister. De Gaulle was dissatisfied, disappointed and even felt betrayed. Georges Pompidou refused to apply the General's policy, giving way to demagogic assaults, hence his meteoric decline. The night of 10-11 May 1968 was dubbed the "*night of the barricades*". Students occupied the Sorbonne and the Odéon Theatre and set up barricades just as Pompidou was on a tour of Iran and Afghanistan, and de Gaulle was due to pay an official visit to Bucharest between the 14th and 18th, the first visit by a French president to Romania.

The youth revolts were born of frustration, a desire for autonomy and required prompt intervention, and a youth culture was emerging. They hastened Charles de Gaulle's political demise and deepened the rift between him and Georges Pompidou, whom he was convinced had been plotting to provoke his resignation. Georges Pompidou, who had already been Prime Minister for six years, promptly announced his candidacy if de Gaulle did not complete his term. These student uprisings were perhaps also prompted by the novelties of the 1950s, when young people from the upper and middle classes in the Anglo-Saxon world were bringing to the fore a new lifestyle, a new fashion, a new energy. From overseas, the process was being reversed: the famous Parisian haute couture was gradually being replaced by unisex, mass-industry jeans. The vulgarisation of the tastes of middle- and upper-middle-class youth could be the basis of the revolutionary politics of the middle-class youth of 1968. [19] We can thus speak not only of a social revolution, but also of a cultural revolution, a search for autonomy, affirmation and freedom.

"The resignation of General de Gaulle in 1969 and the introduction of the new presidential system voted in 1962 reinforces the bipolarity of French political life". [20]

In *Diplomacy*, Henry Kissinger admiringly describes Charles de Gaulle as an iconic figure, recounting a meeting he had with him during President Richard Nixon's visit to the Elysée Palace in Paris in March 1969, when the so-called General gave a grand reception. Asked directly "*Why don't you withdraw from Vietnam?*", Kissinger, then former Secretary of State and security advisor in the Nixon presidency, often considered the real president who left the White House only in 1976 (with the election of Jimmy Carter), was to reply hesitantly that such a withdrawal would undermine American

authority. In an icy offensive, de Gaulle insisted, asking where such a loss of credibility might occur.

The mention of the Middle East reminded de Gaulle of the painful loss of influence in the Suez Canal area which caused him to wistfully remark, "*How strange. I thought it was precisely in the Middle East that your enemies had credibility problems.*" [21] Not coincidentally de Gaulle's discussion partner on the Vietnam War, Kissinger played a key role in world diplomacy between 1969 and 1977, most notably through his decisive contribution to ending it, and was awarded the Nobel Peace Prize in 1973.

After the student and workers' riots of May 1968 and the referendum of 28 April 1969, de Gaulle resigned and retired to Colombey-les-deux-Églises (Haute-Marne), 250 km from Paris, where he spent his weekends when he was free, retiring from political life for good and resuming his memoirs. Although his foreign minister at the time, Jean de Lipkowski, suggested cancelling the referendum, de Gaulle was aware that his political image was deteriorating and his popularity was waning, and that failure to support him would be humiliating. He died on 9 November 1970, aged 80, 18 months after retiring from political life, of natural causes. He died simply, as he lived. He did not want a national funeral, the army being the only official participation in the discreet setting in which he wanted the funeral ceremony to take place. In Paris, however, a solemn service was held in the Cathedral of Notre-Dame, attended by 63 heads of state. An extraordinary council of ministers declared 12 November a day of national mourning. Georges Pompidou was to declare in a televised address that after this painful moment for a nation, "*France is a widow...*" [22]

CONCLUSIONS

Charles de Gaulle remains the most prominent personality of the modern era in France, a total leader who influenced and changed the trajectory of the nation, its people and inspired other leaders. He was not only President of France and the French people, but also a general, a politician, from 1940 - head of the French government, from 1945 - Prime Minister of the post-war provisional government elected by Parliament. He resigned a year later, but in 1947 he even created his own party - the Assembly of the French People. In 1958, he became Prime Minister again, and was notable for drafting a new Constitution, becoming President of the Republic in 1959. He was an ardent supporter of the independence of the French people and their interests, encouraging them to act according to their own will, never to give up their sense of identity, never to be or feel subordinate to anyone.

He was a visionary, a diplomat, a patriot with high aspirations, aware of the inequality of forces between the US and France, but unfailingly dignified, a good strategist, capable, vigilant. Through his friendship with the German Chancellor Adenauer, he strengthened the Franco-German relations that still form the basis of European integration today. De Gaulle was always guided by Cardinal Richelieu's dream of being the leader of a supreme France and succeeded in transforming it into a great world power, in 1960 even becoming the world's fourth nuclear power.

The complexity and greatness of his personality contributed to the brilliance of France today. He managed and reconstruct post-World War II France, created the Fifth Republic, and introduced a new constitution.

In *The Study of Sociology*, the sociologist Herbert Spencer highlights that the leaders are products of the society - "you must admit that the genesis of a great man depends on the long series of complex influences which has produced the race in which he appears,

and the social state into which that race has slowly grown....Before he can remake his society, his society must make him.”[23]

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MY ChatGPT TEACHER. TOWARDS A METHODOLOGY FOR USING ARTIFICIAL INTELLIGENCE IN SELF-DIRECTED LEARNING

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DOI: 10.19062/2247-3173.2023.24.13

Abstract: *Language is the distinctive feature separating humans from the rest of the animal world. Therefore, throughout history, inventions and technologies that changed the way we use language have been crucial turning points. These include the invention of writing, which allowed the communication across space and time, the printing press, which facilitated the rapid and widespread dissemination of knowledge, and the advent of the Internet and mobile phone technology, which resulted in an explosion of communications and faster diffusion of knowledge. The latest revolutionary innovation in the field of language processing is ChatGPT, a generative AI model launched by OpenAI in November 2022, which produced spectacular results in natural language processing (NLP). It appears to be one of the most significant milestones in this field and has the potential to produce major changes in numerous domains, particularly in education. Starting from the available literature and from several experiments with ChatGPT, this paper outlines the main methodological requirements for using this instrument as an aid for self-directed learners.*

Keywords: *education, self-directed learning, ChatGPT, natural language processing, meta-cognition, meta-ignorance.*

1. INTRODUCTION

One of the most important assets to succeed in this fast changing world, flooded with information and highly competitive is the ability to learn continuously and independently. This skill (and the associated processes) received various names in the literature: self-education, self-teaching, autonomous learning, self directed learning, self regulated learning etc. The first attempt to approach scientifically the topics related to self education can be traced back to 1975, when Knowles ([1]) coined the term *self directed learning (SDL)*, defined as a process wherein “individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes”. More recently, in 2002, Zimmerman ([2]) introduced the concept of *self regulated learning (SRL)*, and placed the focus on the metacognitive monitoring and control of the learning process.

The differences between the concepts of SDL and SRL are subtle (for a detailed discussion on this topic see [3]), but, in summary, SDL is a broader concept that encompasses SRL, as it involves taking control of the entire learning process, from identifying learning needs to evaluating progress. SRL focuses more specifically on the process of monitoring and adjusting one's own learning behaviors in order to achieve the

learning goals. A comprehensive review of the literature on SDL and SRL is available in [4] and [5].

Currently, most researchers agree that the essential abilities of a self directed learner are:

- The ability to assess learning needs and to establish learning goals,
- The ability to select learning strategies,
- The ability to monitor the progress and to adjust the behavior towards the desired learning outcome.
- The ability to identify and efficiently use learning resources.

Note that the first three abilities listed above are intrinsically metacognitive, which suggests the existence of a strong correlation between metacognition and SDL (see [6]).

In what concerns the educational resources, a new tool, recently launched, based on emerging technologies sparked the interest of the educators, researchers and of the general public. It is called ChatGPT – a conversational robot (chatbot) equipped with artificial intelligence, capable to understand and generate natural human language in at least 95 languages ([7]). It has been trained using a huge dataset of texts from books, web pages, news archives, scientific articles, and it is capable to generate complex answers to questions on almost any topic.

Of course, ChatGPT is not perfect. A SWOT analysis of its performances is available in [8]. It may not be able to make accurate economic and stock market forecasts, but – at least for education – it seems to be an invaluable tool. This paper is about how to use efficiently this tool for self directed learning.

2. HOW TO KNOW WHAT WE DON'T KNOW

ChatGPT is designed as a conversational robot and therefore the initiative of the dialogues always belongs to the human operator, who must ask questions and issue prompts. In order to get useful answers, the questions must be clear and specific and provide a context, so that ChatGPT can understand the background and the purpose of the inquiry.

For self directed learners this may be a major issue because – as David Dunning noticed in [9] – “there are questions that people do not know enough to ask”. Dunning coined the term meta-ignorance to describe the “unknown unknowns” – the gaps of knowledge that people are not aware of. On the other hand, ignorance is often obscured by misbeliefs that people mistake for valid knowledge.

It appears that meta-ignorance is the most important obstacle in using ChatGPT by self directed learners. Therefore, the dialogues should start by prompting ChatGPT to outline the educational path towards the assumed goal and to propose a table of contents of the course.

3. CASE STUDY. HOW A TOTAL NOVICE CAN USE ChatGPT TO LEARN A PROGRAMMING LANGUAGE

During my formal education as a psychologist, I have never had the opportunity to write computer programs and I am totally ignorant in the field of programming languages. I learned about Python by asking Google to provide examples of modern programming languages, and from the list presented by Google I chose Python because it is said to be easier to learn by beginners. With this background, I prompted ChatGPT to design a course to help me learn Python. The dialogue is shown in Table 1.

Table 1. Initial dialogue with ChatGPT

Assume that you are an expert teacher, and I am a totally novice in programming languages of any type. Please design a course structure for me to learn Python as fast as possible: where to start, what are the basic concepts, how to install the programming environment for exercises.

Sure, I'd be happy to help design a course structure for you to learn Python as quickly as possible! Here's a suggested course outline:

Week 1: Introduction to Python and Installation

- Introduction to Python and its history
- Installing Python on your computer (Anaconda or other distributions)
- Installing an Integrated Development Environment (IDE) for Python (e.g. PyCharm, Jupyter Notebooks, Spyder)
- Creating your first Python script

Week 2: Basic Programming Concepts

- Understanding variables and data types (integers, floats, strings, booleans)
- Operators (arithmetic, comparison, logical)
- Basic control structures (if-else statements, loops)

Week 3: Functions and Modules

- Writing your own functions
- Built-in functions in Python
- Importing and using external modules

Week 4: Working with Data

- Reading and writing data from/to files (text, csv, binary)
- Working with lists and dictionaries
- Introduction to NumPy and Pandas for working with arrays and dataframes

Week 5: Object-Oriented Programming

- Understanding classes and objects
- Creating your own classes
- Inheritance and polymorphism

Week 6: Advanced Topics

- Exceptions and error handling
- Regular expressions
- Debugging and testing
- Introduction to popular Python libraries and frameworks (e.g. Matplotlib, Flask, Django)

Throughout the course, you should also work on small projects and exercises to reinforce your learning and apply the concepts you have learned.

This looks pretty close to the table of contents of some popular textbooks on Python programming (e.g. [10]) with the obvious advantage that ChatGPT offers an interactive course, answers additional questions, may change the order of the presentation upon request, provide as many code examples as needed, and can even ask multiple choice questions to verify the progress of the learner.

The most important feature of this table of contents is that it allows the learner to circumvent his own initial meta-ignorance and lets him ask meaningful questions. Table 2 contains shows how the dialogue with ChatGPT continued.

Table 2. Excerpt from the dialogue with ChatGPT

Now, let's start with the first lesson: Introduction to Python and its history. Please include a story about people who created Python.

Python is a popular high-level programming language that was created in the late 1980s by Guido van Rossum, a Dutch computer programmer. Van Rossum created Python as a side project while working at the Netherlands Centrum Wiskunde & Informatica (CWI), a Dutch national research institute for mathematics and computer science.

The language was initially conceived as a successor to the ABC programming language, which was designed to be easy to use and learn. Python, like ABC, was designed with simplicity and ease-of-use in mind, and has since become one of the most popular programming languages in the world. The name "Python" was chosen by van Rossum as a tribute to the comedy troupe Monty Python, which he admired. In fact, some of the original Python documentation even includes references to Monty Python sketches and characters.

Python has been continuously developed and improved over the years, with a large and active community of developers contributing to its growth and evolution. Today, Python is used for a wide range of applications, from web development and scientific computing to machine learning and data analysis. Its popularity is due to its simple syntax, readability, and ease-of-use, making it a great language for both beginner and advanced programmers alike.

Besides simplicity, what are other reasons for choosing Python? Compare it with other popular programming languages.

In addition to its simplicity, Python has several advantages that make it a popular choice for many applications:

1. Versatility: Python can be used for a wide range of applications, from web development and scientific computing to machine learning and artificial intelligence.
2. Readability: Python code is easy to read and understand, thanks to its clean syntax and use of whitespace.
3. Large Community: Python has a large and active community of developers who contribute to its development, create libraries and tools, and offer support to other developers.
4. Cross-platform compatibility: Python code can run on multiple platforms, including Windows, macOS, and Linux, making it a versatile choice for software development.

When compared to other popular programming languages, such as Java, C++, and JavaScript, Python stands out for its simplicity and ease of use. It requires less code to accomplish many tasks, and its syntax is designed to be easy to read and understand. Additionally, Python's wide range of libraries and tools make it a popular choice for data science, machine learning, and artificial intelligence applications.

Note that I asked ChatGPT to include stories in the presentation because stories are likely to elicit emotions and provide anchors that link the new information to my prior knowledge. Also, by asking details about the advantages of Python, I had the chance to improve my motivation for learning and identify possible applications of the new information in my activity.

CONCLUSIONS

It is now possible to formulate a few methodological guidelines for using ChatGPT by self-directed learners:

- Always start by asking ChatGPT to present a list of what is important to know about <topic>, and provide a rationale for its recommendations.
- Continue by asking details on the advantages and benefits of gaining knowledge about <topic>.
- Prompt ChatGPT to place the information provided in a larger (historical, technological, social) context. Ask it to tell stories about the people who contributed to the <topic>.

- Start by clarifying the basic concepts and the terminology specific to the <topic>. Ask as many questions as needed. Request details on the differences between the new concepts and other related or similar terms.
- Ask for examples whenever is needed.
- Ask ChatGPT to summarize the ideas discussed.
- Prompt ChatGPT to create multiple choice questions to verify the progress of the learner.
- Be aware that ChatGPT is not infallible and sometimes it makes mistakes.

By following these simple rules, it is easy to create a personalized learning experience and tailor the educational content according to individual needs and interests. This can help learners to stay engaged and motivated, and to make progress at their own pace.

Moreover, ChatGPT can provide learners with a sense of autonomy and control over their learning, which can help to reduce anxiety and stress. Knowing that help is always available can also help learners to feel more confident and capable.

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THE IMPORTANCE OF FEMALE ENGAGEMENT TEAM MISSIONS IN THEATRES OF OPERATION IN AFGHANISTAN

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DOI: 10.19062/2247-3173.2023.24.14

***Abstract:** The main topic is the theme of the missions carried out by the Female Engagement Team (FET) in the theater of operations in Afghanistan. The main pillars in this analysis are given by the cultural environment, the status of the Afghan women and gender differences, which will determine the impact and effectiveness of the FET. We will determine the degree of necessity and results achieved during the missions. Success is due to the positive impact it has on the population that helps to provide information and prevent conflicts based on tradition violations. The precise setting of FET tasks leads to the consolidation of local support, which will help achieve the final goal and solve problems and needs.*

***Keywords:** FET, Afghanistan, civil, cultural environment, women, gender differences, missions, population, information, traditions, transformation, religions, cultural, taliban, Islam, family, position of women in the family.*

1. INTRODUCTION

Today, society is undergoing a continuous, significant transformation process, that is increasingly present and influences human activities. This also affects the way in which military actions are carried out.

The main pillar of current missions is the civilian population, which influences the way the mission is carried out and the success at the same time. The success is influenced by the cooperation relationship and support offered by the civil sphere to the armed forces and vice versa, for this reason I chose the case study where I will analyze the military operations carried out in the theater of operation in Afghanistan, the focus being on the necessity and effectiveness of the FET teams. Through this case study I wanted to deepen and analyze the strategic environment and its evolution, the importance of understanding the cultural difference, the final goal being the success of the mission, thus analyzing the importance of the cultural factor and how it can be exploited through FET.

The security field has become more and more vast, which is why the degree of vulnerability is high and the attention given must be as high as possible. In this context, the armed forces have to become aware of the level of complexity and the need to use a new instrument, this being the introduction of FET teams in various fields and areas of security.

FET teams that consist only of female soldiers will be the main subject of this chapter. The International Security Assistance Forces (ISAF) has for the first time deployed FET teams to communicate with women in Afghanistan for intelligence processing purposes.

2. ANALYSIS OF THE DIFFICULTY OF THE RELATIONSHIP BETWEEN CIVILIAN-MILITARY AND THE COMPLEXITY OF THE THEATER OF OPERATIONS IN AFGHANISTAN FROM A CULTURAL POINT OF VIEW

The values of a state are a component of culture, and culture is the defining element of a people. Therefore, these values that belong to the people are the elements that produce differentiation from other people. The loss of values leads to the blurring of culture. The members of a culture have to conform to the norms in order to exist and function in the culture.

Culture consists of behavior, habits, beliefs and other common characteristics that bind members of a group or society. With the help of culture, people in groups define and conform to common values and contribute to the formation of society.

In February 1977, the Great Assembly took place, where a new constitution was adopted. But the following year, it was repealed when another coup created the Democratic Republic of Afghanistan, being governed by the Afghan Revolutionary Council. In the last coup in September 1979, a socialist government was installed.

After the fall of communism, Taliban leaders took over the power of the state by advocating the supremacy of Islamic law. With the help of the United States, in December 2001, the Taliban were removed from power, and a new constitution was ratified in January 2004, which would elect the president with two vice-presidents.

Islam is the official religion in Afghanistan and a large part of the population is Muslim (about 99% of the population). However, there are very small communities of other beliefs: Christians, Sikhs, Hindus and Bahai.

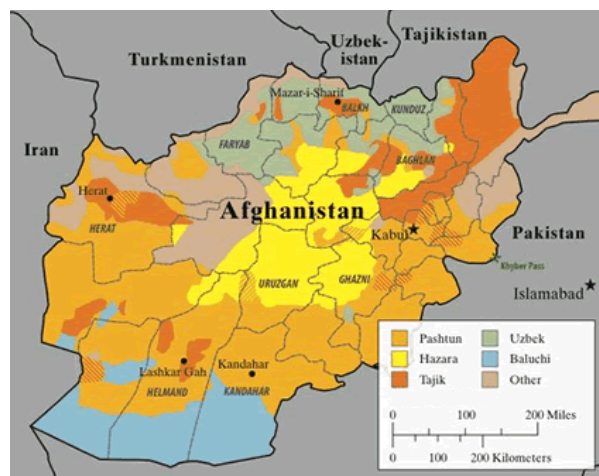


FIG.1 Islamic Republic in Afghanistan

The population of Afghanistan is guided by strict values, beliefs and rules that provide for the family and behavior of members. However, these complex rules change depending on ethnicity and region. The family is an important institution in society.

The rules that guide the traditional family are shown in the following rows:

- Afghan families emphasize age and worship motherhood.
- Extended families serve a system of support, economic and social.
- The process of socializing the child occurs in the family.
- Extended family dwellings can contain three or even four generations, including the man who is considered the family pillar with his wife, his brothers, their sons and families, but also unmarried daughters and grandparents, if this can be done.

- The oldest woman in the house is responsible for establishing internal responsibilities.
- Women in the same household cooperate to educate and care for children.
- The man who has accumulated the greatest experience, usually the grandfather, controls all expenses.
- Even though family members work a lot, on weekends and sometimes during the week they organize visits and entertainment activities.
- The family of an Afghan is sacred. For this reason, it is considered a violation of manners if one man expresses any interest of in the female relatives of another
- Women are responsible for distribution of supplies obtained after a harvest and for them to reach the following year, this is usually dealt with by an elderly member of the family.
- The man can decide how women in the family must behave for the preservation of the male prestige and honor of the family.
- There is no possibility for a woman to be independent, otherwise the social situation of families may suffer if women do not remain subject and dependent on their husbands.
- Women are responsible for the prestige of the family

Historically, women in Afghanistan have always been marginalized, living together in subordinate relationships. The position of women in the family and society has been shaped over time by many factors, and there are cultural and historical roots aimed at the existence of gender discrimination.

3. ANALYSIS OF FET MISSIONS IN THE THEATER OF OPERATIONS IN AFGHANISTAN

History has shown that most insurgents are men. But in traditional societies, women are influential when it comes to forming social networks that insurgents use for support. By gaining the trust of women through social and economic programs aimed at helping society, the power of insurgents is undermined. To achieve this, women in the armed forces are needed who contribute to the counterinsurgency effort.

To address 50% of the Afghan population, the FET concept was implemented by the United States Marine Corps (USMC), which tried to use a similar concept in missions in Iraq. The FET is a group of female soldiers who aim to build a connection with Afghan women, report information that can help combat insurgents and support them, and therefore get in touch with their families and community.

The Afghan conflict had a gender dimension, the insurgents understood this and used the Afghan sensitivity of honor to women. The Taliban have realized that American male soldiers avoid intervening inside homes to dishonor female women and used this to their advantage by storing improvised weapons and explosive devices in women's rooms. The Taliban also disguised themselves as women to smuggle weapons through checkpoints without being suspected. Women were used to transport arms, money and drugs.

Finally, it was concluded that FET groups can be engaged in other types of missions, not just in carrying out female population controls, these employed women have a responsibility to form relationships with Afghan families.

After receiving the agreement from the men to dialog with the women in the house, the female soldiers managed to get close to them and persuade them to speak.

They had discussions about daily life, their concerns, the environment, etc. The teams spent an average of an hour with Afghan families, during the discussion they received tea and bread, and instead offered medicine.



FIG. 2 FET teams interacting with the local female population

The FET has been able to demonstrate its usefulness in the missions in Afghanistan. There are various reasons that demonstrate their need, such as the need to use female personnel in a visible way, the need to show that the military addresses gender issues, and the effectiveness demonstrated during the missions.

The possibility of interacting with Afghan women during patrols is inevitable, as they make up half of the country's population. FET teams are therefore a vital asset in the deployment of missions in Afghanistan.

CONCLUSIONS

For starters, the civilian population feared how their traditions could be changed and how women could be influenced, later realizing the help they could receive. Over time, the effectiveness of the armed forces has been demonstrated with the implementation of the FET teams and how they influence the missions to success.

There are several important factors that improve the actions taken. Cultural environments are different and there is also a linguistic difference, to improve FET interventions a female translator or performer is required during the conversation. Eye contact is a very important element during a dialogue, for this reason the translator must be positioned behind or aside so as not to become the center of the conversation.

Credibility is a key factor, and to achieve this it is necessary to pay attention to any detail. In order to form a relationship with the Afghan family, FET must learn their habits to participate in their daily activities, gradually removing barriers to communication.

Another important aspect is the healthcare that can be provided by FET and can involve Afghan women in study activities. Health care is paramount, through the intervention of FET and a female doctor, Afghan women can be consulted. FET teams have to perform multiple tasks that help the population.

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DIGITAL TRANSFORMATION IN CRISIS MANAGEMENT: THE KEY ROLE OF ARTIFICIAL INTELLIGENCE

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DOI: 10.19062/2247-3173.2023.24.15

Abstract: *In today's world, crises can occur at any time, and efficient crisis management is essential to minimize the impact on society. With the advancement of technology, digital transformation has become an integral part of crisis management. Artificial Intelligence (AI) is one such technology that plays a key role in crisis management by enabling faster, more accurate, and data-driven decision-making. This article explores the impact of digital transformation on crisis management and the key role of AI in this process. It discusses the various ways in which AI can be used in crisis management, such as predicting and mitigating disasters, analyzing social media for real-time information, and providing insights to aid decision-making. The article also highlights the challenges and ethical considerations associated with the use of AI in crisis management. Overall, this article emphasizes the importance of leveraging digital transformation and AI in crisis management to improve the speed, accuracy, and effectiveness of response efforts.*

Keywords: *crisis management, digital transformation, artificial intelligence, emergency response, risk assessment, machine learning.*

1. INTRODUCTION

Safety and security are two crucial aspects in crisis management. In this context, artificial intelligence and digitalization play an increasingly important role. In recent years, we have witnessed a significant increase in the number of AI technologies and digital solutions that can be used to cope with crisis situations such as natural disasters, aggressions, cyberattacks or global pandemics.

In this article, we will explore how artificial intelligence and digitalization can be used to improve crisis management and ensure safety and security in crisis situations. We will analyze concrete examples of the use of AI and digital technologies in crisis situations, as well as the challenges and opportunities that these technologies bring.

In a context where crisis situations can arise at any time, it is important to have efficient tools to manage and quickly solve these situations. Digitalization can be a key factor in this regard, offering the possibility to monitor crisis situations in real-time and to make quick, informed, and efficient decisions.

However, an increase in the use of technology and artificial intelligence can also bring risks, especially regarding data and personal information security. It is essential to ensure that the tools and technologies used to manage crises are secure and that data is protected.

We will also examine how world leaders and managers can use these technologies to efficiently manage crises, ensuring a quick and coordinated response to crisis situations.

Finally, we will offer some conclusions and recommendations for those who want to integrate AI and digital technologies into their crisis management strategies.

2. ARTIFICIAL INTELLIGENCE

Artificial Intelligence (AI) is a branch of computer science that focuses on developing systems capable of performing tasks that would typically require human intelligence. John McCarthy, one of the pioneers in the field, argues that "Artificial Intelligence is the study of how to make machines do things that would require intelligence if done by men." These systems are programmed to learn and improve their performance based on the data and information they receive.

AI can be divided into two main categories: weak AI and strong AI. Weak AI is programmed to perform a single specific task, such as voice recognition or facial recognition. In contrast, strong AI is capable of performing a variety of tasks and can make decisions autonomously. [1]

How does Artificial Intelligence work?

To function, AI requires data. Artificial Intelligence systems are programmed to process and analyze the data they receive and identify patterns and trends within it. Based on this information, the system can make specific decisions and take action. An example of the use of AI in the digitalization of military management is the use of machine learning algorithms to analyze data from drones and other surveillance systems to detect enemy activities and generate real-time situation reports. These reports can be used by commanders to make faster and better-informed decisions. [2]

There are several methods of training AI systems, including supervised learning, unsupervised learning, and reinforcement learning. In supervised learning, the system is trained to perform a specific task using pre-labeled and classified datasets. In unsupervised learning, the system is trained to identify patterns and trends in unlabeled and unsupervised data. In reinforcement learning, the system learns through interaction with the environment and receives feedback based on its actions.

What are the benefits that Artificial Intelligence can bring to digital transformation in crisis management?

Artificial Intelligence (AI) can bring several benefits to digital transformation in crisis management, including improving efficiency and productivity and enhancing precision and accuracy. AI algorithms can be used to automate repetitive processes and speed up decision-making processes. This streamlining can lead to improved responsiveness and increased productivity of military personnel. They are also used to analyze data with much greater precision than is possible for humans. This can lead to greater accuracy in identifying threats and opportunities, as well as improving the quality of the decisions made.

Increasing data analysis capacity: AI can be used to process and analyze large amounts of data from various sources. This analysis can lead to a better understanding of the situation and better planning of military operations. [3]

Reducing risks and costs: The use of AI can reduce the risks associated with military operations and can help identify and prevent threats before they become dangerous.

Additionally, the use of AI can reduce costs by eliminating repetitive tasks and improving operational efficiency. "Improving security and data protection: AI can be used to detect hostile activities and prevent cyber attacks, as well as monitor data access and ensure compliance with security policies.

In general, the use of AI in digitizing military management can bring significant benefits, but potential challenges such as cybersecurity issues and the need to train military personnel in the use of new technologies should also be considered." [4]

How can artificial intelligence be used in crisis management?

AI can be used in crisis management in several ways. One example is using AI algorithms to analyze data and information in real-time, providing a comprehensive picture of the crisis situation. AI can also be used to identify potential problems and risks, make predictions, and assist in making quick and efficient decisions during a crisis.

Additionally, AI can be used to develop predictive models that identify potential crisis situations before they occur, allowing for proactive management. Furthermore, AI can be used to analyze and manage resources during a crisis, as well as coordinate intervention and recovery efforts.

3. CRISIS MANAGEMENT

Jaques and Clement (1991) argue that Crisis Management is "the process of identifying potential crises, determining appropriate responses, and implementing selected responses." According to Pearson and Mitroff (1993), Crisis Management is "a systematic way of managing crisis situations, including prevention and recovery activities, to minimize the damage they can cause." [5]

The theorist Karl E. Weick considers a crisis to be "a significant event that exceeds an organization's capacity to cope, endangering the organization's existence and/or reputation."

According to management professor Ian Mitroff, a crisis is "an apparently uncontrollable event that threatens an organization's values and/or existence and requires fundamental changes in the way the organization operates."

Charles Herman defines it as "a situation that threatens the high-priority objectives of the decision-making unit; restricts the time available for a response, before the situation is altered; when it occurs, it catches decision-making unit members off guard."

Michel Brecher defines it as "a situation characterized by four conditions, as perceived by decision makers: a mutation in the external or internal environment; a threat to core values; a high probability of involvement in predominantly military hostilities; a response to the values."

As for the use of artificial intelligence in managing interstate military crises, limited research is available. However, some potential applications of AI in this context include predictive analysis, in which artificial intelligence can be used to analyze historical data and current events to predict the probability and severity of an interstate military crisis.

Artificial intelligence can provide decision support to leaders in the form of real-time data analysis and scenario planning. AI can be used to develop autonomous systems for surveillance, recognition, and other military operations.

Examples of AI use in recent military crises are also limited, but a notable example is the use of AI-powered drones by both sides in the Armenia-Azerbaijan conflict over Nagorno-Karabakh in 2020. These drones (UAVs) were able to conduct precise attacks on enemy targets and provide real-time information to commanders.

Autonomous vehicles are capable of operating without direct human intervention. They are equipped with different types of sensors, such as video cameras, radar, or lidar, and with data processing systems that allow them to move on roads and make decisions based on traffic and environmental conditions.

There are different levels of autonomy for these vehicles depending on the degree of driver involvement or intervention. The levels of autonomy are established by SAE International and include the following:

Level 0: The driver has full control of the vehicle.

Level 1: Driver assistance systems can be activated, but the driver remains responsible for controlling the vehicle.

Level 2: The vehicle has driving assistance systems that temporarily take control of certain functions, but the driver must be prepared to take control again.

Level 3: The vehicle has the ability to take full control under certain conditions, but the driver must be prepared to take control if the system requests it.

Level 4: The vehicle can operate without human intervention under certain conditions or in certain predefined areas.

Level 5: The vehicle is completely autonomous and requires no human intervention. [6]

Autonomous vehicles have the potential to reduce the number of human casualties in a theater of operations, decrease civilian casualties during an armed conflict, reduce the number of road accidents, and improve safety on public roads. They can also be useful in reducing pollution and optimizing traffic. However, there are still many technological, legal, and social challenges to overcome before autonomous vehicles can be widely used. Crisis management refers to the process of identifying, analyzing, and managing situations that threaten the objectives and interests of an organization or a nation. These crises can be political, social, economic, environmental, or security-related, and their management involves making quick and efficient decisions to minimize negative impact. Interstate military crises are those crisis situations involving two or more states and may include direct or indirect threats such as armed conflict, diplomatic or security crises. In such situations, the use of artificial intelligence can be particularly important as it can help reduce the risk of human error or make rapid decisions in the face of imminent threats. Concrete examples of using artificial intelligence in the context of military crises include: Using surveillance and facial recognition systems to identify militants or individuals with terrorist potential in conflict zones; Using data analysis algorithms to monitor troop movements and identify potential threats in real-time; Using simulation technology to test and develop security strategies and to train military forces in crisis scenarios. A recent example of using artificial intelligence in the context of a military crisis is the use of the autonomous MQ-9 Reaper drone by the US Air Force to target individuals in Afghanistan during the 2021 evacuation.

The drone used advanced data analysis and facial recognition technology to identify targets and carry out attacks with precision and speed. Overall, the use of artificial intelligence in managing interstate military crises can be particularly useful in reducing the risk of human and material losses, as well as making informed and efficient decisions in a timely manner.[7]

4. DIGITIZATION

Digitization is the process of transforming information, processes, and activities into digital or electronic formats. It involves the use of digital technology to replace or improve traditional processes that use paper, analog records, or other analog methods.

Digitization can include converting physical documents into digital format, storing data in digital media, transferring information through digital networks, processing information using algorithms, and using automation to improve process efficiency and accuracy.

It has become increasingly important in recent years, fundamentally changing the way we manage crises. By using digital technology and artificial intelligence, we can better manage crises, anticipate issues, and provide more efficient and rapid solutions.

One of the biggest changes brought about by digitization is the way we communicate and access information. With the help of the internet and social networks, we can receive real-time information about crises and communicate quickly with those involved in crisis management. This allows us to respond more quickly and make better decisions in real-time. Additionally, digitization provides us with tools and technologies to better manage crises. [8]

For example, we can use drones and other advanced technology systems to perform rescue operations or evaluate the damages caused by a crisis. Through artificial intelligence, we can analyze the data collected by these technologies and identify patterns and trends that can help us anticipate future crises. Furthermore, through digitization, we can use data analysis and artificial intelligence to develop crisis scenarios and action plans. This allows us to test solutions before they are needed and identify gaps in our plans. This means we are better prepared for any crisis that may arise in the future. National security and defense are areas where artificial intelligence (AI) is increasingly being used to improve military capabilities and enhance military operations efficiency. Here are some examples of digitization achieved in the military field thanks to artificial intelligence: An example of using artificial intelligence in the military field is the development of autonomous weapon systems. These systems can be controlled through a network of sensors and AI algorithms that allow them to detect and identify targets and decide when and how to attack. AI can be used to analyze images captured by drones or other surveillance devices, identifying suspicious objects and activities and alerting the operator. These systems can be useful in detecting and tracking enemies or other potential threats. AI can be used to analyze information data, including those from human and electronic information sources, such as intercepting enemy communications. These systems can help identify enemy schemes and generate intelligence reports for commanders. Planning and decision-making systems: AI can be used to develop planning and decision-making systems that help military commanders make more informed decisions regarding military operations. These systems can take into account a variety of factors, such as terrain, weather conditions, and enemy threats, to help develop efficient military strategies.

AI can be used to develop training simulations for military personnel, allowing them to train in a safe and controlled environment. These simulations can be used to improve decision-making, communication, and coordination capabilities of military operations. [4]

These are just a few examples of the use of artificial intelligence in the military domain to enhance military capabilities and increase the efficiency of military operations.

Another example of digitalization in military management could be the use of digital communication systems to improve communication and coordination between military units. In the past, communication within the armed forces was often done through radios and other analog technologies, which were susceptible to interference and communication errors.

Today, digital communication systems such as satellite networks or mobile data networks are used, which allow for fast and secure transmission of information. These digital communication systems allow military officers to quickly transmit information such as enemy coordinates, attack orders, and situation reports between military units. Additionally, the information can be digitally stored and processed to provide a better overall picture of the situation and aid in decision-making.

Furthermore, digital technologies are used in the military to monitor and manage stocks of weapons and equipment, as well as to plan and coordinate logistical operations. This can help reduce waste and streamline processes, which can have a positive impact on military capability and resilience.

CONCLUSIONS

In conclusion, digitization has fundamentally changed the way we manage crises and provides new opportunities to maximize efficiency in crisis management through artificial intelligence and advanced technology. However, it is important to ensure that we use these tools in a responsible and efficient manner to ensure the safety and security of those involved in the crisis.

An example of preventing an international conflict through the use of artificial intelligence is the case of the United States applying AI technology to identify the risks of nuclear weapon proliferation in North Korea.

In 2017, the United States developed a system for detecting intercontinental ballistic missile (ICBM) launches from North Korea, called HBTSS (Hypersonic Ballistic Tracking Space Sensor). This system was developed using AI technology and is capable of identifying and tracking ballistic missile launches from a great distance and with high accuracy.

Using this AI technology, the United States was able to closely monitor North Korea's activities and detect ballistic missile launches before they occurred. This allowed the United States to take preventive measures and avoid escalating conflict with North Korea.

Additionally, using AI technology to monitor and analyze the flow of information from diverse sources (such as social media, information reports, press releases, etc.) can help quickly detect events that could lead to international conflicts. This information can be used to develop conflict prevention strategies and take preventive measures in a timely manner.

Overall, the use of artificial intelligence can contribute to the prevention of international conflicts by improving the ability to identify threats and monitor suspicious activities, which can allow for faster and more efficient decision-making in conflict prevention.

In conclusion, AI is very useful in crisis management and conflict prevention due to its ability to monitor and map terrains using specialized cameras or sensors; research and monitor the environment by monitoring air, water, or vegetation pollution and climate change.

There are companies that use UAVs to deliver packages to desired addresses, with lower costs and faster delivery times than traditional methods. This solution is particularly important in the conditions of an armed conflict.

UAVs can be used to help rescue teams and firefighters locate and rescue people in danger.

In conclusion, they were initially developed to be used in the military field and continue to be used for this purpose. Military personnel use UAVs in a wide range of missions, including:

Terrain surveillance and reconnaissance: UAVs can be used to perform surveillance and reconnaissance missions, allowing military personnel to observe and collect information about areas of interest without exposing themselves to unnecessary risks.

Target identification: UAVs can be equipped with specialized video cameras and other sensors to identify targets of interest, such as vehicles, buildings, or individuals.

Traffic and border monitoring: UAVs can be used to monitor road and sea traffic or to surveil borders, allowing military personnel to detect and intercept potential threats.

Close air support: UAVs can be used to provide close air support to ground troops, tracking enemy movements and providing real-time information to help military personnel make faster and better-informed decisions.

In conclusion, UAVs continue to be an important tool for military personnel in various missions, offering advantages such as discreet observations and real-time information.

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Aeronautical and Atmospheric Sciences

RISK MANAGEMENT APPLIED TO AEROSPACE ENGINEERING DESIGN

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DOI: 10.19062/2247-3173.2023.24.16

Abstract: *The intent of this paper is to present applications of risk management to aerospace engineering design; the study was focused on composite materials design and manufacturing of parts, assemblies from aircraft and spacecraft, such as aerostructures, fuselage, aircraft wings and controls, jet engines parts such as fan blades, widely used in aerospace engineering. The use of composites in aerospace engineering provides significant reduction of costs for manufacturing, technology and operation, provided adequate management. Management in composites design, manufacturing and technology may allow to achieving performance and cost-effectiveness for such aerospace engineering parts, which are critical from the safety standpoint.*

Keywords: *Risk Management, Aerospace Engineering, Composite Materials, Design, Manufacturing, Safety.*

1. INTRODUCTION

Design of aircraft and space product constructions must be compliant with the safety standards specifically stated in regulations for the commercial and military aircraft industry, prior to all other criteria.

Then, subordinated to safety standards are the general and specific design criteria, like: geometry, loads, mechanical stress, thermal stress, reliability, then manufacturing, operating and maintenance costs, and the last but not the least, aesthetics. Improved properties as high strength and stiffness, combined with low density can be provided by the use of composite materials when compared with bulk materials, allowing for a weight reduction in the finished product/ assembly/ part.

Composite materials are widely used today in aerospace engineering, due to their provided advantages, such as: lighter weight, the ability to tailor the layup for optimum strength and stiffness, improved fatigue life, corrosion resistance, long working life, lower density with respect to steel alloys, high strength to weight ratio, low coefficient of

thermal expansion, five times stronger than steel, reduced assembly costs due to fewer detail parts and fasteners in case of mastering good design practice.

On the other hand, disadvantages of composites must be taken into account and contingency plans must be provided, where applicable or available; disadvantages of composites refer to: high raw material costs and usually high fabrication and assembly costs, adverse effects of both temperature and moisture, poor strength in the out of plane direction where the matrix carries the primary load, susceptibility to impact damage and delimitations or ply separations, greater difficulty in repairing composite parts when compared to metallic structures.

Aircraft design represents an intricate exhaustive task, since it involves specific design of aircraft structure, propulsion system, aircraft controls, engine controls, avionics, Auxiliary Power Unit (APU), landing gear and other parts.

The design cycle of an aircraft can cover a duration of more than 20 years, because it is an iterative process, which supposes a step by step development following a Technology Readiness Assessment (TRA) that examines program concepts, technology requirements, and demonstrated technology capabilities.

Technology Readiness Levels (TRLs) are based on a scale from 1 to 9, with 9 being the most mature technology, as detailed in Table 1, [18].

Table 1 – Technology Readiness Levels (TRLs), [18]

TRL	NASA usage, [19]	European Union, [20]
1	Basic principles observed and reported	Basic principles observed
2	Technology concept and/or application formulated	Technology concept formulated
3	Analytical and experimental critical function and/or characteristic proof-of concept	Experimental proof of concept
4	Component and/or breadboard validation in laboratory environment	Technology validated in lab
5	Component and/or breadboard validation in relevant environment	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
6	System/subsystem model or prototype demonstration in a relevant environment (ground or space)	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
7	System prototype demonstration in a space environment	System prototype demonstration in operational environment
8	Actual system completed and "flight qualified" through test and demonstration (ground or space)	System complete and qualified
9	Actual system "flight proven" through successful mission operations	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Mathematical Modeling and Numerical Simulations have an important role in design and concept development. Design improvements and/or design optimizations often result as consequences of feedback from Mathematical Modeling and Numerical Simulations.

This paper presents some of the most significant and common topics encountered in aerospace engineering design and the approach to problem's study and solving from the standpoint of associated risk management. The proposed topics for this paper are: 1/ thermo-gas-dynamics of turbojet engines, 2/ design and reverse engineering in case of axial compressor and fan rotor blades, 3/ guidelines of risk management customized for aerospace engineering design.

For each of these topics, an approach of Risk Management in the meaning of Risk Intelligence will be addressed. The steps assume the successive completion of the following stages: 1/ Risk Identification, 2/ Risk Assessment, from the standpoint of impact and likelihood, 3/ Prioritization of risks, 4/ pointing out the actions to be taken, which can be one of the following options: a/ tolerate, b/ treat, c/ substitute, d/ terminate.

Risk Intelligent is a holistic approach of Risk Management, considered globally, that is looking at the entire system as a whole, not just focusing on some parts of the system, without also considering the determining relationships and interactions between the various parts of the general system. Risk Intelligent can be considered as a tool for Active Control serving Risk Management to control and maintain the adjusted balance between risks and reward. The ultimate goal of Risk Intelligent is to create added value by assuming risks and enabling simultaneously to protect, keep and maintain the values already accumulated.

2. TOPIC #1: THERMO-GAS-DYNAMICS OF TURBOJET ENGINES

Problem Statement and Framework: The thermo-gas-dynamics analysis of the turbojet engine is carried out in order to achieve the following objectives:

1/ to calculate the performances of the turbojet engine at Design Regime and to do its performance prediction at Off-Design Regime;

2/ to investigate the engine operating regimes, concluded within the determined turbojet engine's Operation Maps (Altitude Map, Velocity Map, Rotor Speed Map) and engine's Universal Map, based on turbojet engine performances, previously calculated;

3/ to carry on the Steady State Analysis, which consists in the investigation of the engine's operating regimes and equilibrium states, based on the performances of the turbojet engine calculated in previous steps;

4/ to provide calculated data as input to carry on the Transient State Analysis, which reveals the dynamic behavior of the turbojet engine and further enables to complete the study of turbojet engine automate control. The results from Transient State Analysis enable the design of jet engine's automate control and further, the design and management of the aircraft engine controls.

The design of the turbojet engine supposes the completion of the thermo-gas-dynamics analysis performed initially at the level of the entire engine, as a system and then at the level of turbojet engine main parts (air inlet & intake, compressor system, combustion chamber, turbine and exhaust unit), Fig. 1.

The accuracy of the results is strongly influenced by the Mathematical Modeling of the turbojet engine and the assumptions related with the turbojet engine's operation. The accuracy is influenced by the level of the approximation, that is the way the assumptions are taken into consideration.

The numerical accuracy depends on the numerical methods and algorithms chosen for solving numerically the equations that define the turbojet engine's mathematical model. Only few equations can be solved analytically.

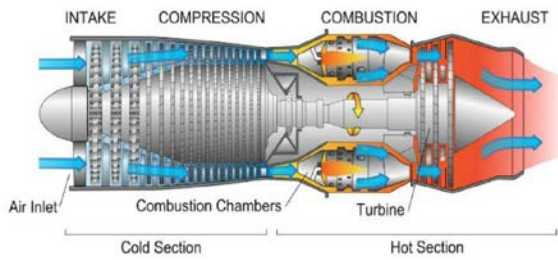


FIG. 1 Turbojet Engine (TJE), [22]

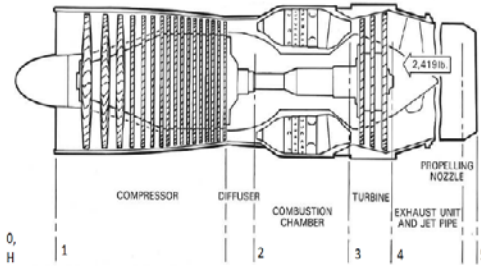


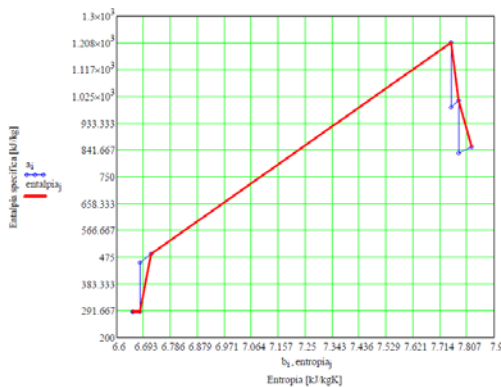
FIG. 2 Definition of Turbojet Engine Stations, [21]

The study is concluded by the results obtained from Numerical Simulations.

This paper is focused on the turbojet performance analysis, with the application to the TJ100 single spool turbojet engine, as Test Case, [23-26].

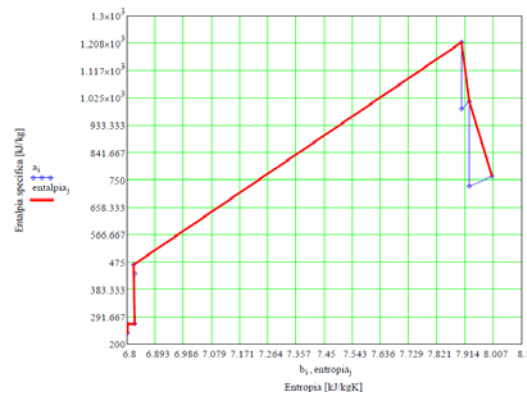
Turbojet engine Performance Prediction refers to the calculation of the turbojet engine's performances: Thrust [N], Specific Thrust [N*s/kg] and Specific Fuel Consumption [kg/N/h) – TSFC, for the entire range of parameters: flight altitude [m] and flight velocity V [m/s] or flight Mach number, as expressed by the Aircraft's Flight Envelope and for all the operating regimes of the turbojet engine.

The algorithm for determining the Brayton Diagram provides eventually the turbojet engine's performances: Thrust [N], Specific Thrust [N*s/kg] and Specific Fuel Consumption [kg/N/h).



a/ Design Regime:

Altitude $H = 0$, Flight Mach number = 0,
Flight Velocity $V = 0$ [m/s]



b/ Off-Design Regime:

Altitude $H = 8$ [km], Flight Mach number = 0.8,
Flight Velocity $V = 246$ [m/s]

FIG. 3 Brayton Diagram, calculated for the Design Regime (left) and an Off-Design Regime (right), in case of TJ 100 Turbojet Engine, [23-26]

The Brayton Diagram express the turbojet engine's thermodynamic cycle and it is usually described by the coordinates: specific entropy [kJ/kg/K] and specific enthalpy [kJ/kg]. The turbojet engine stations, defined as shown in Fig. 2, match the points within the field of the Brayton Diagram.

In blue contours is the thermodynamic evolution of the ideal flow along core engine flow path, with the supposed assumptions: the fluid is an ideal gas, one species, adiabatic processes, no losses.

In red contours is the thermodynamic evolution of the core engine real flow, modeled with the supposed assumptions: the fluid is a perfect gas, two species, adiabatic processes, considered losses due to drag, friction, local turbulence, the thermodynamic system representing the engine model is considered open.

The Brayton Diagram presented in Fig. 3-a was calculated for the Design Regime, at SLS, ISA conditions (i.e. "fixed point", which usually means altitude $H = 0$ [km] and flight velocity $V = 0$ [m/s] or flight Mach number = 0), Fig. 3-a, while the Brayton Diagram exposed in Fig. 3-b was determined for a selected Off-Design Regime, (Altitude $H = 9$ [km], Mach number = 0.8, which gives Flight Velocity $V = 246$ [m/s]).

Main input data for calculating the Brayton Diagram and the performances of the TJ 100 turbojet engine: Thrust [N], Specific Thrust [N*s/kg] and Specific Fuel Consumption [kg/N/h]:

Pressure ratio = 5.0, Airflow Mass Rate = 1.74 [kg/s], Turbine Inlet Temperature $T_3^* = 1123$ [K].

$$\pi_c^* = \frac{p_2^*}{p_1^*} \quad \dot{M}_a = 1.74 \left[\frac{kg}{s} \right] \quad T_3^* = 1123 [K]$$

Other turbojet engine parameters:

- $\eta_c^* = 0.85$ - Adiabatic efficiency on compression
- $\eta_t^* = 0.89$ - Adiabatic efficiency on turbine expansion
- $\eta_m = 1$ - Mechanical (shaft) efficiency, = 1 / single spool construction
- $\sigma_{da}^* = 0.92$ - Pressure loss at engine intake
- $\sigma_{ca}^* = 0.98$ - Pressure loss in combustor
- $\xi_{ca} = 0.998$ - Combustion efficiency
- $\varphi_{ar} = 0.940$ - Exhaust nozzle velocity loss

The **Mathematical Model** of the turbojet engine describing its behavior as close to reality is based on the following set of **Assumptions**:

- the working fluid is considered perfect gas,
- two species:
 - // **air** // - from engine intake to compressor, stations: 0-1-2;
 - // **burned gas** // - within combustor, turbine and exhaust unit, stations: 2-3-4-5;
- fuel specific power, for JET A, JET A1 and/or JET B (aviation kerosene):

$$P_{Cl} = 43500 \left[\frac{kJ}{kg} \right],$$

- ratio of specific heat $k = \frac{C_p}{C_v}$, see Table 1.
- constant pressure specific heat $C_p \left[\frac{kJ}{kgK} \right]$:
- gas constant $R \left[\frac{kJ}{kgK} \right]$; the relation between R and C_p is: $C_p = R \cdot \frac{k}{k-1}$

Table 1 Properties of the working fluids

Fluid	k	C_p [kJ/kg/K]	R [J/kg/K]
Air	1.4	1.005	287.3
Burned Gas	1.33	1.165	288.4

The **Mathematical Model** for computing the turbojet engine performances is defined by the following equations:

- SLS, ISA conditions: $p_0 = 1.01325$ [bar] (1), $T_0 = 288$ [K] (2) and $i_0 = C_p \cdot T_0$ [kJ/kg], (3)
- conditions at engine inlet (intake) - station 0 (SLS) or H (flight):
- if $H = 0$ [km] then $p_1^* = \sigma_{da}^* \cdot p_0$ [bar], (4), $T_1^* = T_0$ [K] (5), and $i_1^* = C_p \cdot T_1^*$ [kJ/kg] (6),
- if $H > 0$ then $p_1^* = p_H^* \cdot p_0$ [bar] (7), $T_1^* = T_H^*$ [K] (8) and $i_1^* = C_p \cdot T_1^*$ [kJ/kg] (9),

where $T_H = T_0 - 6.5 \cdot H$ [km], [K] (10) and $p_H = p_0 \cdot \left(\frac{T_H}{T_0} \right)^{5.2553}$ (11)

$$\text{and } T_H^* = T_H + \frac{V^2}{2 \cdot c_p} \quad (12)$$

$$\text{or } T_H^* = T_H \cdot \left(1 + \frac{(k-1)}{2} \cdot Mach^2\right) \quad (13)$$

$$\text{and } p_H^* = p_H \cdot \left(1 + \frac{(k-1)}{2} \cdot Mach^2\right)^{\frac{(k-1)}{k}} \quad (14)$$

- dynamic pressure ratio:

$$\pi_d^* = \frac{p_H^*}{p_H} = \left(\frac{T_H^*}{T_H}\right)^{\frac{(k-1)}{k}} = \left(1 + \frac{(k-1)}{2} \cdot Mach^2\right)^{\frac{(k-1)}{k}} = (\theta(Mach))^{\frac{(k-1)}{k}} \quad (15)$$

- dynamic pressure ratio at Off-Design Regime (Mach number = 0.9) is:

$$\pi_d^* = \left(1 + \frac{(k-1)}{2} \cdot Mach^2\right)^{\frac{(k-1)}{k}} = \left(1 + \frac{(1.4-1)}{2} \cdot 0.8^2\right)^{\frac{(1.4-1)}{1.4}} = 1.035$$

- conditions at compressor inlet-station 1*: $p_1^* = \sigma_{da}^* \cdot p_H^*$ (16), $T_1^* = T_H^*$ (17)

$$, i_1^* = i_H^* \quad (18)$$

- conditions at combustor inlet - station 2*:

$$p_2^* = \pi_c^* \cdot p_1^* \quad (19), \quad i_2^* = i_1^* \cdot \left(1 + \frac{\left(\pi_c^*\right)^{\frac{k-1}{k}} - 1}{\eta_c^*}\right) \quad (20), \quad T_2^* = \frac{i_2^*}{c_p} \quad (21)$$

- conditions at turbine inlet - station 3*:

$$p_3^* = \sigma_{ca}^* \cdot p_2^* \quad (22); T_3^* \text{ being given, then: } i_3^* = C_{pg} \cdot T_3^* \quad (23)$$

- fuel flow coefficient (from energy balance eqn. in combustor):

$$m_c = \frac{(i_3^* - i_2^*)}{(\xi_{ca} \cdot p_{ci} - i_3^*)} \quad (24)$$

- burned gas flow coefficient (from mass balance eqn. in combustor):

$$m_g = 1 + m_c \quad (25)$$

- fuel flow coefficient: $m_c = \frac{\dot{M}_c}{\dot{M}_a}$ (26)

- burned gas flow coefficient: $m_g = \frac{\dot{M}_g}{\dot{M}_a}$ (27)

- conditions at turbine exit - station 4*:

$$i_4^* = i_3^* - l_t^* \quad (28), \quad T_4^* = \frac{i_4^*}{c_{pg}} \quad (29); \quad p_4^* = \frac{\delta_t^*}{p_3^*} \quad (30),$$

- where δ_t^* is the pressure ratio in turbine, and it comes out from the expression of

$$\text{specific work in turbine. } \delta_t^* = \left(1 - \frac{l_{t-id}^*}{i_3^*}\right)^{-\frac{(kg-1)}{(kg-1)}} \quad (31)$$

- conditions at nozzle exit - station 5:

case: full exhaust nozzle expansion: $p_5 = p_H$ (32), then the thrust obtained is maximum

case: partial exhaust nozzle expansion:

$$p_5 = p_{cr} < p_H \quad (34), \quad p_{cr} = \left(\frac{2}{kg+1}\right)^{\frac{(kg-1)}{(kg-1)}} \cdot p_4^* \quad (35)$$

- velocity of expelled gas c_5 [m/s], (36):

$$c_5 = \varphi_{ar} \cdot \sqrt{2 \cdot \left\{ \begin{array}{l} \left[i_3^* \cdot \left(1 - \pi_d^* \cdot \sigma_{da}^* \cdot \pi_c^* \cdot \sigma_{ca}^*\right)^{-\frac{(kg-1)}{(kg-1)}} \right] - \\ - i_1^* \cdot \left[\frac{\left(\pi_c^*\right)^{\frac{k-1}{k}} - 1}{\eta_c^* \cdot \eta_t^* \cdot \eta_m} \right] \end{array} \right\}} \quad (36)$$

- the turbojet engine performances:

- specific thrust: $F_{sp} = m_g \cdot c_5 - V, \left[\frac{Ns}{kg}\right]$, (37)

- thrust: $F = F_{sp} \cdot \dot{M}_a, [N]$, (38)

- specific fuel consumption: $C_{sp} = \frac{3600 \cdot m_c}{F_{sp}}, \left[\frac{kg}{Nh}\right]$ (39)

- the influence of altitude, flight Mach number and rotor speed on Airflow Mass Rate and compressor pressure ratio:
 - Airflow Mass Rate (40) is influenced by the change of altitude and flight Mach number, by the means of the variation of compressor pressure ratio, dynamic pressure ratio and the ratio of static pressures at altitude H [km] versus SLS, ISA conditions:

$$\dot{M}_a = \dot{M}_{a0} \cdot \frac{\pi_c^*}{\pi_{c0}^*} \cdot \pi_d^* \cdot \frac{p_H}{p_0} \quad (40)$$

- specific work on compression (41) changes with the square of rotor speed (42)

$$l_c^* = l_{c0}^* \cdot \bar{n}^2 \quad (41)$$

- rotor speed % (42) represents the ratio of speeds at operating versus nominal engine regime:

$$\bar{n} = \frac{n}{n_{NOMinal}} \quad (42)$$

- the relations between specific work of compressor, compressor pressure ratio, intake enthalpy and rotor speed, are (43) for SLS, ISA conditions and (44) for the flight at altitude:

$$l_{c0}^* = i_0 \cdot \left(\frac{(\pi_{c0}^*)^{\frac{k-1}{k}} - 1}{\eta_{c0}^*} \right) \quad (43)$$

$$l_c^* = i_H^* \cdot \left(1 + \frac{(\pi_c^*)^{\frac{k-1}{k}} - 1}{\eta_c^*} \right) \quad (44)$$

- the influence of altitude, flight Mach number and rotor speed on compressor pressure ratio (45) - (48) is deduced from relations (43), (44) and (41); the ratio of compressor efficiencies at operating regime versus nominal can be taken about 1.0 (as initial approximation or in case that the universal compressor map is not available):

$$\pi_c^* = \left[1 + \left((\pi_{c0}^*)^{\frac{k-1}{k}} - 1 \right) \cdot \frac{i_0}{i_H^*} \cdot \bar{n}^2 \cdot \frac{\eta_c^*}{\eta_{c0}^*} \right]^{\left(\frac{k}{k-1} \right)} \quad (45)$$

$$\pi_c^* = \left[1 + \left((\pi_{c0}^*)^{\frac{k-1}{k}} - 1 \right) \cdot \frac{i_0}{i_H^*} \cdot \bar{n}^2 \right]^{\left(\frac{k}{k-1} \right)} \quad (46)$$

$$\pi_c^* = \left[1 + \left((\pi_{c0}^*)^{\frac{k-1}{k}} - 1 \right) \cdot \frac{i_0}{i_H^*} \cdot \bar{n}^2 \right]^{\left(\frac{k}{k-1} \right)} \quad (47)$$

$$\pi_c^* = \left[1 + \frac{l_{c0}^*}{i_H^*} \cdot \bar{n}^2 \right]^{\left(\frac{k}{k-1} \right)} \quad (48)$$

The results of Numerical Simulations for the Design Regime and Off-Design Regime, in case of the TJ 100 turbojet engine are summarized in Table 2:

Table 2 – Results of Performance Prediction at Design Regime and Off-Design Regime

Pressure Ratio	5			
Airflow Mass Rate [kg/s]	1.74 [kg/s]			
Fuel Flow Mass Rate [kg/s]	0.0185 [kg/s]			
Turbine Inlet Stagnation Temperature T3T [K]	1123 [K]			
Turbine Exit Stagnation Temperature T4T [K]	956 [K]			
Velocity of expelled gas c_5 [m/s]	524 [m/s]			
Performance Prediction at Design Regime (H=0, Mach =0)				
Thrust [N] ; Thrust [daN]	1000.881 [N]	100.09 [daN]		
Specific Thrust [N*s/kg]	574.21 [N*s/kg]	574.21 [N*s/kg]		
Specific Fuel Consumption [kg/N/h]	0.1077 [kg/N/h]	1.077 [kg/daN/h]		
Flight Regime: H [km], Mach number				
H [km]	9 [km]	9 [km]		
Mach	0.8	0.8		
V [m/s]	246 [m/s]	246 [m/s]		
The influence of the flight regime on turbojet engine parameters (Pressure Ratio, Airflow Mass Rate, Fuel Flow Mass Rate) and performances				
Pressure Ratio	5.0	5.517	5.7123	5.7123
Airflow Mass Rate [kg/s]	1.74	1.2501	0.9366	0.9366 [kg/s]
Fuel Flow Mass Rate [kg/s]	0.0185	0.0338	0.0259	0.0259 [kg/s]
Velocity of expelled gas c_5 [m/s]				708 [m/s]
Performance Prediction at Off- Design Regime (H=9, Mach = 0.8)				
Thrust [N] ; Thrust [daN]	494.85 [N]		\cong 49.50 [daN]	
Specific Thrust [N*s/kg]	474.06 [N*s/kg]		474.06 [N*s/kg]	
Specific Fuel Consumption [kg/N/h]	0.1343 [kg/N/h]		1.343 [kg/daN/h]	

Altitude Map is presented in Fig. 4 and Velocity Map is depicted in Fig. 5.

Rotor Speed Map, illustrated in Fig. 6, was calculated for the following rotor speed regimes:

- rotor speed: $\bar{n} = 1.05 \rightarrow$ Emergency Max. Regime $\rightarrow 105\% n$
- rotor speed: $\bar{n} = 1.00 \rightarrow$ Design Regime $\rightarrow 100\% n$
- rotor speed: $\bar{n} = 0.91 \rightarrow$ Cruise Regime $\rightarrow 91\% n$
- rotor speed: $\bar{n} = 0.84 \rightarrow$ Lowered Cruise Regime $\rightarrow 84\% n$
- rotor speed: $\bar{n} = 0.50 \rightarrow$ Ground Idle Regime $\rightarrow 50\% n$

where: $\bar{n} = \frac{n_{Operating\ Regime}}{n_{Design\ Regime}}$ is the non-dimensional rotor speed.

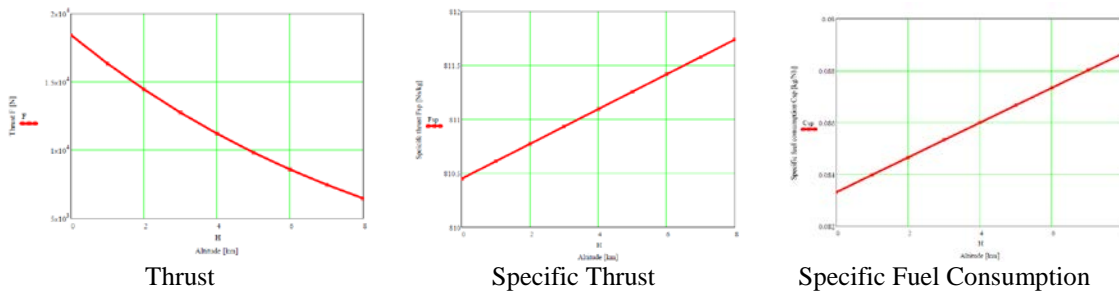


FIG. 4 Altitude Map

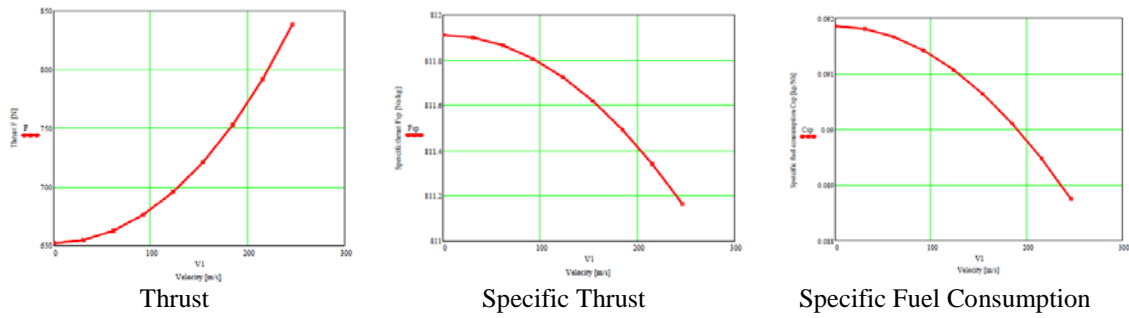


FIG. 5 Velocity Map

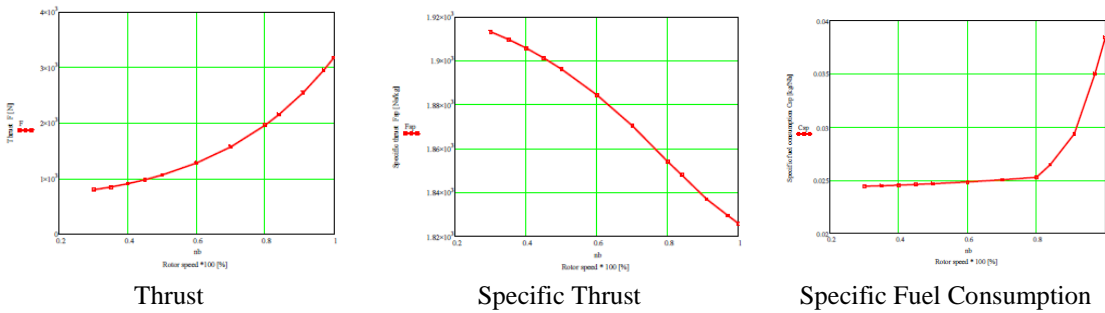


FIG. 6 Rotor Speed Map

3. TOPIC #2: DESIGN AND REVERSE ENGINEERING IN CASE OF AXIAL COMPRESSOR AND FAN ROTOR BLADES

The design of the blade airfoil results from the kinematics of the blade cascade; the velocity vectors determine the deflection of the fluid flow and by way of consequence the twist of the blade airfoil.

Reverse Engineering enables to obtain the geometry of a 3D body.

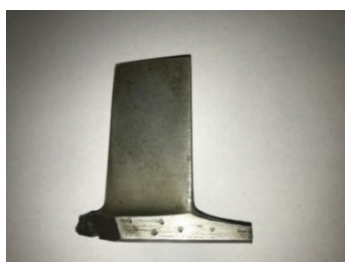
In case of the axial compressor rotor blade, presented in Fig. 7, direct measurements provided the following values for the Blade chord = 30 [mm] and Blade-max_thickness = 3 [mm].

Since the blade chord is constant along the blade span, then the airfoil surface is generated by the translation of the NACA 4-digits Airfoil from blade hub to blade tip.

By using Airfoil Tools, [27] following the selection of the NACA 2412, result the non-dimensional coordinates (X, Y) and the real (dimensional) coordinates (Xr, Yr) of the NACA 2412 Airfoil:

$$X_r [\text{mm}] = X * \text{Blade chord}$$

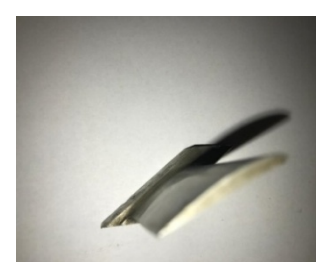
$$Y_r [\text{mm}] = Y * \text{Blade max_thickness}$$



View from Pressure Surface



View from Suction Surface



View from Blade Tip

FIG. 7 Axial Compressor Rotor Blade

The significance of the digits in case of the NACA 2412 Airfoil is:

- Max Camber = 2 (%); first digit can range between 0 to 9.5%
- Max Camber position = 40 (%); second digit can range between 0 to 90%
- Thickness = 12 (%), third & fourth digit can range between 1 to 40%

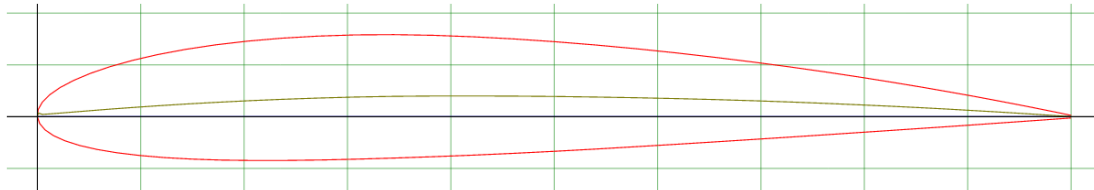


FIG. 8 NACA 2412 Airfoil (M=2.0% P=40.0% T=12.0%), [27]

NACA 2412 Airfoil using the NACA 4-digit Airfoil generator, [27], results as illustrated in Fig. 8, with Max thickness 12% at 30.7% chord and Max camber 2% at 38.3% chord.

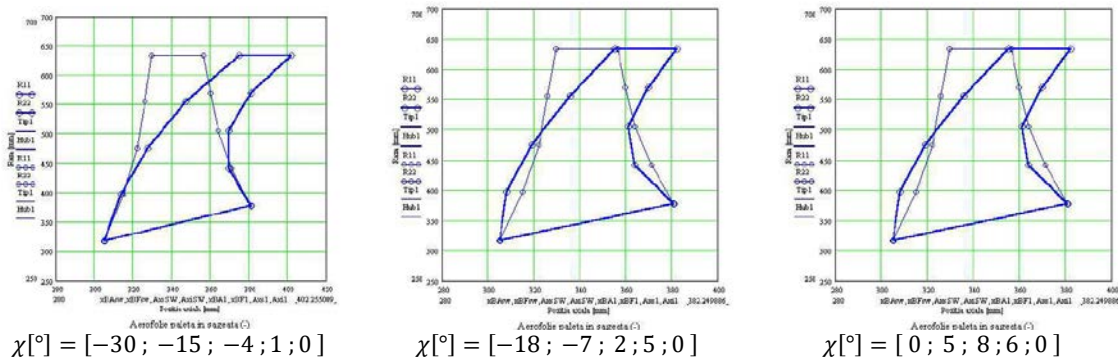


FIG. 9 Numerical Simulations of Sweep Effect Applied to Axial Compressor Rotor, [28]

In other situations, the blade chord is not constant along the blade span, but the airfoil surface can still be generated by the translation of a NACA Airfoil from blade hub to blade tip.

An effective method to increase the accuracy consists in considering different NACA airfoils for more intermediate blade spanwise sections, as well as for the blade hub and blade tip.

In case of higher velocity airflow blade cascades, NACA 65 Series Airfoils behave better and therefore are more appropriated.

In case of rotor fan blades, for large bypass turbofan engines for commercial aircraft, while running the engine at higher rotor speed regimes (cruise and design regimes), then shock waves may occur at blade tip, followed by boundary layer detachment and later re-attachment. This is a risk situation and can be avoided or mitigated from blade design, following the application of sweep effect to different stations located blade spanwise.

Numerical Simulations of sweep effect applied to an axial compressor rotor blade was performed and thorough details have been presented in [28]. In Fig. 9 are concluded the Numerical Simulations for different blade spanwise distributions of sweep angle χ [°]; in light blue contours is represented the reference blade, while in dark blue contours is depicted the blade with sweep effect.

4. TOPIC #3: GUIDELINES OF RISK MANAGEMENT CUSTOMIZED FOR AEROSPACE ENGINEERING DESIGN

Technology advancements in case of large turbofan engines for commercial aircrafts:

1/ increased engine thrust due to enlargement of fan blade tip diameter resulting an increase of ingested airflow,

2/ application of sweep to fan blades such that to avoid the occurrence of shock waves at blade tip while the engine is operated at high rotational speeds, Fig. 10, Fig. 11,

3/ expanding the use of composites to fan parts (rotating blades, guiding vanes, casings), Fig. 12, allowed advanced aerodynamic design of fan blades and important decline of weight, and in the same time, as composites provide higher strength and stiffness, allowed product life cycle extension and the diminishing of costs related to manufacturing and maintenance.



FIG. 10 Fan blade design evolution, [29]



FIG. 11 GE 90 fan blade, [30]

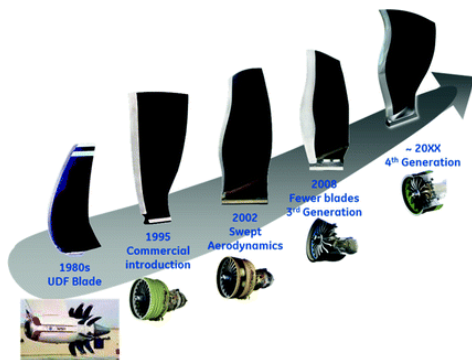


FIG. 12 Evolution of fan blade design, [31]

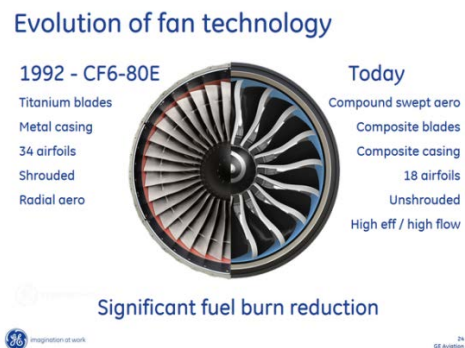


FIG. 13 Evolution of fan technology, [32]

The advantages provided by a composite fan blade, Fig. 11, to large bypass turbofan engines for commercial aircraft, are expressed by the following facts:

1. Titanium leading edge, which ensure ingestion protection, serviceability, replaceable,
2. Polyurethane coating, that brings reduced wear,
3. Composite airfoil, due to higher strength and stiffness, increases the capability to support higher stresses and loads with lowered weight,
4. Low crush stress, does not require lubrication.



FIG. 14 Design and technology advances in jet engines, GE NX Turbofan Engine, [33]

The use of composites in jet engines, Fig. 13, Fig. 14, Fig. 15, can be successfully applied for the engine cold parts, like air inlet, fan, and partially to LPC – Low Pressure compressor, fuel system, FADEC system, fuel tanks.



FIG. 15 Advanced LEAP turbofan engines, [34]

Key elements of design and technology advances in jet engines are highlighted in Fig. 14 for the GE NX large bypass turbofan engine and in Fig. 15 for the CFM International's advanced LEAP product line, which is the engine of choice to power the Airbus A320neo, the Boeing 737 MAX, and the COMAC C919.

Advanced technology of new LEAP turbofan engines enables to set new standards in utilization, reliability, and performance. Since CFM's first LEAP engines entered revenue service in August 2016, the fleet has demonstrated world-class daily utilization rates and delivered a 15 percent improvement in fuel efficiency, along with significant reductions in noise and emissions signatures - all while maintaining CFM's industry-leading reliability and overall cost of ownership, [34].

The design and technology advances in jet engines emerged from continuous search for performance improvement and as well as the need to mitigate or to completely avoid risks in aircraft and jet engine operation.

Management of assumed risks in case of damage tolerance is used in aircraft design. Damaged tolerance concept represents an assumed risk from the standpoint of the safety management of loads and stresses to which the aircraft is subjected. Examples for design load cases and resulting stresses in case of commercial aircraft are shown in Fig. 16. In Fig. 17 are shown levels of damage tolerance assessments.

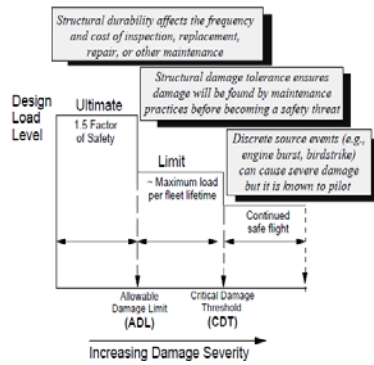


FIG. 16 Design load and damage considerations for durability and damage tolerance, [16].

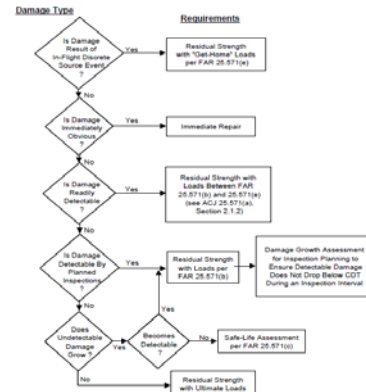


FIG. 17 Levels of damage tolerance assessments, [16]

In case of composites, and especially carbon fiber composites, the “No Crack Growth” Concept of Carbon Fiber Reinforced Polymer CFRP is one of the most important Damage Tolerance Requirements. For the aircraft safety operation, health monitoring HM on composite material structures CMS is crucial.

The lessons learned from the primary and secondary composite structures, up to B 787, provided solid information and validations for the implementation of a variety of composite materials structural design constructions and fabrication methods. Summarizing the lessons learned on composite use in aerospace engineering, there were successfully used:

- application of innovative design and technology advances in jet engines;
- advanced technology of new LEAP turbofan engines that enables to set new standards in utilization, reliability, and performance;
- application of advanced composites to aircraft and fiberglass rotor technology;
- carbon fiber epoxy laminates, for all fuselage sections, main wing box, horizontal and vertical stabilizer boxes;
- carbon fiber laminate materials, for wing leading edge slats and trailing edge flaps;
- carbon sandwich constructions, for secondary structures (rudder, elevators, winglets, nacelle cowlings)
- glass fiber epoxy, other composites or similar materials, for several fairings on the wing stabilizers, radome, wing-to-fuselage fairings,
- metal alloys, for the leading edge of the nacelles, for the reason of serving as a good heat conductor, for thermal anti-icing,
- titanium based alloys, for some joints and internal substructures like heavy-load carrying fittings, and for most of the landing gear components,
- advanced composites as fiberglass rotor technology, helicopters and rotor blade helicopters.

Table 3 – Examples of composite use in aircraft and helicopter parts

Aircraft Parts	Composite Materials, Composite Technology	Helicopter Parts	Composite Materials, Composite Technology
Leading edges	RTM (Resin Transfer Molding)	Main rotor hub plate	Prepreg curing
Clips	TP Stamping	Tail rotor blade	RTM (Resin Transfer Molding)
Structural interior parts	RTM, Curing	Blade	Prepreg Curing

Thermoplastic rotating parts	Consolidation	Structural parts	RTM, Curing
Stiffeners	HDF (Hot Drape Forming)		
Preforms	HDF		
TP consolidated plates	Consolidation		
Honeycomb structural parts	Compression & Curing		
Turbine blade	Hot forming, Consolidation, RTM		

Before a new aircraft can obtain FAA certification, numerous tests must be performed in order to validate composite materials performance and to verify structural integrity. The test set includes Static Test, fatigue Test, Ground and Flight Tests.

Analysis and testing ensure safety and reliability must be performed increasing the levels of complexity, from material specimens, elements, assemblies, components up to airplane.

5. CONCLUSIONS

This paper is structured on three main parts: 1/ analysis of turbojet engine performance prediction at Design Regime and Off-Design Regimes, based on the thermo-gas-dynamics of turbojet engine; 2/ design and reverse engineering in case of axial compressor and fan rotor blades, design and technology advances in jet engines, 3/ guidelines of risk management customized for aerospace engineering design.

The topics considered for this study are the most significant and common encountered in aerospace engineering design. Each study subject was developed such that to highlight the appropriate solution and to perform Risk Management, following the successive completion of the stages:

- 1/ Risk Identification,
- 2/ Risk Assessment, from the standpoint of impact and likelihood,
- 3/ Prioritization of risks, 4/ pointing out the actions to be taken, which can be one of the following options: a/ tolerate, b/ treat, c/ substitute, d/ terminate. The options for Risk mitigation are: a/ tolerate, b/ treat, while the options to avoid or to eliminate risks are: c/ substitute, d/ terminate.
- 6/ Risk monitor and report, to develop the Risk Register, which is a database of information on risks;
- 7/ Risks reviewed periodically.

Risk Intelligent is a holistic approach of Risk Management, considered globally, that is looking at the entire system as a whole, not just focusing on some parts of the system, without also considering the determining relationships and interactions between the various parts of the general system. Risk Intelligent can be considered as a tool for Active Control serving Risk Management to control and maintain the adjusted balance between risks and reward. The ultimate goal of Risk Intelligent is to create added value by assuming risks and enabling simultaneously to protect, keep and maintain the values already accumulated.

ACKNOWLEDGEMENT:

This research is supported by INCAS - National Institute for Aerospace Research Elie Carafoli, as a beneficiary of the Project - Technological Development Platform for Green Technologies in Aviation and Ecological Manufacturing with Superior Added Value, TGA

- TECHNOLOGIES FOR GREEN AVIATION, financed by the Competitiveness Operational Program 2014-2020 (POC), POC/448/1/1/Large R&D Infrastructures, SMIS CODE 127115, Contract of Financing no. 313 / 14.07.2020 funded by Romanian Ministry of Research, Innovation and Digitization.

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WI-FI COMMUNICATION SYSTEM FOR A FIXED-WING TWIN-ENGINE AIRPLANE UAV

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DOI: 10.19062/2247-3173.2023.24.17

Abstract: *Unmanned Aerial Vehicle (UAV) systems have automated pilots that can be configured to suit various mission requirements. In this study, we assess, develop, and evaluate a bidirectional Wi-Fi communication link for an automated piloting system, utilizing the Cube Orange architecture that is mounted on a fixed-wing twin-engine airplane UAV. This Wi-Fi link enables seamless data exchange between the UAV and the ground control station. Using this bidirectional communication link, the user gains access to telemetry data, providing real-time insights into the UAV's flight parameters. Additionally, the user can send commands to the UAV, ensuring dynamic mission control and adaptability, while, the Wi-Fi link facilitates the retrieval of live video data from the UAV's onboard camera, enabling display on the command station screen or recording for future analysis and utilization. This comprehensive Wi-Fi communication system enhances the overall functionality and efficiency of the UAV's automated piloting, enabling smooth and reliable operations for various mission scenarios.*

Keywords: *Aerospace, Fixed-wing UAV, Automated Pilot, UAV Mission Planning, Additive manufacture*

1. INTRODUCTION

Unmanned Aerial Vehicle (UAV) systems have witnessed a decline in cost, making them more accessible to build. However, their successful development still requires meticulous planning, thoughtful design, and precise implementation. Current research in this field is concentrated on several key areas: advancements in quad-copter UAV technology, focusing on enhancing their capabilities, efficiency, and performance [1,2,4,5,7], development of fixed-wing UAVs, aiming to improve their design, stability, and operational characteristics [6,10,11,12], integration of automated systems seeking to create seamless and intelligent UAV operations for various applications [1,2,3,4,5,6,10,11,12], communication interfaces to ensure reliable and efficient data transmission between UAVs and ground control systems [3,8,9,10,11,12], developing sophisticated simulations, refining navigation algorithms, enhancing stability during flight, and exploring diverse mission types for UAVs[1,2,3,4,5,6,7,10,11,12]. As the technology continues to evolve, these research directions pave the way for more capable and versatile UAV systems in various industries and applications.

The UAV community is continuously expanding, with an array of products and solutions spanning across underwater, ground, and air vehicles. As prices decrease in the near future, the number of UAVs is expected to rise, resulting in a more crowded sky and less communication band.

To address this, the development of an onboard autopilot capable of achieving its mission without relying on ground guidance becomes crucial. This paper presents such an autonomous flying vehicle with a bidirectional Wi-Fi communication system to relay data and video info to a ground station.

The establishment of an autonomous flying vehicle hinges on a crucial element - the precise determination of the aircraft's flight path. Adaptations to the flight path may be necessary based on the mission profile, and these adjustments might occur even while the vehicle is in flight. For our study, we employed a 3D printed airplane with 3D printed engines, incorporating an automated control system centered around a CubePro Orange processor. This processor is interconnected with a ground control station via a bidirectional Wi-Fi system, enabling the seamless transmission of flight path corrections, flight data, and a live video feed during the mission.

The airplane was fabricated utilizing additive manufacturing technologies. Specifically, for the fuselage and wings, we employed Fused Deposition Modeling and as fabrication material we used reinforced composite with short fiberglass for the fuselage and short carbon fiber for the wings. The parts were produced using a Zortrax M300 Dual for composites with fiberglass, and an Ultimaker S5 for composites with carbon fibers.

To power the aircraft, we installed two brushless motors, manufactured using the Selective Laser Sintering method, using A6 steel on a 3D System SPRO 60 SD. Each of these motors generates a thrust of 10 kgf and comes equipped with 15-inch counter-rotating blades for enhanced efficiency.



FIG. 1 Fixed-wing twin-engine aircraft made from 3D printed composite materials [10]

The CubePro Orange controller was integrated into the airplane using a PixHawk motherboard as interface. This controller serves a dual purpose: commanding the servos responsible for controlling various flight components such as engines, flaps, ailerons, stabilizer, and direction, while also facilitating the transmission of telemetry data to the ground control station via a wireless 868 MHz transmitter (Fig. 2).

Additionally, we setup a live video feed from a Tau 2 Longwave Infrared Thermal Camera Module using a 2.4 GHz analog video transmitter. To ensure efficient data transfer, the video signal is overlaid with the telemetry information gathered during flight, providing real-time feedback and crucial data during the mission (Fig. 3).

The CubePro Orange controller is an onboard device specially designed for unmanned aerial vehicles (UAVs). Its primary function is to act as the central processing unit, efficiently managing the aircraft's flight operations and automation. The controller comes equipped with a diverse range of input/output (I/O) ports, enabling communication with various components and peripherals, as:

- 14 PWM servo outputs (8 from IO, 6 from FMU) to control multiple servo motors responsible for maneuvering the UAV.
- Radio control receiver (R/C) inputs, supporting different signal types such as CPPM (Combinatorial Pulse Position Modulation), Spektrum / DSM (Digital Spectrum Modulation), and Serial Bus for flexible control options.
- Analogue / PWM (Pulse Width Modulation) RSSI (Received Signal Strength Indicator) input to monitor signal strength.
- Serial Bus servo output for interfacing with compatible devices.
- 5 general-purpose serial ports, with 2 featuring full flow control for data communication.
- Two I2C ports, providing connectivity to compatible sensors and peripherals.
- One SPI port (un-buffered) suitable for short cable connections, though not recommended for extensive use.
- Two CAN Bus interfaces for communication with devices using the Controller Area Network protocol.
- 3 analogue inputs for reading analog signals from sensors or other devices.
- High-powered piezo buzzer driver for audio feedback and alerts.
- High-power RGB LED for visual indications and status updates.
- Safety switch / LED for added safety and control.

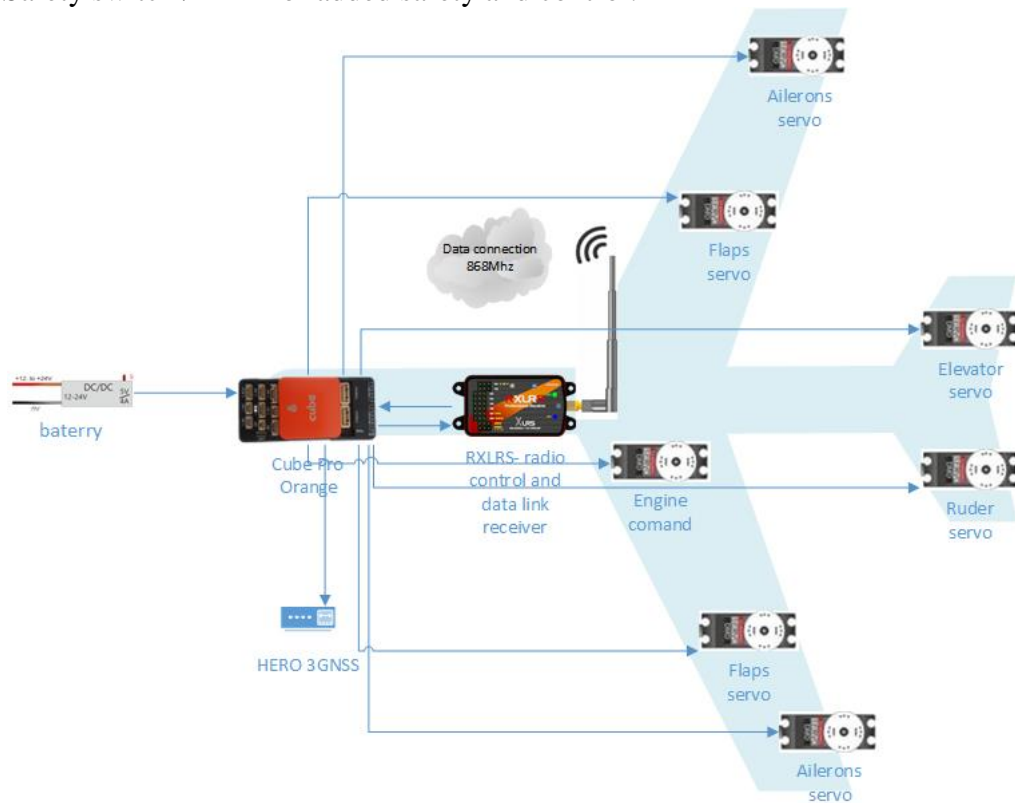


FIG. 2 CubePro Orange controller integrated on the airplane. Linkage configuration of the controller

This powerful controller offers robust connectivity options, enabling it to interface with a wide array of devices, including servos, sensors, cameras, and other electronic modules. It plays a crucial role in interpreting flight instructions, adjusting control surfaces such as ailerons, flaps, rudder, and elevator, ensuring precise maneuverability during flight. The chosen configuration for our UAV airplane, depicted in Fig. 2, consists of the following components:

- one CubePro Orange controller;
- one RXLRS- radio control and data link receiver;
- one HERO 3 RTK GNSS (Global Navigation Satellite System);
- two servos for flaps;
- two servos for ailerons;
- one servo for elevator;
- one servo for ruder;
- one ESC (Electronic Speed Controller) for engine control;
- and a 5V Lipo battery.

With its compact and lightweight design, the CubePro Orange controller optimizes the UAV's weight distribution and stability, contributing to enhanced performance. It is also designed to handle real-time telemetry data, allowing for efficient communication between the UAV and the ground control station.

The HERO 3 RTK GNSS (Global Navigation Satellite System) system is a high-precision positioning solution that enhances the capabilities of the CubePro Orange controller for unmanned aerial vehicles (UAVs). With RTK technology, it significantly improves the UAV's positioning data accuracy and reliability.

By integrating the HERO 3 RTK GNSS system with the CubePro Orange controller, the UAV gains access to highly precise location information, ensuring stable and accurate flight trajectories, even in challenging environments. This enables the UAV to execute complex missions with utmost precision. The system's robust signal reception supports multiple satellite constellations, including GPS, GLONASS, Galileo, and BeiDou, providing comprehensive global coverage for navigation, and increasing the reliability and availability of satellite signals, making the UAV less susceptible to signal obstructions or interference.

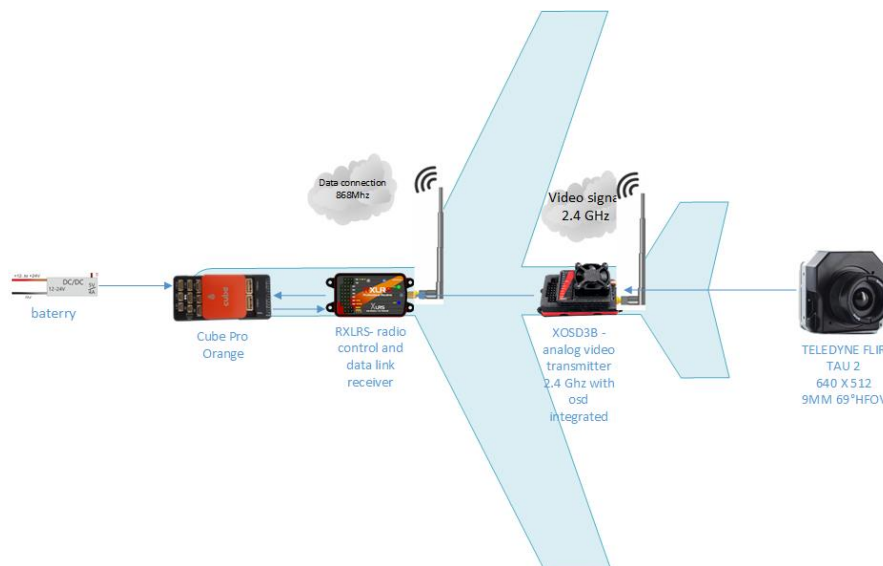


FIG. 3 UAV airplane Wi-Fi communication system configuration

The RXLRS- Radio Control and Data Link Receiver is a device crafted for unmanned aerial vehicles (UAVs) and other remote-controlled applications, serving as a communication link between the UAV and the ground control station. With a god range, it supports long-distance operations, making it perfect for applications requiring expansive coverage.

Its robust radio communication capabilities ensure real-time transmission of control commands, enabling instantaneous response and control during flight. Additionally, acting as a data link, the RXLRS- receiver facilitates the transmission of telemetry data and flight information back to the ground control station, enhancing situational awareness and enabling real-time monitoring of vital flight parameters like altitude, speed, battery status, and GPS coordinates.

We have enhanced the Wi-Fi communication system by integrating the XOSD3B with a built-in On-Screen Display (OSD) capability Fig. 3. This feature allows flight data and telemetry information to be overlaid directly onto the transmitted video feed in real-time. Key flight parameters such as battery status, altitude, speed, and GPS coordinates are displayed, improving situational awareness for the operator without the need for additional displays or telemetry equipment. Furthermore, the XOSD3B's analog video transmission technology ensures a stable and low-latency video feed, essential for real-time monitoring and precise control of the UAV during flight. Operating on the 2.4 GHz frequency, this setup provides a reliable connection, reducing signal interference and ensuring a smooth and uninterrupted video transmission experience.

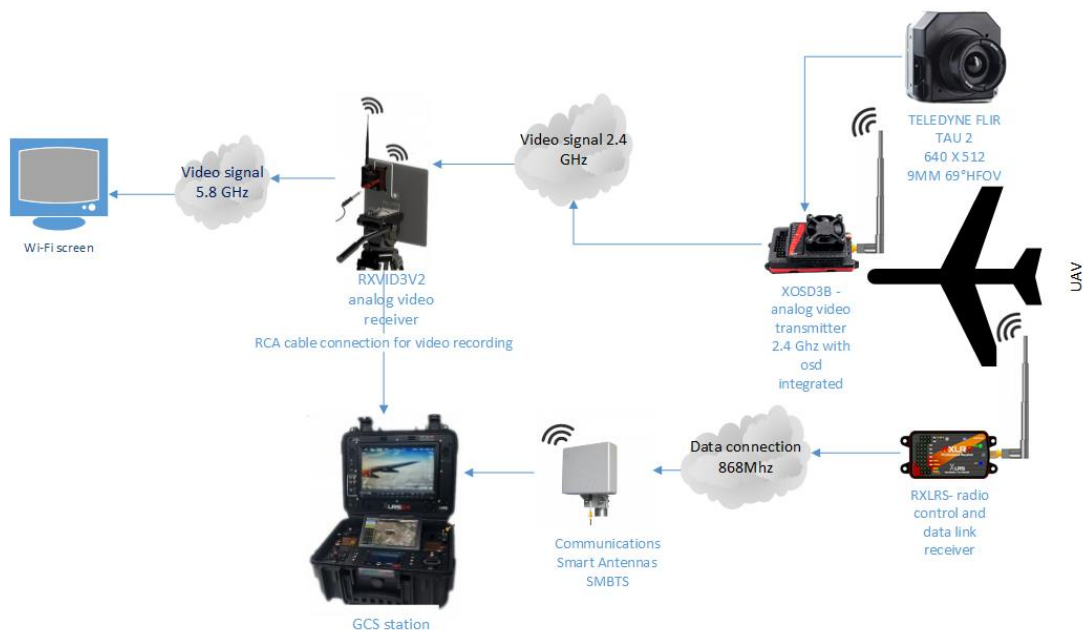


FIG. 4 Complete Wi-Fi communication system

Using the XOSD3B, we transmitted a real-time video feed from the Teledyne FLIR TAU 2 640 x 512 9mm 69°HFOV - LWIR Thermal Imaging Camera Core (Fig. 3). This camera core operates in the long-wave infrared (LWIR) spectrum, enabling detailed thermal imagery even in challenging environmental conditions like low light or adverse weather. Its wide 69° horizontal field of view (HFOV) ensures comprehensive scene coverage, making it suitable for monitoring and reconnaissance tasks. Equipped with image processing capabilities, the Teledyne FLIR TAU 2 camera core provides precise temperature measurement and radiometric data. Additionally, it offers various imaging modes, allowing users to customize settings according to specific applications and requirements.

To finalize the communication system, we integrated the GCSD4 ground control station from Digital Micro Device, alongside two ground antennas: Communications Smart Antennas SMBTS and the RXVID3V2 analog video receiver, as depicted in Fig 4.

This setup ensures communication between the ground control station and the unmanned aerial vehicle (UAV), enabling real-time monitoring, data transmission, and video reception for the UAV operation.

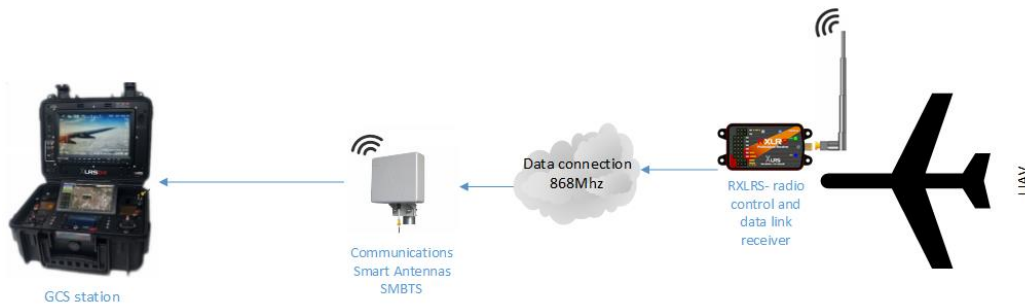


FIG. 5 Data link Wi-fi communication system

The entire Wi-Fi system can be divided into two distinct components: the video feed, depicted in Fig. 5, and the data link communication, illustrated in Fig. 6. These two essential elements work together to ensure transmission of video and data, enabling real-time monitoring, control, and communication between the ground control station and the unmanned aerial vehicle (UAV).

The data link communication channel is formed from three main components, as seen in Fig.5:

- the RXLRS- radio control and data link receiver, operating on the 868 MHz band, serves to transmit and receive data between the ground control station (GCS) and the UAV;
- the Smart Antenna SMBTS facilitates bidirectional data transmission between the GCS and the UAV, also utilizing the 868 MHz frequency;
- and the GCS station that acts as the central hub, receiving data from the UAV through the data link, visualizing the information, and sending commands to update the flight path as needed.

This communication loop ensures data exchange and real-time control over the UAV's operations during flight.



FIG. 6 Wi-fi VIDEO feed system

The video feed channel is formed from five components, as illustrated in Fig. 6, that ensure data transmission and real-time control over the UAV's operations during flight. The components are as follows:

- The Teledyne Flir Tau 2 640 x 512 9mm 69°hfov - LWIR thermal imaging camera core captures infrared imaging data, providing thermal imagery during the UAV's missions.
- The XOSD3B analog video transmission technology with built-in On-Screen Display (OSD) capability ensures a stable and low-latency video feed. This feature is crucial for real-time monitoring and control of the UAV throughout its flight. The XOSD3B operates on the 2.4 GHz frequency range, ensuring reliable video transmission.
- The RXVID3V2 Analog Video Receiver plays a crucial role in the video feed channel, receiving data on the 2.4 GHz band from the XOSD3B and retransmitting it on the 5.8 GHz band. This enables display of the video feed on the GCS. Additionally, the receiver has an RCA connector output, allowing the video signal to be displayed or recorded on a secondary device.
- As an optional component, a second device can be utilized to record the video feed from the analog receiver. This secondary recording device can be a laptop or any other compatible recording equipment.
- The GCS station serves as the central hub for the video feed channel, receiving, and visualizing the transmitted video data. This enables the operator to have real-time access to the UAV's thermal imagery and make informed decisions during the mission.

The integration of these components ensures a robust video feed channel, providing critical thermal imaging data and enabling effective control and monitoring of the UAV's operations from the ground control station.

CONCLUSIONS

Creating a bidirectional Wi-Fi communication system with video feed capabilities for a fixed-wing twin-engine airplane UAV, along with a ground control station, is a challenging task that requires specialized equipment and careful planning. However, such a system offers numerous advantages:

- **Information Telemetry:** The system provides real-time telemetry data about the UAV's flight to the ground control station, enabling the monitoring of flight parameters.
- **Real-Time Flight Path Updates:** The bidirectional communication allows for updating the UAV's flight path in real-time and sending new commands to the autopilot, enhancing mission flexibility and adaptability.
- **Real-Time Video Feed:** The system facilitates the transmission of live video information about the flight, providing visual feedback to the operator and enhancing situational awareness during operations.
- **In the case of a Search and Rescue Missions:** Coupling the system with a thermal core allows real-time tracking of a person's whereabouts, enhancing the effectiveness and efficiency of such operations.

When designing the communication system, careful consideration must be given to the selection of the communication band. RF 868MHz is a public bandwidth in European Low Power Networks (LPWAN) and regulated in Europe by ERC-REC-70-3E, while the 2.4 GHz band is also available but can be crowded with Wi-Fi, Bluetooth, and other radio

devices, especially in urban areas. Therefore, selecting the appropriate frequency band is crucial to avoid interference and ensure reliable communication.

As the main mission involves search and rescue tasks, incorporating a thermal module is essential. However, it's vital to take precautions to protect the expensive thermal module during landing or in the event of a crash. This requirement necessitates the transmission of thermal imagery, adding complexity to the system. By using two separate frequency bands and employing separate compression and transmitting devices for video and data, the challenges associated with the complex communication system can be effectively addressed, ensuring efficient and reliable operation.

ACKNOWLEDGEMENT

This work was supported by a grant of the Ministry of Research, Innovation and Digitization, CNCS/CCCDI – UEFISCDI, project number PN-III-P2-2.1-PED-2019-0739, within PNCDI III.

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WEAPON SYSTEMS AND MISSIONS SPECIFIC TO THE F16 AIRCRAFT IN THE ROMANIAN AIR FORCE

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DOI: 10.19062/2247-3173.2023.24.18

Abstract: *The vision of gradual realization of the air defense capacity within the program “Multirole aircraft of the Romanian Air Force”, with the gradual realization by continuing the endowment with the squadrons of F-16 aircraft up to three squadrons. Modernization of the armament line with the latest generation of air-to-air weapons.*

Keywords: *integration, upgrade, variants of armament, enhanced agility.*

1. INTRODUCTION

The military response potential is represented by the armament in the endowment and by the combat technique.

In the article I proposed to analyze these aspects at the endowment level of the Romanian Air Force, focusing on the acquisition of the F-16 aircraft. It should not be forgotten that the MiG-21 LanceR aircraft has served this country for a long time and the knowledge of the pilots regarding the use of this aircraft could be further exploited on the F-16 MLU 5.2.R aircraft.

A multirole or omnirole combat aircraft is intended to perform various tasks or missions in combat, such as air-to-air, air-to-surface, reconnaissance, electronic warfare, air support, escort-escort, or deterrence [1].

Analyzing the current war, it can be observed that the composition aerospace is one of major importance in determining the outcome of military action.

In this framework, fighter-bomber aviation came to be a necessary component in confrontations current. The term multirole or omnirole has been assigned to aircraft designed to use the same basic structure that is flexible and can be adapted to various missions. If we make a breakdown of the roles in which the F16 aircraft can be used, specific to us, we can conclude:

Attack	Interception	Maritime patrol
Aerial reconnaissance and surveillance		Electronic warfare in aviation
Air support		Bomber

2. THEORETICAL ASPECTS OF THE ARMAMENT ON BOARD

The use of artillery armament with the optimal caliber, sufficient to have the desired effect with a sufficiently high rate of fire, thus 20-37 mm caliber guns are used, depending on the tactical destination.

Artillery armament is complemented by reactive armament, the two are complemented by the fact that reactive armament has the advantage of firepower, long firing distance and a high firing accuracy for the directed one and the disadvantage of a small amount, which artillery armament can compensate [3].

The ammunition reserve must be well calculated and optimized according to the number of possible attacks.

Consider, for example, the mission of the fighter plane, which can deliver 3-4 attacks with a fire autonomy of 10 seconds.

Fire control must be optimized by number of shots and types respectively automated.

To ensure the necessary firepower, the armament is allocated up to 12% of the aircraft's flight weight.

Its placement is done in the optimized points to reduce the effect of the recoil on the flight and to maintain the accuracy required for the fire in the case of artillery weapons [3].

3. SEVERAL TYPES OF ARMAMENT SPECIFIC TO THE F16 MLU /5.2.R AIRCRAFT

When designing the plane, the realization of standardized connectors is taken into account, which allow the modernization of only some components over time without replacing the entire assembly.

The F-16 Block 15 MLU/5.2.R is the variant with superior modifications to the previous variants, incorporating advanced weapons.

The aircraft F=16 Block 15 MLU can access among other weapons:		
Air-to-air missiles	AIM-9X Sidewinder	The AIM-9X Sidewinder missile is a triple-threat missile that can be used for air-to-air engagements, surface-attack and surface-to-surface launch missions without modifications. The AIM-9X Block II, II+ missile adds a redesigned fuze and a digital ignition safety device to improve handling and in-flight safety. It's equipped with updated electronics, including a lock-on-after-launch capability using a new weapon datalink to support beyond visual range engagements [5].
	AIM-120(C7/D) Advanced Medium Range Air-to-Air Missile	The AIM-120 AMRAAM is an all-weather, all-environment radar-guided missile (active principle) developed to improve capabilities against very low-altitude and high-altitude, high-velocity targets in a hostile electronic jamming environment [3].
Air-ground rockets	AGM-65 H Maverick	Maverick is a precision-guided weapon that can be used for defence suppression, close air support and interdiction missions. [4]

Unreacted reactive weaponry:	CRV 7	The CRV 7 , short for “Canadian Rocket Vehicle7”, is a 2.75-inch (70 mm) folding-fin ground attack rocket. [3]
Unruly Bombs:	MK 82&84; MK 82 “SNAKEYE”	The MK 82&84 is one of a series of long-drag, general-purpose aerial bombs, which are collectively known as the MK 80 series of bombs. [3]
Bombs directed:	GBU-10/12/49 Paveway II	Paveway II is a laser-guided, free-fall bomb for use against surface targets at short to standoff range. [6]
Electronic Warfare Pod	CHAFF/FLARE	Chaff and Flares are defensive counter measures used on aircraft to confuse radar and heat seeking missiles. [3]
M61A1 Vulcan	20 mm (TP) training munitions; 20 mm incendiary ammunition (HEI)	The General Electric M61A1 Vulcan is a 6-barrel 20 mm cannon. [3]

Below we propose three arming options for attacking ground targets, Fig.1.

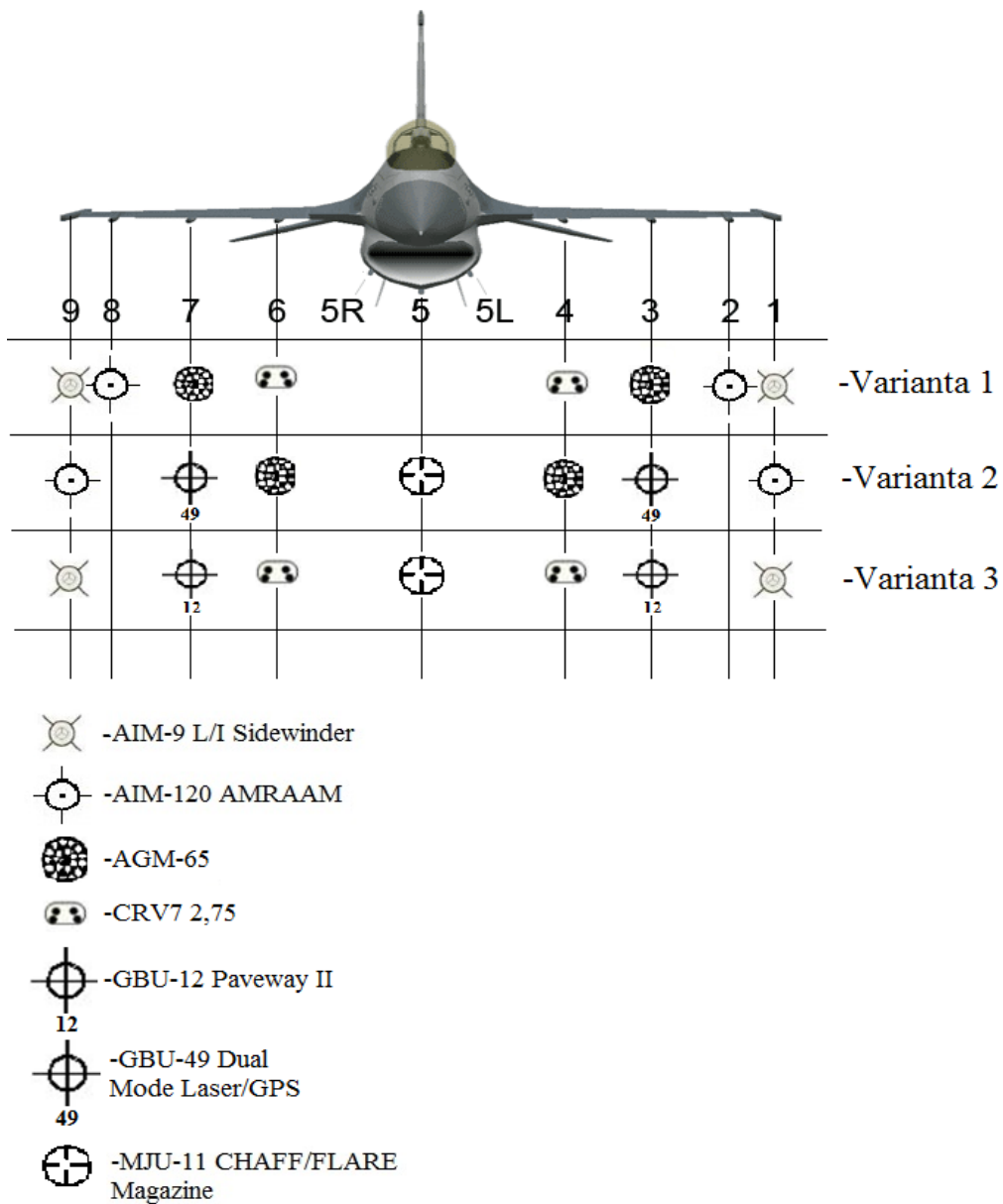


FIG. 1 Arming variants [3]

Installing software on the on-board computer, which over time can be replaced with better ones, improves the aircraft's qualities.

The possibility to replace the control surfaces over time and the systems that ensure the kinematic chain of the handle-control surface, make it possible to adapt the aircraft to new conditions imposed by the development of the war phenomenon.

4. EFFICIENCY CALCULATION

The maximum effectiveness (E_M) is defined as the sum of all the proposed targets ($\sum_{i=1}^n n_i$) wanted to be destroyed and their destruction weight (Ω_i), related to the number of aircraft exits ($\sum_{j=1}^n i_j$) multiplied by the number of aircraft per exit (M) [7,8].

$$\Omega_i = \frac{\sum_{k=1}^n p_k}{N} \quad (1)$$

Where

$$E = \frac{\sum_{i=1}^n n_i + \Omega_i}{\sum_{j=1}^n i_j \cdot M} \quad (2)$$

$\sum_{k=1}^n p_k$ represents the sum of hits/target to destroy it, - the number of targets;

We have:

4 targets (a command center, a weapons and ammunition depot, a radar station, a multiple rocket launcher),

9 F16 multi-role aircraft scheduled in 3 departures of 3 aircraft each.

The following armament is used: GBU-12 and AGM-65 H.

$$\Omega_i = \frac{3+4+5+6}{4} = 4,5$$

$$E_M = \frac{\sum_{i=1}^n n_i + \Omega_i}{\sum_{j=1}^n i_j \cdot M} = \frac{8.5}{9} = 0,94 = 94\%$$

94% efficiency is achieved provided it takes 3 hits to destroy the first target, 4 hits to destroy the second target, 5 hits to destroy the third target, and 6 hits to destroy the last target.

This weighting is achieved using advanced sensors and modern weaponry diversified in relation to the minimum number of hits. The great ability to survive in a hostile environment, in the conditions of electronic warfare, refers to the possibility of attaching specialized containers from the electronic warfare range, which can ensure the information of the pilot about the real threats, the possibility and the way of creating

active jamming, both for communications and for enemy radars or enemy sensors. The high survivability in a hostile environment can be increased by the use of passive jamming systems (Chaff/Flare), the creation of absorbent surfaces and under deviant angles for the aircraft, which lead to the reduction of the radio footprint [3]. Equipping the aircraft with a threat warning system (RWR - Radar Warning Receiver), provides data to the pilot regarding the distance and number of threats, in case the pilot is left without passive jamming systems, and is tracked by a surface-to-surface missile air to perform evasive maneuvers to try to escape the threat.

5. CONCLUSIONS

- The armament on the F-16 MLU/5.2.R aircraft is very efficient, agile and flexible, with 9 points on which missiles, bombs, of the latest generation can be attached. The equipment of the aircraft with high-performance air-to-air ammunition is noted, which indicates the direction towards the air police mission.
- Air supremacy is the basic role that provides an essential added value in an armed conflict of any size. By increasing the number of F16 aircraft (+32) and by modernizing all of them with optoelectronic search and sighting equipment, with superior electronic warfare systems and the diversification of smart weapons and ammunition, the Romanian military aviation will be a critical point of thought for any external threat.

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MODERN AIRCRAFT BRAKING SYSTEMS

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DOI: 10.19062/2247-3173.2023.24.19

***Abstract:** This paper presents some problems concerning the present trends in the field of aircraft braking systems. New solutions like electro-mechanical or electro-hydrostatic actuators are considered the future, but some big aircraft producers do not renounce yet to classical electro-hydraulic braking systems. New solutions are not generally accepted, they have to prove their reliability and that they bring considerable more advantages than penalties.*

***Keywords:** aircraft, braking systems, electro-hydraulic, electro-hydrostatic, electro-mechanical*

1. INTRODUCTION

Hydraulic braking systems were used on aircraft relatively early on the aircraft. First hydraulic braking system appeared in the beginning of 1930s. Their function was only to stop the aircraft on the ground at the landing run. They developed rapidly and become more and more sophisticated once the aircraft evolved. Additional functions appeared, as the aircraft turning on the ground by differential braking of the main landing gears wheels. Gradually, this solution was replaced on big aircraft by the steering of the nose wheel, but some small aircraft still use this solution.

Once the flight speed increased and also the aircraft mass became necessary to use stronger braking. The problem to avoid the wheel blocking in the braking process became acute. Hydraulic braking systems were provided with anti-skid function, which release the brakes when the wheels begin to slide on the ground. By this way, a better aircraft control at the landing run is achieved and also the tyres wearing reduced. The first anti-skid systems were implemented with simple mechanic-electric-hydraulic devices. Development of the analogical electronic devices and later digital electronic devices led to improved anti-skid systems, controlled by analogical or digital computers. Better performances regarding the wheels sliding and landing run decrease were obtained, maintaining acceptable tyres wear.

Later, parking brake was introduced on aircraft. Aircraft have a big surface reported to their mass and for this reason wind gusts can easily move the aircraft on the ground. Before that, using braking logs in front and behind wheels prevented this phenomenon. Now, this function is accomplished also by the braking system.

In order to reduce more rapidly the landing speed, in present, many systems as jet reverser, propeller windmill regime, aerodynamic brakes and spoilers and braking parachutes. In this manner, the braking system stress reduces.

Hydraulic braking systems use the hydraulic pressure to press together the braking discs. Braking control is obtained by braking pressure control.

This control is realized using mechanic-hydraulic devices for braking systems controlled by the pilot pedals, or by electric-hydraulic devices when automatic brake is activated. We do not insist here on these aspects, well known in aeronautic world. An electro-hydraulic braking system is presented in Fig. 1 [1].

At the end of 20th century appeared the trend to move to “More Electric Aircraft” and even “All Electric Aircraft”. This trend appeared after two aeronautic catastrophes. In that situations all aircraft hydraulic systems failed and aircraft control lost. First intention was to replace electric-hydraulic or mechanic-hydraulic servo-actuators for flight controls with electro-hydrostatic or electro-mechanic servo-actuators. Until now only electro-hydrostatic servo-actuators implementation succeeded.

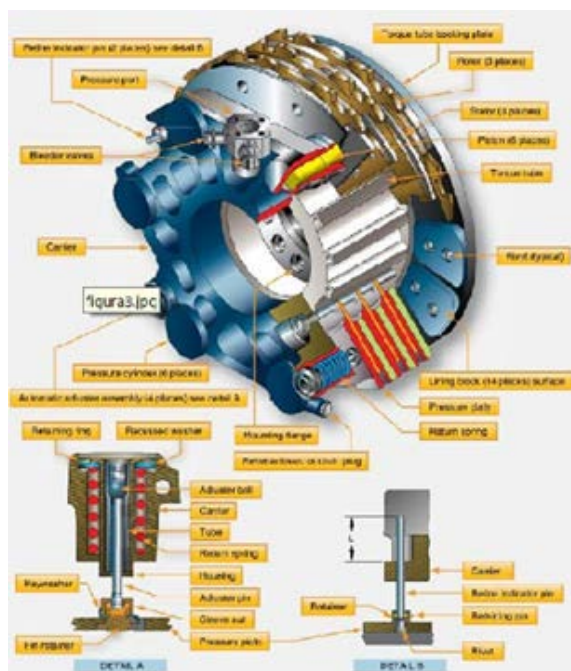


FIG. 1 Multi-disc electric-hydraulic braking system [1]

The main aims were to improve the flight controls reliability, to reduce production and maintenance costs, to simplify maintenance procedures. Another aim is to reduce the aircraft drives mass, but this fact is doubtful. Electro-hydrostatic servo-actuators are heavier than electro-hydraulic servo-actuators but the pumps and pipes are eliminated. Instead, electrical energy converters and electrical cables are necessary. We cannot say precisely overall electro-hydrostatic drives are less heavy than the classical electro-hydraulic drives.

In the last period the intention is to replace all the classical hydraulic drives with new drives, preferably electro-mechanic or electro-hydrostatic drives but also other solution for on board drives are studied.

2. ELECTRO-HYDROSTATIC AND ELECTRO-MECHANICAL BRAKING SYSTEMS

Electro-hydrostatic and electro-mechanical braking systems are very alike with electro-hydraulic once. The main difference is the manner to obtain the pressing force between the braking disks. In this case electro-hydrostatic and electro-mechanical servo-actuators develop this force. A braking system with electro-hydrostatic servo-actuators is in Fig. 2 [2].

Electro-hydrostatic servo-actuators present the advantage of lacking of centralized hydraulic system on aircraft. Necessary pressure in hydraulic system is produced by a local pump driven by an electric motor fed either from the 28 VDC electric system, either the 270 VDC electric system.

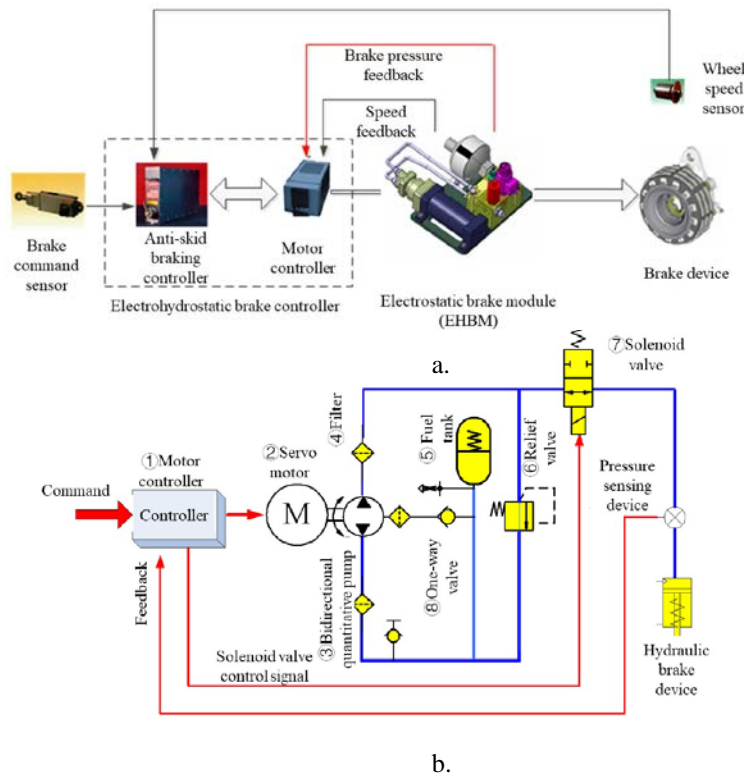


FIG. 2 a. Structure of a a braking system with electro-hydrostatic servo-actuators [2];
b. Principle scheme of a electro-hydrostatic servo-actuator [2]

This solution avoids all the difficulties concerning manufacturing and maintenance of the centralized hydraulic system. However, electro-hydrostatic servo-actuator is heavier than electro-hydraulic servo-actuator. Electro-hydrostatic servo-actuator system has a hydraulic accumulator, valves and filters in addition to electro-hydraulic servo-actuator. Are also necessary a power conversion electronic system and two feedback loops for braking control.

Figure 3.a [3] shows an electro-mechanic braking system. Servo-actuators in this care are electro-mechanic. These servo-actuators have simpler construction than electro-hydrostatic servo-actuators. Electro-mechanic servo-actuators are also fed from the 28 VDC electric system or from the 270 VDC electric system. In most cases the 270 VDC is used as main feeding system and in emergency situation the 28VDC feed the servo-actuator through a power converter.

System in Fig. 3.b [3] contain two redundant control block for brake intensity (BCU), four controllers for the electro-mechanic servo-actuators (EMAC), four sensors for braking pedal positions (PUCU), 8 data acquisition systems from the wheels (SPEED) and 8 electric braking systems with electro-mechanic servo-actuators. Each wheel has a braking system with four electro-mechanic servo-actuators. Information is transferred between the control blocks through ARINC 429 and RS 422 digital data busses. Each servo-actuator has two control loops, one force loop and one position loop. System architecture allows implementing very efficient braking control algorithms.

Electro-mechanic braking system has the advantage of centralized hydraulic system absence, but electro-mechanic servo-actuators are still heavier than electro-hydraulic servo-actuators. Power electronic system is also a supplementary feature in this case.

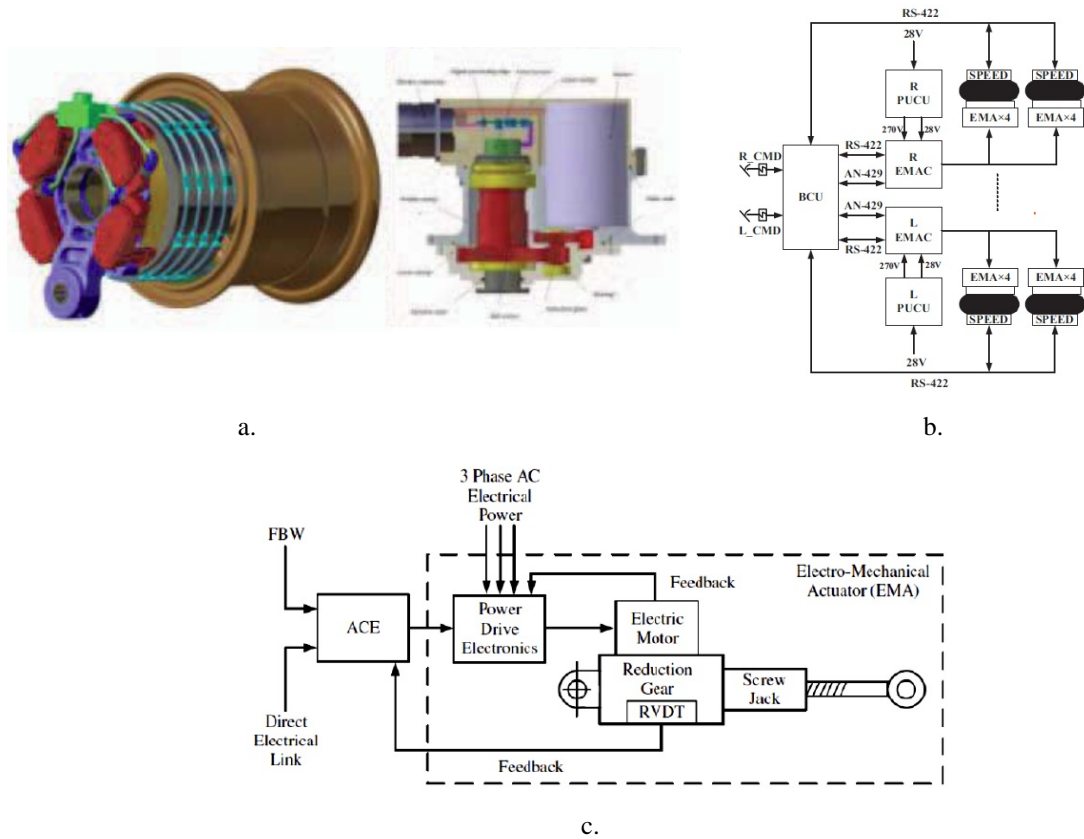


FIG. 3 a. Electro-mechanic braking system [3];
 b. Control scheme for electro-mechanic braking system [3];
 c. Electro-mechanic servo-actuator structure [3]

Both electro-hydrostatic and electro-mechanic braking systems use the energy from electric system. All the power from the hydraulic system used by the electro-hydraulic braking system is now transferred now to the electric system. In this manner, the electric systems load increases very much. This is one of the big problems for More Electric Aircraft and All Electric Aircraft.

In [4] we find a comparison between electro-mechanic servo-actuators (EMA), electro-hydrostatic servo-actuators (EHA) and classical electro-hydraulic servo-actuators considered as base level.

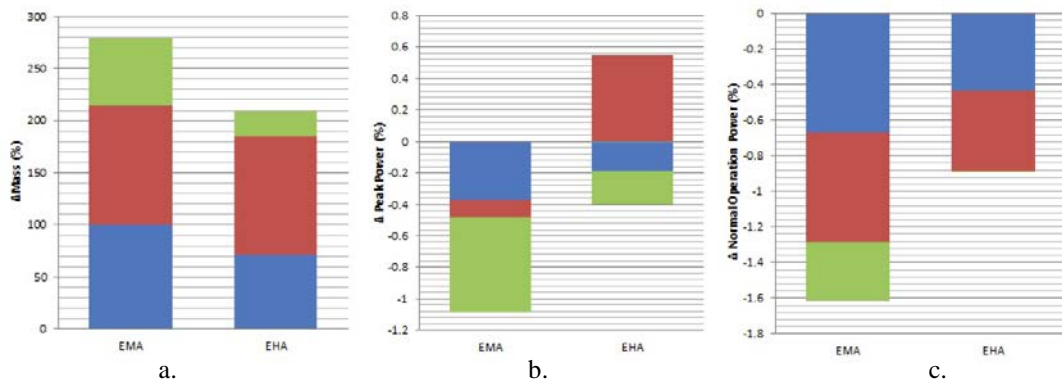


FIG. 4 Comparison between EMA, EHA and classic electro-hydraulic servo-actuators (base level)
 a. Mass variation [4]; b. Maximum power variation [4]; c. Variation of normal functioning power [4]

We notice EHA is twice heavier than electro-hydraulic one and EMA is 2.7 times heavier (Fig. 3.a). Peak power is 1 % lower for the EMA and .4 % higher for EHA (Fig. 3 b). Normal operation power is 1.6 % lower for EMA and 0.8% lower for EHA. In conclusion, for braking systems, overall advantages of EMA and EHA are doubtful. They are much heavier, but the power difference is negligible.

In [4] we find also a comparison between the entire braking system, in classical version, with EMA and with EHA.

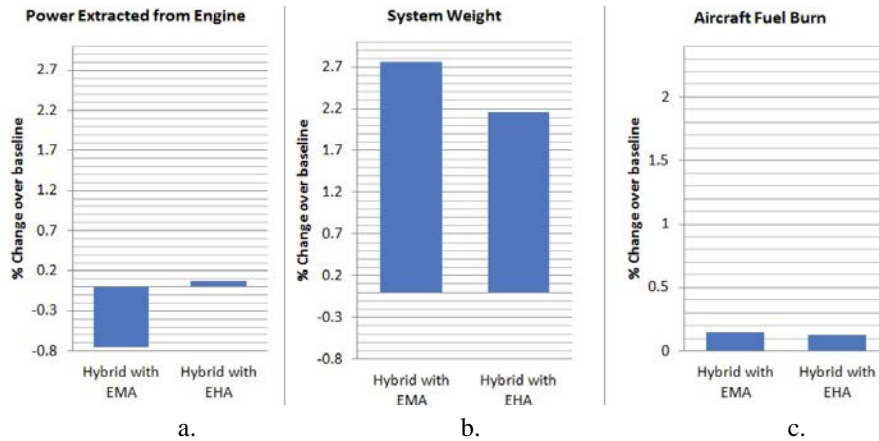


FIG. 5 Comparison between classic hydraulic braking systems, hybrid systems with EMA and hybrid systems with EHA. a. Power absorbed from the aircraft engine; b. System mass; c. Fuel consumed by the aircraft [4]

We notice here hybrid system with EMA absorbs 0.8 % less power and hybrid system with EHA absorbs 0.1% more power. Entire system mass is 2.7% higher for systems with EMA and increases 2.2% for systems with EHA. Aircraft fuel consumption is 1.5% higher both for systems with EMA and systems with EHA. An interesting solution we find in [5]. In order to reduce the power consumed by the braking systems with EHA, it is used a hydraulic pump driven by the landing gear wheels.

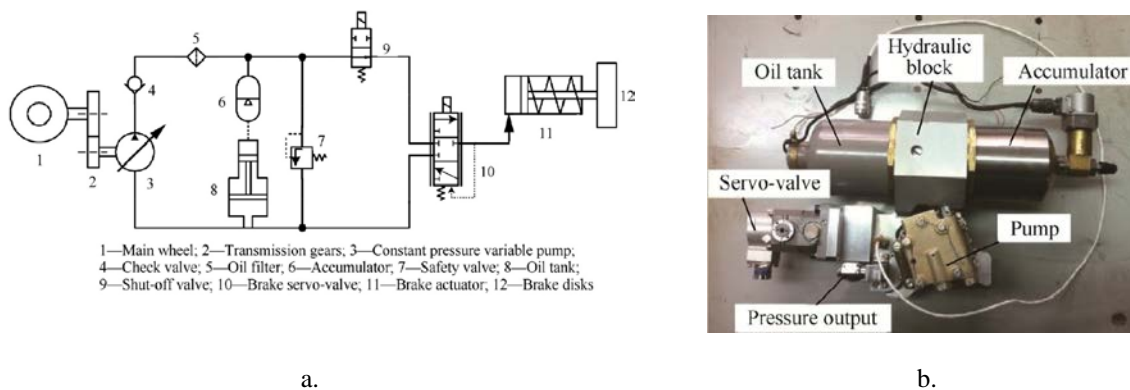


FIG. 6 EHA Servo-actuator for braking system with pump driven by the landing gear pump [5]. a. Servo-actuator scheme [5]; b. Servo-actuator prototype [5]

In this case, the braking system consumes from the aircraft electric system only the control power that is low. The high power needed to drive the servo-actuator pump is obtained from the landing gear rotating wheels. At high aircraft speed, the pump driven by the wheels feed the hydraulic cylinder and fill the hydro-accumulator. At low speeds and for parking brake, hydro-accumulator energy ensures the braking process. Prototype of this type of servo-actuator is in Fig. 6.b [5].

In [5] we find also versions of this servo-actuator with pump backup drive from an electric motor or from the aircraft hydraulic system (Fig. 7.a and 7.b [5]). Mainly the disk brakes dissipate the aircraft kinetic energy. The servo actuator pump absorbs also a small quantity of the aircraft kinetic energy.

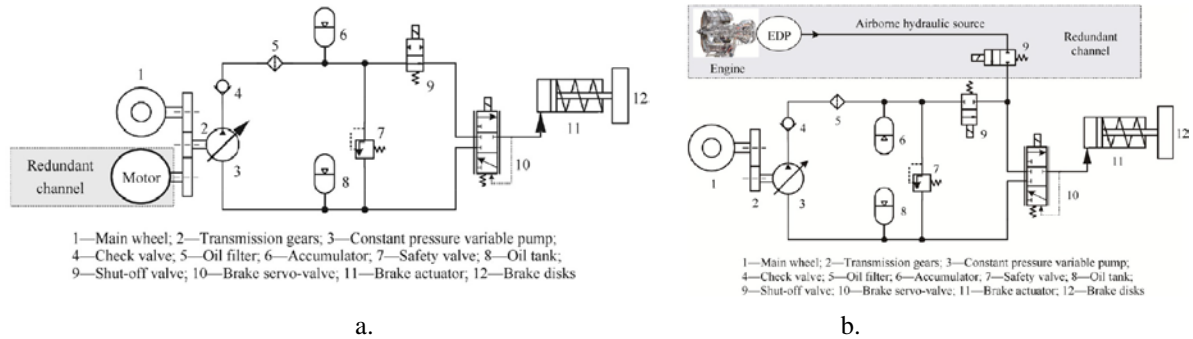


FIG. 7 EHA servo-actuator with aircraft wheels driven pump and electric motor backup [5];
 b. EHA servo-actuator with backup hydraulic feeding from the aircraft hydraulic system [5]

3. ALTERNATIVE BRAKING METHODS

3.1 Electromagnetic Braking Systems

Regenerative braking systems for aircraft appeared by analogy with regenerative braking systems for railway trains and auto vehicles. In those situations, the electric drive motor is switched in generator regime in the braking period. Generator produced energy is in fact absorbed from the kinetic energy of the vehicle and pushed back in the feeding network or stored in batteries. However, in many situations the braking torque is much higher than the generator drive moment. For this reason the regenerative braking system coexist with classical disk braking system. Nearly the same problems appear at the aircraft landing run braking.

Two regenerative braking strategies exist: parallel regenerative braking and series regenerative braking. In first case both regenerative and disk brakes work in parallel all the time. This solution ensures a smoother braking, without acceleration bounce. System control is easier but recovered energy is smaller.

The second solution, for braking accelerations below boundary level, uses only the regenerative brake and for accelerations above the boundary level, both regenerative and disk brakes are used together. Figure 8 [6] shows these situations.

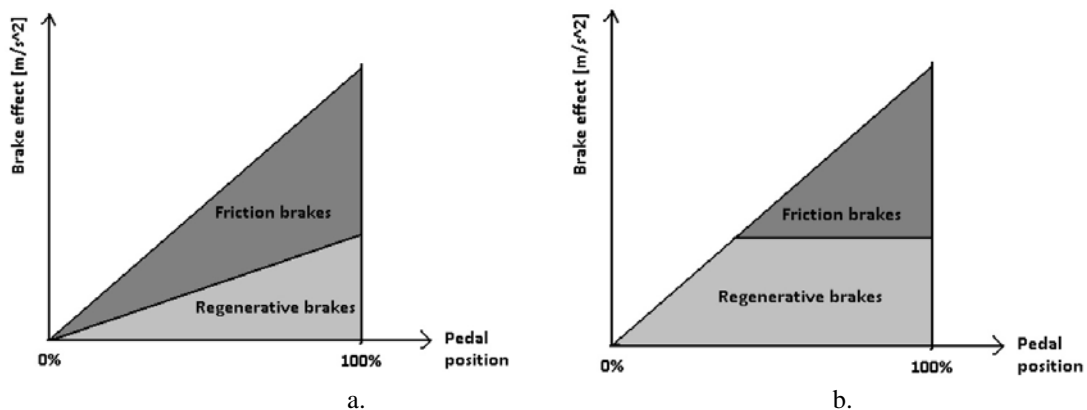


FIG. 8. a. Parallel regenerative braking; b. Series regenerative braking [6]

For aircraft regenerative braking, it is necessary to install on the main landing gear wheels and possibly on the nose landing gear wheels, electric machines working in generator regime during the landing run. In aircraft landing run, the dissipated energy is much higher than the case of auto vehicles braking. For this reason supplementary batteries or even dissipation electric resistor could be necessary. The braking intensity is controlled by the brakes electronic control system. Because the disk brakes has to remain on the landing gear it is difficult to install this system on the wheels. One solution is presented in Fig. 9 [6].

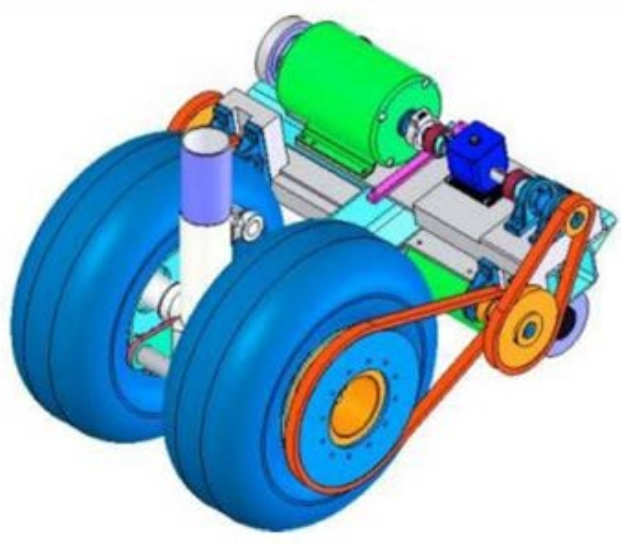


FIG. 9 Regenerative braking system installed on the landing gear [6]

This system has as an important disadvantage a big additional mass and it is much bulky than the disk brakes. One advantage is in taxi run the electric machine could be switched in motor regime and used for aircraft drive in this period. In this manner aircraft engines can be stopped in the taxi period, both at take-off and landing. Less toxic emission will be produced on the airport and less fuel burned. For short and medium range aircraft, the taxi burned fuel represents an important fraction from the total fuel consumed. On the congested airports, when the take-off expecting time can be long, stopping the aircraft engine in this period saves an important quantity of fuel, even in this period the engine is idle.

3.2 Fluidic Brake Systems

This braking system development started from the idea the kinetic aircraft energy is transformed in heat energy. This heat energy is dissipated usually on the brake disks. In some emergency braking, brake disks temperature can rise above admitted limits and to endanger other aircraft components. In [8] authors propose another solution to dissipate this energy.

The braking system has a hydraulic pump that circulates a magnetorheological fluid. This fluid is used to generate the braking torque in the braking system. The energy produced in the braking process dissipates on a heat exchanger. Magnetorheological liquid evacuates better the heat generated than the braking disks. Fig. 10 [8] presents this system.

Magnetorheological fluids increase their viscosity when a magnetic field is applied. Braking system consists in a chamber filled with magnetorheological fluid. One chamber wall is linked with the brake stator and the opposite wall is linked with brake rotor.

Liquid flow between these walls produces a big brake torque when the magnetic field is applied. Fluid viscosity increases proportionally with the magnetic field. By consequence, the braking intensity increases proportionally with the magnetic field. The pump circulates the fluid out of the brake chamber and passes it through the heat exchanger.

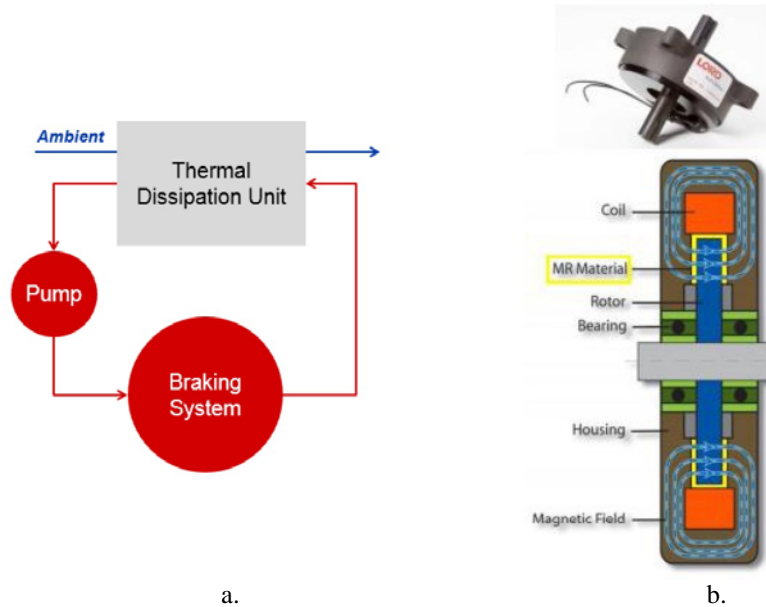


FIG. 10 a. Architecture of the fluidic brake system; b. Section through the fluidic brake system [8]

4. ENHANCED SOFTWARE BRAKE SYSTEMS

Airbus implemented already on aircraft Airbus 380 and Airbus 320, as optional system, the “Brake to Vacate” (BTV) system. This system is provided as standard feature on Airbus 350. BTV system aims the automatic management of the braking process and is a supplementary selection in classical automatic braking system. The classical automatic brake management allows the pilot to select only the brake intensity between many levels, in concordance with the airplane type (Fig. 11 [9]). It is a software implemented system that allows pilot to select during the approach phase the landing speed and desired runway exit. Using the GPS, airport navigation system, electronic data base with airport maps, auto-pilot and automatic braking system, BTV optimizes the braking intensity in order the airplane reach the taxi speed when it arrives at the desired runway exit. Between optimization criteria are passengers comfort and tyres and brakes wear.

On the navigation display appears a supplementary page for BTV set-up. From this page the pilot can select the parameters in order to the landing run evolves according the selected plan. Pilot makes the set-up according to the traffic control indications. During the landing run it is used the optimum combination of all the braking devices: jet reverse, aerodynamic brakes, spoilers and brake system.

This system proved useful especially on the congested airports. As main advantage, BTV avoid the situation the pilot misses the runway exit indicated by the traffic control. This means the medium Runway Occupancy Time (ROT) reduces. This situation frequently appears in low visibility landings and requires redefining the taxi trajectory to the allocated terminal, and by consequence taxi time increases.

Another advantages are the passengers comfort improving during the landing run, brakes wear reducing, allows the pilot to exit from the runway at a higher speed, avoids the runway outrun. From the traffic control point of view, runway occupancy time minimizes for each landing by avoiding the misses of the optimum runway exit. Even for a single flight this means only few seconds delay, on congested airports this delay can produce important traffic disrupt, especially in low visibility conditions. Small delay times added for many flights produces, overall, important delays and missing of the allocated time slot.

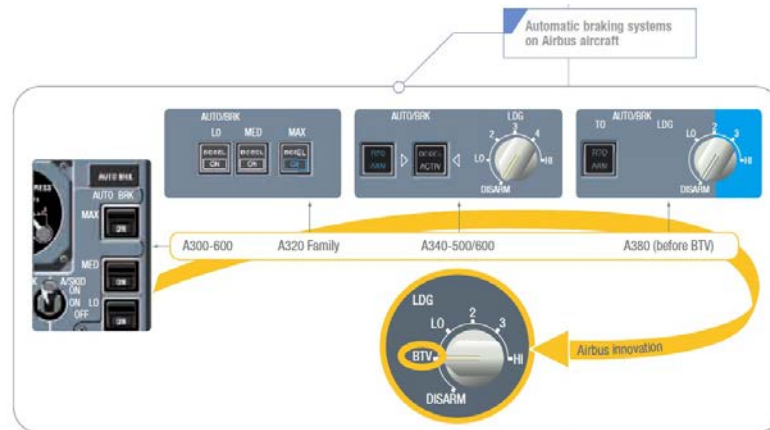


FIG. 11 Automatic brake systems on Airbus aircraft [9]

5. PRODUCERS INTEREST FOR NEW INOVATION IMPLEMENTING

Aircraft producers' interest on the implementation of the innovation in the landing gear system is different taking into account in some situations overall advantages are doubtful. We can mention here the EMA and EHA brake systems. Boeing implemented on Boeing 787 Dreamliner EMA braking system from SAFRAN. The main advantage took into account was maintenance improvement and reduce of immobilization time of the aircraft on ground. However, according the comparison from paragraph 2, that shows a heavier brake system for EMA and EHA than the classical braking systems, and more fuel burned. Airbus choose the classical version, produced also by SAFRAN for Airbus 350 XWB [10]. Besides that, Airbus did not discard classical braking system neither for Airbus 380. For this aircraft Honeywell produces the braking system.

However, flight controls became to use EMA and EHA servo-actuators. Both Airbus and Boeing uses this kind of servo-actuators. Airbus 380 uses EHA and EBHA servo-actuators for the main flight controls. Boeing 787 Dreamliner secondary flight controls uses EMA servo-actuators. Fighters like F35, uses EHA servo-actuators for flight controls.

Electromagnetic and electro-fluidic braking systems presented in this work are in the research phase yet. Their advantages are not suitable to produce a trenchant choose of these solutions. They also increase the mass and volume of the braking system with consequences upon the fuel consumption. For long-range aircraft 0.2 % additional consumed fuel at a flight with 70 tones total consumption means 140 kg. This is a negligible quantity for that airplane, but a pretty big absolute value.

An important improvement introduces the BTV system, already implemented by Airbus. It is expected that other producers will introduce this feature.

CONCLUSIONS

Gradually are implemented more and more improvements of the aircraft braking systems. This process implies careful studies on the innovations proposed. Hydraulic braking systems still present some advantages that were not crucially outdated by new technical solutions. Unlike flight controls, where all the big producers step by step move to EHA or EBHA servo-actuators, there is not such a trend for braking systems. Some big producers still prefer classical hydraulic brake systems.

Researcher investigate the possibility to implement some system from the railway trains or auto vehicles, but the landing gear configurations make difficult to adapt that systems. One problem is the huge kinetic energy of the aircraft that has to be dissipated in the landing run, comparing the auto vehicles situation.

Important improvements concerning the automatic braking management appeared in the last period. Airbus already implemented the BTV system that has as main advantages the reducing of the ROT, possibility to exit from the runway at higher speed, reducing of the brakes wears and enhancement of the passengers comfort, while the hydraulic braking system has no additional components.

Important research efforts are in development for aircraft brake system improvement, but new solutions penetration is difficult. It has to prove the overall progress in relation to the classical hydraulic brake systems.

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IMPACT OF WEATHER CONDITIONS ON FLIGHTS AND AIRCRAFT

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DOI: 10.19062/2247-3173.2023.24.20

Abstract: *Examine the effects of three phases of flight—takeoff and climb, enroute, descent, and landing and five different forms of unfavorable weather—fog, wind shear, thunderstorm, icing, and snow on aircraft operations and accidents. Methods: collect statistically up-to-date data and compare the data to estimate the impact of the various meteorological conditions on flights and the dangers of flight incidents. Use EJM to establish expert systems to report the impact of various weather conditions on flights. Results: evaluate the impact of weather events on flights and the necessity of prevention systems. Discussion: define the need of advanced numerical modeling techniques of time in Air Traffic Management systems.*

Keywords: *accident; adverse weather conditions; expert judgement method; machine learning; stages of flight*

1. INTRODUCTION

Aircraft operations can be greatly impacted by a variety of weather factors, from the routine consideration of wind speed and direction to the more unusual difficulties posed by snow or dense fog. Low cloud, fog and rain may reduce visibility at or around an airport while thunderstorms and lightning can cause serious disruption to flight schedules [1]. Operations may be significantly impacted by fog, which can reduce surface visibility to less than 1 km. Snowfall and wind-blown snow can have a significant impact on aircraft when they are in the air, as well as during ascent and descent. Due to its influence on the aircraft's control, wind shear has a substantial impact during takeoff and landing and has been a primary or contributory factor in numerous aviation accidents. In-flight icing is one of the main dangers of flying in cold weather because it messes with airflow and impairs control and performance. Thunderstorms are among the most dangerous weather events you can experience, making them one of the worst risks to aircraft.

The derived estimations in this article could be used in airplane operations to evaluate the impact caused by weather and to implement the new technology and new 'ways' of displaying meteorological information in a way that is consistent with safe and efficient practices [2].

The reliability of a human operator and his prompt professional judgements are the primary factors that determine the efficacy of aviation systems and the supply of flight safety. The Human Factor still has a significant impact on flight safety – nearly 80% of aviation events are due to the fault of people [6].

2. IMPACT OF WEATHER CONDITIONS

Atmosphere and weather conditions.

There is no upper limit to the atmosphere, which surrounds and revolves around the globe. The earth and its atmosphere move together. It mostly consists of nitrogen (78%), oxygen (21%), and a mixture of other gases (1%), including carbon dioxide, hydrogen, and argon. Air created by these gases behaves almost identically like liquid.

Commercial aircraft fly in the bottom two layers of the atmosphere, the troposphere, which is closest to the surface, and the stratosphere, which is immediately above it. The atmosphere is divided into five primary layers.

The air pressure, temperature, and air density all drop as you ascend into the troposphere. You will experience a 35°F drop in air temperature for every 1,000 feet you ascend. The Tropopause, the boundary layer before entering the Stratosphere, is encountered after ascending for around 36,000 feet. At this point, the temperature no longer drops with height and instead stabilizes.

The temperature of the air below the tropopause has an impact on it. The Tropopause rises with increasing air temperature. It thus tends to be higher at the equator (about 55,000 feet) and lower over the poles (about 25,000 feet). Because it effectively serves as a lid to keep the majority of the weather below it, the tropopause is significant.

Turbulence

Most of the time, turbulence only causes passengers discomfort, but it can occasionally be highly dangerous when it is strong.

The brief and chaotic movement of air particles is known as turbulence. The airplane may shake occasionally for no apparent reason, but if it is particularly severe or dangerous, it may also crash, mostly affecting small and light aircraft. Turbulence appears in clouds and their vicinity, especially in thunderclouds.[3]

Although less dangerous, clear air turbulence is annoying because it is hard to spot. We experience it as buffeting and it can catch passengers and pilots off guard.

Aircraft Icing



FIG. 1 Aircraft icing Source: <http://aviationtroubleshooting.blogspot.com/2011/01/future-of-deicing-technology-and.html>

A quiet killer might be aircraft ice. An airplane's wings may unexpectedly develop ice, greatly impairing their aerodynamic capabilities and causing the aircraft, which is unable to fly, to rapidly drop.

Because water can exist in the atmosphere in the form of water droplets even at temperatures below 0°C, icing results from the physical characteristics of the atmosphere. However, as soon as they touch a solid, such droplets abruptly freeze.

An aircraft, including its wings and other surfaces, as well as the aircraft engine, might be the solid. In that situation, aircraft icing can be extremely dangerous. Despite having ice protection systems, modern aircraft are still susceptible to icing, especially light aircraft. Today, meteorologists predict icing zones and share this information with their users.

Strong Wind

Strong surface wind while landing is especially risky if it is a crosswind, or wind that is perpendicular to the direction of the airplane. Pilots frequently have to attempt a second landing since it is so difficult to line the aircraft with the runway in such circumstances.

If the wind is so strong that it also causes strong turbulence, an additional problem arises, making it quite difficult to stabilize the aircraft to land safely. That sometimes happens at Dubrovnik and Rijeka airports during the bora. As a result, meteorologists pay close attention to such circumstances, forecast them, and alert users.

High-altitude wind is also common and is connected to jet streams. Strong wind can be problematic if it is a headwind since it slows down the aircraft, depending on where the jet stream is and what direction it is moving in. But it can also be advantageous because a jet stream causes the plane to accelerate.

Modern airlines use wind forecasts into their route planning since doing so can considerably shorten travel times and cut expenses. On February 12, 2020, a British Airways plane broke the previous record for the quickest trip between New York and London for subsonic aircraft. In a jet stream, the Boeing 747 reached a speed of 1327 km/h and landed in 4 hours, 56 minutes—80 minutes earlier than expected.

Wind Shear

When landing, wind shear is also particularly risky because it can result in an abrupt drop of the aircraft.

It occurs when winds of different speed or direction blow at different points which can be near each other. Wind shear can be horizontal or, more often, vertical. When that happens, the aerodynamic flight parameters are suddenly altered, causing the aircraft to rise or stall out of control. If it is close to the ground when landing, this can be fatal.

Today, wind shear is forecasted and also detected by onboard or ground-based devices. The majority of current heavy aircraft have wind shear detection equipment to alert pilots of this phenomena, which poses a serious risk to their safety.

Mountain Waves

Mountain waves are a type of meteorological phenomenon that can both help and hurt aviation.

When air moves over a barrier, like a mountain, mountain or lee waves are created. They emerge from behind the mountain as updrafts and downdrafts. Light aircraft, balloons, ultralight aircraft, hang gliders, and paragliders are all at risk from them.

For instance, they most frequently occur in Croatia on the lee side of the Dinaric Alps because to a strong southwest breeze. They can happen during the bora over the Adriatic.

A cloud on a mountain's lee side can also be seen visually in conjunction with the mountain wave phenomena. Mountain waves are dangerous because the downdrafts that occur in them can make steering the aircraft difficult, but they can also be useful because the updrafts can be used for flying and gaining altitude (gliders).

Reduced Visibility

Flying in clouds and fog is the technical term for conditions with low visibility. In fact, it frequently involves flying blind while using navigational aids. In terms of safety, technology has mostly solved the issue of flying in low visibility situations. It refers to using a variety of radio navigation aids during all flight phases so that the aircraft can be operated even in low visibility situations with less than 50 meters of vision.

Of course, for such aircraft operations, all safety standards must be satisfied. There must be enough ground- and air-based radio navigation and other equipment, and the flight crew must be properly educated.

Fog, on the other hand, is the main problem at airports. It is routinely predicted by meteorologists, who use this information to alert travelers to potential issues. Flight operations may be halted due to fog if all safety criteria are not met. However, even if the safety requirements are met, fog can still be a problem. For safety reasons, separation requirements between aircraft are raised under low visibility circumstances, which reduces capacity. Due to flight delays, this can be extremely problematic in congested skies or at busy airports.

Thunderstorm

A thunderstorm is regarded as the most hazardous meteorological occurrence for aircraft due to the massive energy it produces and the following meteorological phenomena.

The thundercloud itself, as well as those above, below, beside, and inside of it, are put at risk. It is dangerous for airplanes not only when they are in the horizontal flight phase but also when they are taking off or landing.

It can be brought on by a single cloud or a cumulonimbus cloud, a group of clouds. Pilots typically steer clear of them since they tend to build overland during the summer and can reach heights of up to 15 km. This makes flying challenging and risky.

A thunderstorm is often accompanied by a number of other dangerous meteorological phenomena, including turbulence, strong wind, wind shear, strong updrafts and downdrafts, ice, electrical discharge, heavy precipitation (rain, snow, or hail), microbursts, gust fronts, and funnel clouds.

The Aeronautical Meteorology Service pays particular attention to thunderstorms due to their importance for flight safety by anticipating their formation and disappearance and offering a variety of information for users.

Variations in air pressure are what cause the sustained horizontal movement of air we refer to as "wind". When you view the weather report on TV, the wind speed is stated in mph. In aviation, it is calculated in knots (kt), where 1kt is equivalent to 1.15mph. Most likely, you've seen a chart similar to the one below that displays areas of high and low pressure. Similar to how water will flow down a slope and fill in a lower lying area, air will naturally move from locations of high pressure to areas of low pressure.

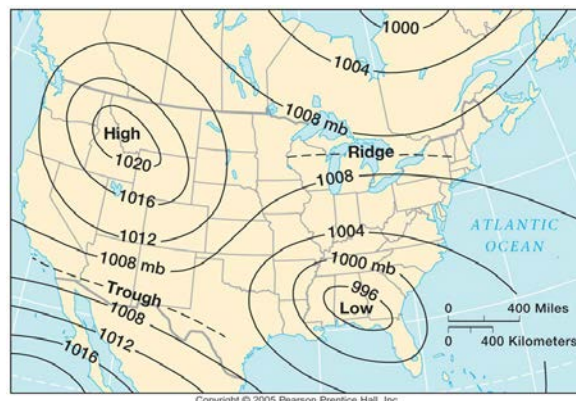


FIG. 2 Charts like this show pilots areas of high and low pressure. (Image courtesy web.gccaz.edu), <http://thepointsguy.com/news/how-weather-affects-flight/>

The rings on the chart are called isobars and they indicate areas of equal pressure. The closer the isobars are together, the greater the pressure change for a given distance, and therefore the stronger the wind. We also know that air circulates around areas of low pressure and high pressure in the northern hemisphere in opposite directions. In the southern hemisphere, the situation is the opposite.

As a result, you can determine the direction and strength of the wind by looking at a chart like the one above. One of the most crucial things that pilots need to know for their trip is what the wind is doing. Why is that important for pilots? First up, let us dispel a common myth. Contrary to popular belief, an aircraft's wings, not its engines, are what cause it to fly. The engines merely provide forward acceleration.

That's because a wing works by air flowing over its surface. The wing begins to provide lift as soon as the airflow reaches a particular speed. The airplane ascends into the air when the lift produced exceeds the weight. The driving power behind the airflow across the wing is provided by the engines. Because of this, the wind's strength and direction (velocity) are crucial to aircraft at all times throughout flight, but especially during takeoff and landing.

Latest research

Data of the National Transportation Safety Board (NTSB) shows, that during the last 10 years 21,3% aviation accidents happened due to weather conditions, of which 39,1% – in bad weather conditions. The major cause of aviation accidents in bad weather conditions (68%) considered improper and untimely DM by crew of the aircraft [5]. According to the IATA Safety Report for 2016, inclement weather was a contributing factor in 49 percent of incidents, making it the most significant environmental issue.

The proper communication between the pilot and ATC is essential for both the safety of air travelers and those on the ground.

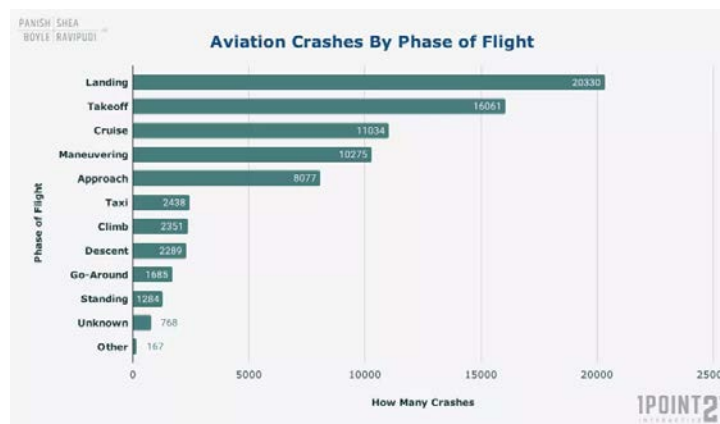


FIG. 3 Aviation crashes by phase of flight
https://www.psb.law/aviation_accident_statistics.html

ATC interference with the flight crew, language barriers, communication issues, incorrect ATC instructions or commands, etc. caused about 2 000 fatal aviation accidents in the second half of the 20th century, according to statistics from the Aviation Safety Network (ASN).

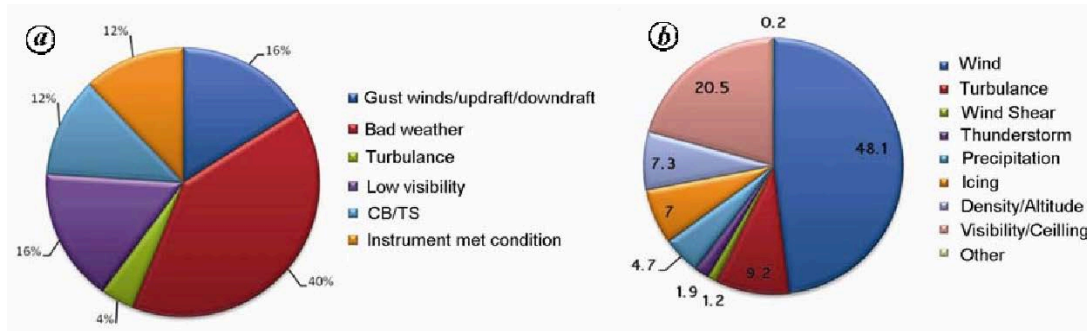


FIG. 4 Proportional occurrences of various accidents by further classifying all weather-related aircraft accidents into various categories of fog, winds (squalls, gusty, updraft, downdraft), low visibility, CB/TS and turbulence for (a) India and (b) USA. [7]

Thus, the Aviation Safety Network safety database presents the following accident statistics with weather as a contributing factor:

- 1) 224 incidents resulting from icing (including 133 loss of control, 15 forced landings away from the airport, and 11 total engine power loss);
- 2) 132 incidents resulting from low visibility (including 55 CFITs - Ground, 26 CFITs - Mountain, and 9 loss of control);
- 3) 116 incidents resulting from windshear or downdraft (including 36 loss of control, 18 runway mishaps, and 9 heavy landing)

According to research done by the (Aviation Accident and Incident Database) and Plane Crash Information, the percentage of aeronautical accidents caused by weather conditions decreased from 31% in the 1990s to 24% between 2003 and 2007. Approximately 17% of aviation accidents today are weather-related. Aerial accidents and incidents that occur during the descent phase, first and final approach, landing, beginning and final ascent, and takeoff phases are also mostly caused by unfavorable weather conditions. Even though the percentages of incidents and accidents caused by weather are declining year after year, meteorology still has a significant impact on aeronautical activities, both in terms of aviation safety and the economy.

Expert System is one of the type of the Artificial Intelligence (AI) systems. Besides AI technologies can be clustered in the following capabilities, such as Machine Learning (ML); Natural Language Processing (NLP); vision; speech; planning; robotics, decision support system, etc. In AI, an expert system is a computer system that simulates the decision-making ability of a human [4].

Expert systems are made to reason through knowledge bases that are expressed as if-then rules rather than procedural code in order to tackle complex problems..

The first stage in creating an expert system is to analyze a complex system.

Second is to break complex systems down into smaller units:

- a. Define subsystems for expert estimation of their significance and describe their characteristics;
- b. Define estimation criteria (3-5 criteria) and describe their features;
- c. Estimate subsystems using the Expert Judgment Method (EJM) by criterion No. 1 and calculate the weight coefficients of subsystem significance by criterion No. 1;
- d. Analogously calculate the next criterion.

In three stages of flight, the impact of five different types of bad weather—fog, wind shear, thunderstorm, icing, and snow was estimated using the expert judgement method:

- Takeoff and climb
- Enroute
- Descend and landing.

Using the results of calculations, a general histogram of weight coefficients for three different stages of flight was built that illustrates that the biggest influence: Using the expert judgement method, the impact of five different types of bad weather conditions (fog, wind shear, thunderstorm, icing, and snow) on the aircraft operations was estimated during three stages of flight:

- On takeoff and climb has Fog
- On enroute has Thunderstorm
- On descend and landing has Wind shear.

And for all three stages of flight the most influential is wind shear.

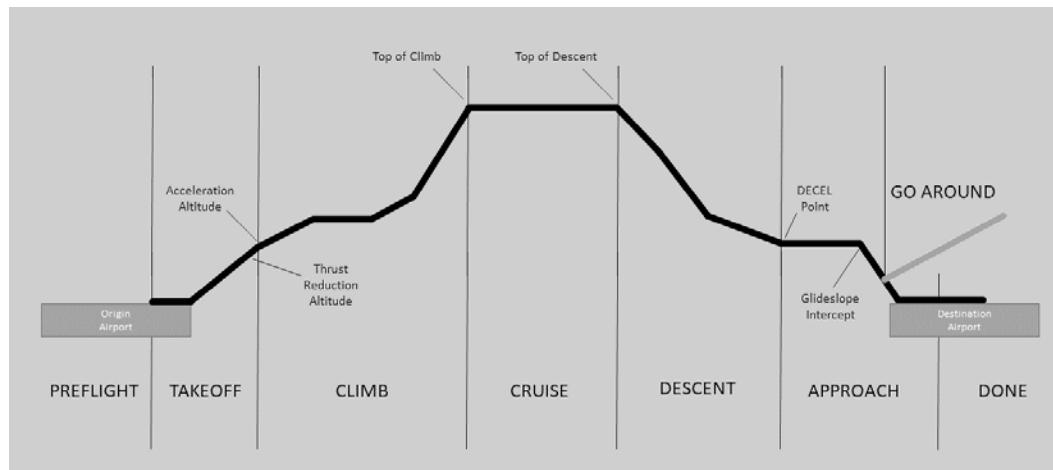


FIG. 5 Stages of flight,

<https://docs.flybywiresim.com/pilots-corner/advanced-guides/flight-phases/>

3. CONCLUSIONS

The methodology described in this article assesses how weather occurrences affect the flight. In order to make the aviation system less susceptible to weather events, these estimates could be used to further enhance situational awareness and decision-making in pilots through the application of current technologies and the development and deployment of new artificial intelligence technologies.

When it comes to ATM operations, issues including sudden changes in wind direction and speed, the presence of wind shear, instances of low visibility, and other unfavorable weather conditions need to be taken into account. Information is therefore crucial for the organization and security of air operations, both in airports and on flight routes. As a result, it is essential to supply ATMs with forecasted meteorological data utilizing current state-of-the-art numerical modeling techniques.

It is crucial for ATM systems to be able to have correct knowledge of meteorological conditions both at a synoptic scale and at smaller sizes due to the varying spatial resolutions with which they operate.

Implementation of the modern and developed Expert systems as a type of the Artificial Intelligence (AI) systems will lead to management and aviation security improvements.

4. ACKNOWLEDGEMENT

The creation of this paper was possible by the active support of the participants in National Science Program "Security and Defense" financed by the Ministry of Education and Science (MES) of the Republic of Bulgaria

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PROJECT MANAGEMENT APPLIED FOR COMPOSITE MATERIALS USED IN AERONAUTICS. CARBON FIBER AND NANO-ADDITIVES

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DOI: 10.19062/2247-3173.2023.24.21

Abstract: *This paper presents the results of theoretical and applied research related to composite materials, carbon fiber and nano-additives. The objective of this work is to investigate the properties and behavior of custom designed composite materials which are intended for applications in aerospace engineering. The holistic approach is expressed by the structure of this research project which consists of the technical part and the economic part, that is analyzed in terms of project management. The specificity of the work is given by the requirements of the European Project Semester EPS, where international teams of students actively experience a multidisciplinary and multicultural project for one semester in another university, which has developed research and industrial partnerships. For developing such project, the approach provided by INCAS as Research Partner is oriented towards Problem Based Learning and Project Organized Learning. The University as Organizer provides Project Related Courses and some complementary Project Organized Learning. The research was oriented towards the customized design and analyzing of composite materials samples for potential use in aerospace engineering, the development and validation of materials and methodologies. The benefits of the research project are related to the applications of composite materials and in the subsidiary to allow the students learn valuable professional lessons and experience from this research project.*

Keywords: *Project Management, Composite Materials, Carbon Fiber, Nano-Additives, Aerospace Engineering, Applications*

1. INTRODUCTION

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part.

Composite materials have emerged as a major class of advanced elements and are either used as substitutions of metals/traditional materials in aerospace, automotive, civil, mechanical, and other industries. A unique feature of composites is that the characteristics of the finished product can be tailored to a specific engineering requirement by a careful selection of matrix and filler, [1]. Composite materials are commonly classified at following two distinct levels, with respect to the matrix and with respect to the reinforcement form - fiber reinforced:

1. The first level of classification is made with respect to the matrix constituent. The major composite classes include organic matrix composites, metal matrix composites and ceramic matrix composites. Types of composite matrices: a/ Polymer Matrix Composites (PMC), b/ Metal matrix Composites (MMC), c/ Ceramic Matrix Composites (CMC), d/ Carbon and Graphitic Matrix Composites (CGMC).

2. The second level of classification is made with respect to the reinforcement form - fiber reinforced: Composites, laminar composites and particulate composites. Fiber reinforced composites can be further divided into those containing discontinuous or continuous fibers. Fiber reinforced composites are composed of fibers embedded in matrix material. Laminar composites are composed of layers of materials held together by matrix. Sandwich structures fall under this category. Particulate composites are composed of particles distributed or embedded in a matrix body. The particles may be flakes or in powder form.

The advantages provided by the use of composites are many, including lighter weight, the ability to tailor the layup for optimum strength and stiffness, improved fatigue life, corrosion resistance, and, with good design practice, reduced assembly costs due to fewer detail parts and fasteners. Other pro's for composites use are: a/ long working life, b/ lower density with respect to steel alloys, c/ high strength to weight ratio, d/ low coefficient of thermal expansion, e/ five times stronger than steel.

On the other hand, the disadvantages of composites use refer to: a/ high raw material costs and usually high fabrication and assembly costs, b/ adverse effects of both temperature and moisture, c/ poor strength in the out of plane direction where the matrix carries the primary load, susceptibility to impact damage and delimitations or ply separations, d/ greater difficulty in repairing composite parts when compared to metallic structures.

The extensive use of carbon fiber composites in the construction of the modern airplane was one of the main reasons the team has decided to study and to research for potential improvements on the mechanical properties of a custom designed & made composite test samples.

2. STATE OF ART ON COMPOSITE MATERIALS USED IN AEROSPACE ENGINEERING

A wide range of load-bearing and non-load-bearing components are already in use in both fixed-wing and rotary wing aircraft. Many military and civil aircraft now contain substantial quantities of lightweight, high-strength carbon-, kevlar- and glass-fiber composites, as laminated panels and moldings, and as composite honeycomb structures with metallic or resin-impregnated paper honeycomb core materials.

Many modern light aircraft are being increasingly designed to contain as much lightweight composite material as possible. For elevated-temperature applications carbon-fiber-reinforced carbon is in use. Concorde's disk brakes use this material, rocket nozzles and re-entry shields have been fashioned from it, and there are other possibilities for its use as static components in jet engines. [3]

In modern aircraft, composite materials are used for the main parts like: 1/ fan, propellers, rotor system, 2/ aerostructure (fuselage, wings, empennage, flight control surfaces (i.e. flaps, elevator, ailerons), 3/ engine components, 4/ nacelle and pylon, 5/ systems.

For the reason of the compliance with the safety standards specifically stated in regulations for the commercial and military aircraft industry, the composite materials were gradually introduced in aircraft and space product constructions.

From the historical standpoint of the introduction and implementation of composite materials in aircraft industry, the evolution was done gradually, so that several phases could be recorded, depending on the damaged tolerance as assumed risk management and the compliance with the safety standards stated for the commercial and military aircraft industry. Phases of composites implementation in aircraft industry:

- The milestone which marks the beginning of using composites in aircraft industry can be associated with the Boeing 707 and DC-9 aircrafts, in the late 1950s.

- Phase #1: the composite materials implementation considered the parts such that the aircraft flying capabilities should not be damaged neither altered by their failure in operation, e.g. tertiary composite components, as: interior parts, sidewalks, bag racks and galleys.

- Phase #2: implementation of the composite materials for secondary aircraft structures, as; spoilers, rudders, ailerons and flaps, after 1960s. After the 1970s, fiberglass was retained for many interior parts and fairings, while for the secondary aircraft structures (i.e. spoilers, rudders, ailerons and flaps) fiberglass was replaced by carbon fibers.

- Phase #3: implementation of the composite materials within aircraft primary structures, such as: stabilizers, wings and fuselage barrels. The design and use of carbon fibers and boron fibers initiated for military aircraft and expanded to commercial aircraft, for flight control surfaces (i.e. rudders, flaps) to stabilizers, wings and fuselage structures. The first high-performance composite materials implementation for primary structures was done in 1980s for the B 737 horizontal stabilizer, which was followed by thorough testing and in-flight evaluations.

- Phase #4: is represented by the design, development and implementation into production of the composite materials for vertical and horizontal stabilizers, customized in purpose to achieving lightweight structures and improved aircraft performances.

- Phase #5: The completion phase consists in expanding the implementation of high-performance carbon fiber composite materials to the stabilizers, wings and fuselage. Another gained advantage is the significant decrease of the aircraft weight, since the stabilizers, wings and fuselage taken together represent about 50% of aircraft structural weight. A representative example of the new generation of commercial aircraft is the B 787 "Dreamliner" aircraft. The components of the B 787 "Dreamliner" which use composite structures, are: 1/ fuselage – almost full body, 2/ upper and lower wing skin, 3/ radome, 4/ flight control surfaces (i.e. wing flaps, elevators, ailerons), 5/ vertical fin, 6/ horizontal stabilizer. The development of composite materials implementation on Boeing aircrafts is detailed in Fig.1; composites implementation on Airbus A380 is presented in Fig.2.

● Phase #6: The current phase corresponds to the increased use of composite materials on both military and commercial aircrafts. Composites use in commercial aerospace (exemplified by Boeing versus Airbus) is shown in Fig.3. Composites use in military aircraft detailed in Fig. 4.

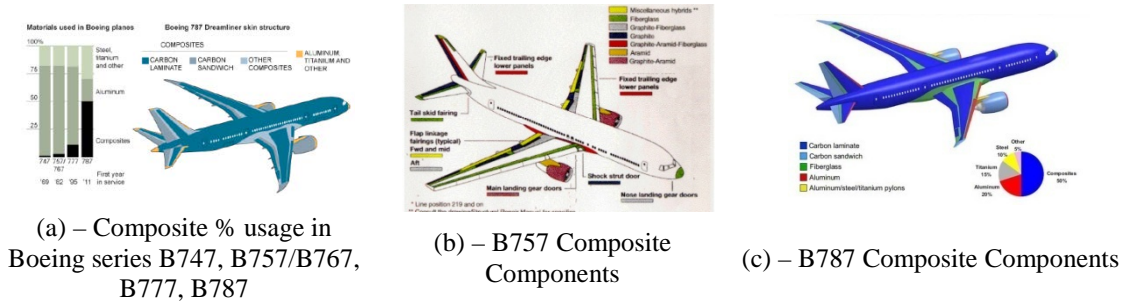


FIG. 1 Composite Materials Used in Boeing Aircraft Series [18-20]

The implementation of the use of composites in the aircraft industry has been gradually done, according to the validation of customized design composite parts, based on matching the capability to overcome loads and stresses with the compliance to the safety standards stated in the regulations of the military and commercial aviation.

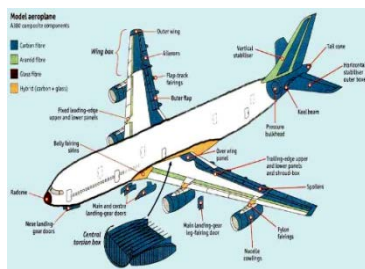


FIG. 2 A380 Composite Components, [21]

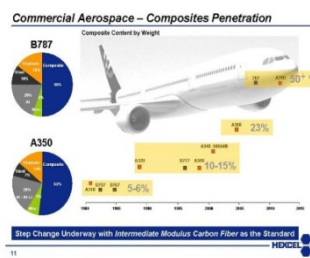


FIG. 3 Composites in Commercial Aerospace, Boeing vs. Airbus, [22]

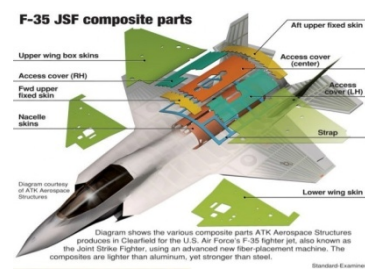


FIG. 4 Composites in Military Aircraft, [23]

The evolution of the use of composites in aerostructures has registered a % increase of composite materials, followed by steel and titanium alloys, compared to the decline in use of aluminum alloys and other metals; nevertheless, improvements of structural aluminum alloy continued to be developed.

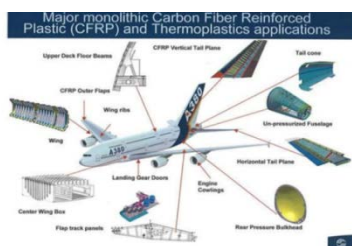


FIG. 5 Aircraft Composite Parts: Carbon Fiber Reinforced Plastic (CFRP) and Thermoplastics Components, [24]



FIG. 6 Key Application of Thermoplastic Composites, [25]

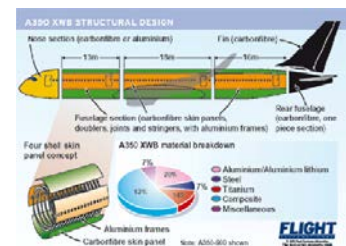


FIG. 7 A350 XWB Structural Design, Composite Parts, [26]

The combination of new construction design (e.g. nacelle and pylon, B 707 versus B 777, improved B 747-8 wing design) with the expanding the use of composites on aircraft (B 747 versus B 777) is the key element to provide improved product performances (higher specific strength and stiffness introduced by composites, which enabled lighter aircraft, powerful engine, and lower noise that declines the environmental impact).

The use of composites in helicopters follows the same objectives (i.e. higher specific strength and stiffness), for parts such as main rotor blades, tail rotor blades, composite weapons pylons. The Bell V-280 Valor helicopter is one of the first military aircraft flying with thermoplastic components, for the reason that thermoplastics can offer advantages in terms of weight, costs, production time and environmental impact. For manufacturing the Bell V-280 Valor helicopter, Bell Helicopter used two thermoplastic composites, induction welded ruddervators, and two compression-molded access panels manufactured from re-used thermoplastic waste material. Ruddervators are the control surfaces for an aircraft with a V-tail configuration; the two compression-moulded access panels were manufactured from recycled thermoplastic waste material from the two ruddervator. The light tactical S-97 RAIDER helicopter, which demonstrated in 2010 to achieve twice the average cruise speed of a conventional helicopter at more than 463 [km/h] (250 knots), integrates HexWeb honeycomb core composites and HexPly prepreg composite technologies, with the ultimate goal to provide the aircraft's structure and blades with light weight and extreme strength.

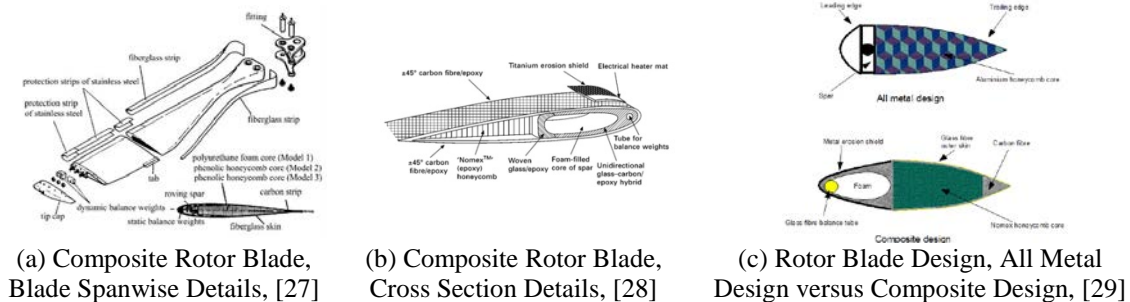


FIG. 8 Composite Materials Implementation for Helicopter Rotor Blades, [27-29]

For both the aircraft structure and the blades carbon-fiber-reinforced composite materials were successfully used. Taking into account the advantages provided by composites, as light weight and extreme strength, the future prospects of composites are to continuous expansion in use for aircraft industry, in large civil aircraft and military aircraft, joined with innovative concept design. New Concept Developments, such as X-48 B Flying Wing, Skyworks Vertijet VTOL, Transcend Air Vy 400 VTOL, represent successfully examples of embedding composite materials implementation.

Table 1- A summary of military, commercial and general aviation aircraft, incorporating composite materials [13]

Type/ Purpose	Manufactured	Aircraft
Fighter Aircraft	U. S., Europe, Russia	AV-8B, F16, F14, F18, YF23, F22, JSF, UCAV Harrier GR 7, Gripen, JAS 39, Mirage 2000, Rafale, Eurofighter, Lavi, EADS Mako MIG 29, Su Series
Bomber	U. S.	B2
Transport	U. S., Europe	KC135, C17, B777, B767, MD1-1, A320, A340, A380, Tu204, ATR42, Falcon 900, A300-600
General Aviation		Piaggio, Starship, Premier 1, Boeing 787
Rotary Aircraft		V22, Eurocopter, Comanche, RAH66, BA609, EH101, Super Lynx 300, S92
New Concept Developments		X-48 B Flying Wing, Skyworks Vertijet VTOL, Transcend Air Vy 400 VTOL

3. BASICS OF COMPOSITES: CARBON FIBER AND NANO-ADDITIVES

3.1 Carbon fiber

In carbon fiber materials the two constituents are reinforcement and a matrix. The main advantages of composite materials are their high strength and stiffness, combined with low density. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. The reinforcement is usually a fiber or a particulate. Particulate composites have dimensions that are approximately equal in all directions. Particulate composites tend to be much weaker and less stiff than continuous fiber composites, but they are usually much less expensive. [4]

Carbon fiber is defined as a fiber containing at least 92 wt % carbons, while the fiber containing a least 99 wt % carbon is usually called a graphite fiber. Carbon fibers generally have excellent tensile properties, low densities, and high thermal and chemical stabilities in the absence of oxidizing agents, good thermal and electrical conductivities, and excellent creep resistance. They have been extensively used in composites in the form of woven textiles, prepare continuous fibers, and chopped fibers. The composite parts can be produced through filament winding, tape winding, pultrusion, compression molding, vacuum bagging, liquid molding, and injection molding. The carbon fiber usually made up of raw material called precursor. It is combination of Polyacrylonitrile (pan) and Petroleum pitch (only 10% of the production).

3.2 Nano-Additives

The use of nano-additives, such as organo-modified layered silicates, carbon nanofibers or nanotubes and others, to reinforce epoxy resins has generated significant interest both academically and commercially in recent times. This interest is primarily a result of the concurrent improvements in mechanical properties such as toughness, strength and modulus. It has been well documented however, that, in order to achieve these property improvements, the nano-additive must be sufficiently dispersed and compatible with the epoxy resin. Depending upon the nano-additive in question, this brings a range of associated challenges unique to the material. [5]

3.3 Carbon nano-tubes

The discovery of carbon nanotubes (cnts) with their exceptional mechanical properties has led to novel approaches of using them as reinforcing nano fillers in composite materials. The results obtained so far promise a unique level of mechanical property enhancement through selective use of cnts and processing conditions. The nanometer scale reinforcing power of cnts in polymers offers an opportunity to develop new composite materials with superior mechanical and physical properties. A homogeneous and stable dispersion of cnts in different polymer matrices is found to be a major difficulty, which most of ten limits performance of the composite materials. Another important issue is the tuning of interfacial adhesion between the cnts and the particular polymer matrix, which also influences the mechanical performance of cnt reinforced polymer composites. An experimental determination of the interfacial strength is still a difficult procedure. Some progress has been made in this field, but to some extent it still relies on theoretical predictions. The stress-transfer from the matrix to the reinforcements is performed via the interface, which can be influenced by chemical functionalization of the surfaces of cnts. [6]

3.4 Organo-nanoclays

Nano clays are nanoparticles of layered mineral silicates which have attracted interest in recent years. Clays are used blended with composites to form nanocomposites which increase the strength, mechanical modulus and toughness of the composite while improving barrier and flame retardant properties.

However, cnt's can be a very good alternative, organo-nanoclays will be a better option. In this research a organo-nanoclay called cloisite-30b is used. The nano-composite powder cloisite 30b with a particle size was obtained from Southern Clay Products, inc. Cloisite 30b is a natural montmorillonite modified with a quaternary ammonium salt and it is designed to be used as an additive for plastics and rubbers to improve various physical properties such as reinforcement, synergistic flame retardant and barrier. Cloisite 30b consists of organically modified nano meter scale layered magnesium aluminium silicate platelets. The platelets are surface modified with an organic chemistry technique and it allows exhaustive dispersion into and provides miscibility with the thermoplastic systems for which they have been designed to improve. While enhancing the flexural and tensile modulus, the clte has lowered when the additives have been proved to reinforce thermoplastics. By incorporating the nano particles into the structure of the surface char formation and flame retardance of the thermoplastic systems have also been found to be improving.

Hydrogen-bonds are so called secondary bonds between two hydroxyl groups. The bond is basically an electrostatic attraction between two hydroxyl groups. A hydroxyl group is a covalent bond between oxygen and hydrogen. But because these atoms don't have the same charge, their electrons are not equally shared between them. The negatively charged electrons tend to spend most of their time around the oxygen atom which makes the atom slightly negatively charged. And the hydrogen atom positively charged. So, the hydroxyl group is very polar, and it will form easily the so-called hydrogen bonds between other polar hydroxyl groups.

The differences between the hardener and the nano clay are the types of bonds and the number of bonds. The hardener will form bonds between four epoxides and can create a 3d network of hardener and epoxides. The nanoparticles can only form bridges between two epoxides. So, this network will be less complex. The forming of the hydrogen bonds is an exothermic reaction. This means that it releases energy in the form of heat during the bonding process. Since its quite hard to mix the nano clay with the resin and takes about 20 minutes of time, the mixture product must be cooled down. If the resin is too hot when mixed with the hardener, it will get hard before it is used with the fibers.

3.5 Nano clay VS. cnt

The production process of nanotubes is very complicated and expensive. This makes the tubes also expensive. Furthermore, the nano clay is perfect for actively making crosslinks between the epoxy molecules. The purpose of both materials is the same, but they work very different from each other. The nanotubes for example are known to be very strong, thin and long. They can act as microfibers in the resin, where the nano clay forms at smaller scale little crosslinks. But there are a lot of different cnt's and they are tunable with different molecules. This is called functionalizing and can improve the solvability and can even form interactions between the epoxy as well, a common interaction for cnt's are the van der Waals attractions. The use of cnt's offers lots of opportunities, but they are very expensive. The nano clay is much cheaper and easier in use, like in the mixing process. As shown in table 10 both are good options, but for this purpose the nano clay is better.

Table 2 - differences between cnt's and cloisite-30b

Name	Costs	Solvability	Opportunities	Strength
Cnt's	--	-	++	++
Cloisite-30b	+	+/-	+	+

4. EXPERIMENTAL RESEARCH

Experimental research based on two test campaigns was conducted at INCAS, within the Materials and Tribology Unit.

The main target during the test campaign was to prove that cloisite 30b has a positive effect on the mechanical properties of carbon fiber composites while also learning the work ethic involved in manufacturing them. In order to produce valid results, instructed by the supervisors at INCAS, the tests were done under strict iso standards regulations. Two different samples were tested during the campaign, a reference material, carbon fiber composite (carbon fiber and epoxy resin) and a nano clay reinforced carbon fiber composite. Both samples were tested using the same input data, following the iso standard for flexure and tensile tests.

4.1 Test rig

In order to obtain conclusive result, the tests were done on a high precision INSTRON 5966 machine that could assure the same input data when testing each sample. [2]

Table 3 - technical data

Tensile strength	3.530 mpa
Tensile modulus	230 gpa
Strain	1.5 %
Density	1.76 g/cm ³
Filament diameter	7 μm

The 5960 dual column tabletop testing systems are universal, static testing systems that perform tensile and compression testing; and also perform shear, flexure, peel, tear, cyclic, and bend tests. For each test, there were used 8 layers of carbon fiber fabric (plain weave 200 gsm) manufactured by INCAS inhouse.

4.2. Epoxy resin I20 and eph 573 hardener

The resin used in the experiment is named I20. It is suitable for the manufacture of particularly high-performance components and structures reinforced with glass, aramid, and carbon fibers. Applications include the fields of satellite design, aerospace, automobile manufacture and ship-building, and the extremely exacting field of high-performance sports equipment as well as model construction. The resin is free of solvents and fillers, it has a low viscosity and has a high static and dynamic strength on its own. The second component, the hardener, is eph-573. This hardener is very suitable with the used resin and has like the resin a low viscosity. Eph 573 exhibits very good wetting properties with respect to glass, aramid, and carbon fibers as well is a superior adhesion to fibers. The combination of these components gives only 15 minutes of processing time.

4.3 TEST CAMPAIGN # 1

4.3.1. Preliminaries on Test Campaign # 1

The reference composite was made out of a simple epoxy matrix with a hardener and a carbon fiber reinforcement. 8 layers of woven carbon fiber were set and resin was added between each one with a brush.

After that, the composite was covered with aluminium sheets and placed under a mechanical press for 24 hours to harden it and avoid air bubbles. Finally, samples were obtained through cutting with the same side and plastic parts were glued on the extremity to avoid weakening the sample during the tightening process.

Moreover, samples were also obtained from pure resin to make a comparison and see how much the reinforcement improved the properties.

4.3.2. Reference carbon fiber composite

- 8 layers of woven carbon fiber (plain weave)

- 100 g of epoxy matrix
- 20 g of hardener
- In the first campaign there were conducted two tests:
 - 1/ Tensile,
 - 2/ Flexure.
- Two materials were tested:
 - 1/ Reference carbon fiber epoxy composite,
 - 2/ Reference hardened epoxy.
- Manufacturing the samples.

4.3.3. Tensile test / Test Campaign # 1

A tensile test, also known as a tension test, is one of the most fundamental and common types of mechanical testing. A tensile test applies tensile force to a material and measures the specimen's response to the stress. By doing this, tensile tests determine how strong a material is and how much it can elongate.

The tensile test was performed in compliance with the European standard iso 527-4:1997, it defines the conditions for the test to be normalized by the iso organism. [9]

The results of the test and dimensions of the samples are resumed in the upcoming figures.

In Fig. 9 are concluded the tests results of tensile test #1 conducted on reinforced samples (i.e. samples n°1 and n°2, which are reinforced with carbon fibers) versus unreinforced samples (i.e. samples n°3 and n°4, which are pure resin). A comparison of two identic samples indicates that the results are reliable.

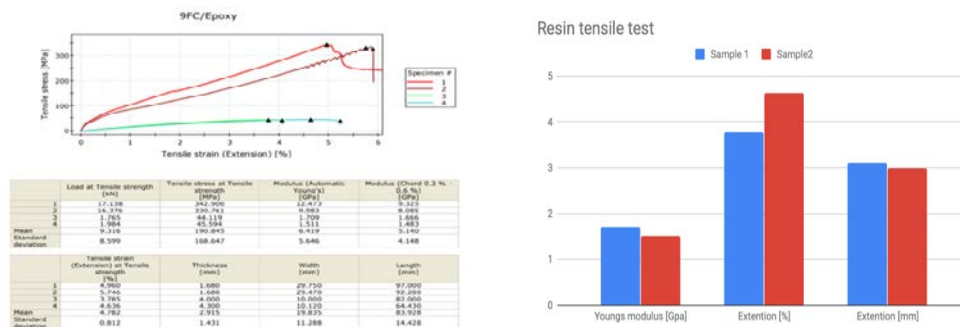


FIG. 9 Test #1 Results of Tensile Test Conducted on Reinforced Samples (n°1,2) versus Unreinforced Samples (n°3,4)

4.3.4. Tensile test in case of carbon fiber composite versus hardened epoxy resin

The results from the tensile test in case of carbon fiber composite were not valid, can conclude that it failed. The graphs show the point where the glue of the fixing tabs broke up, instead of the carbon fiber sample. The first tensile test campaign failed due to the wrong adhesive choice when attaching the tabs that would hold the sample in the grips of the testing machine.

The adhesive was not strong enough the tabs broke during the tensile test. Unfortunately, this occurred when testing both samples and this resulted in the team having to schedule another test campaign.

The results from the tensile test in case of hardened epoxy resin were a success. Both samples had similar values for Young Modulus and Extensions. Furthermore, the test validated the calibration of the testing rig.

The samples had very similar curves drawn in the graphs which clearly shows that having the same input data will result in very similar results.

Differences in the results came from the errors in manufacturing the samples and keeping them in the standard dimensions. From Fig. 10, a comparison of two identic samples indicates that the results are reliable.

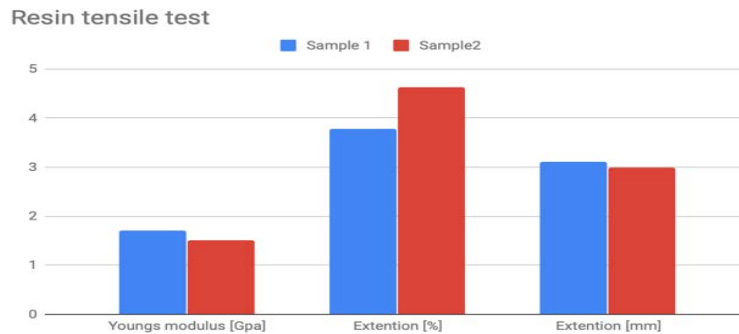


FIG. 10 Test #1 Results of Resin Tensile Test: Young Modulus and Extension

4.3.5. Flexure test / Test Campaign # 1

A flexure test does not measure fundamental material properties like in tensile or compression tests. When a specimen is placed under flexural loading all three fundamental stresses are present: tensile, compressive and shear and so the flexural properties of a specimen are the result of the combined effect of all three stresses as well as (though to a lesser extent) the geometry of the specimen and the rate the load is applied.

The flexure test implies placing a sample on two linear supports and then applying a force at equal distance to those supports. This test is ruled by the European standard Iso 178. [10]

The results obtained on the carbon fiber reinforced composite material are resumed on the first graph and table while the results of pure resin are resumed on the second part.

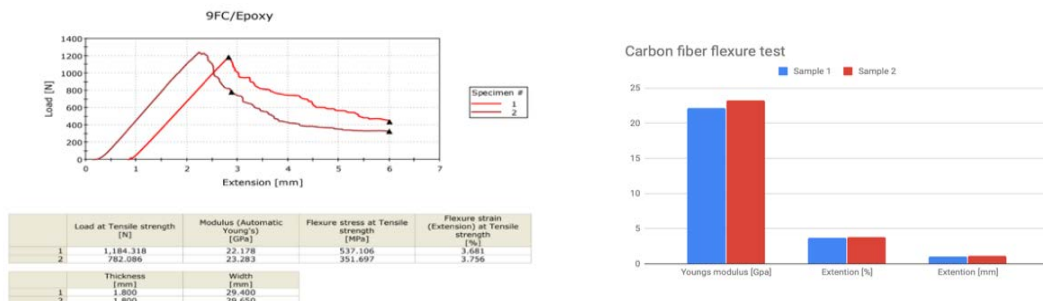


FIG. 11 Test #1 Results of Flexure Test of carbon fibers reinforced material, flexure test results graph and dimensions of carbon fibers reinforced material

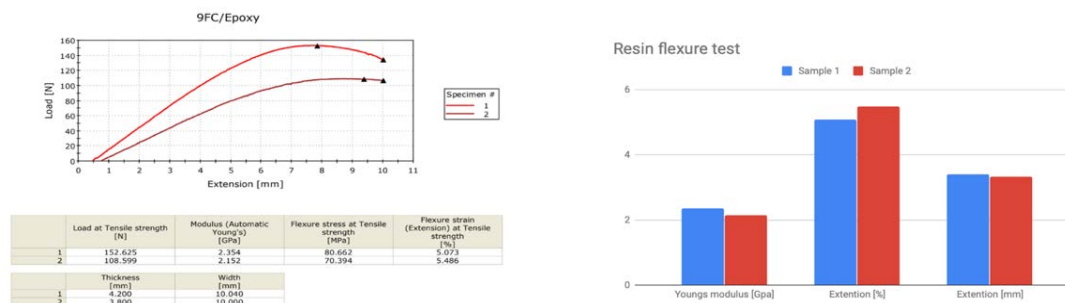


FIG. 12 Test #1 Results of Flexure Test of pure epoxy resin material, flexure test results graph and dimensions of pure epoxy resin material

As shown by the results, there are two differences: with the carbon fibers, samples can resist to a force almost 10 times higher, but they become less flexible. All in all, and after the tests completed, the carbon fibers have a real influence on the mechanical properties of the epoxy resin matrix.

4.4 TEST CAMPAIGN # 2

4.4.1. Preliminaries on Test Campaign # 2

During the second test, two different carbon fiber materials were made. One like the first test as a reference, and one reinforced with nano particles. As a result, from the first test the team has decided to conduct the test without the tabs for the tensile tests. The reference material was manufactured using the same steps as in the first conducted test campaign.

Cloisite-30b reinforced carbon fiber composite.

The used materials are:

- 20 g - hardener eph 573
- 100 g - epoxy resin I20
- 2 g - cloisite-30b

The reference material is the same materials as used in the first test. But this time it only consists 8 layers of carbon fiber instead of 9. The reinforced material took much more time to prepare because the nanoclay (cloisite-30b) has a poor solvability. This extra time is due to the mixing process. The nanoclay is added to the epoxy resin I20 in a concentration of 2% of the mass of the resin. First its roughly mixed with a glass rod, then it was placed in a sonic mixing machine. Because the nanoclay actively bonds to the resin in an exothermic process, the mixture will heat up. Therefore, it must be cooled with iced water around the glass mixing vessel. This process takes approximately 20 minutes.

After the mixing process, the hardener eph 573 was added at a ratio of 1:4 and slightly mixed with a glass rod. Now the resin is ready to be applied on the carbon fibers. After the 8th layer of carbon fiber, the resin cured to much because of the heat to add another layer. The composed material is prepared for the press to cure for 24 hours. First it was packed between two metals plates with a thin layer of mold release to get the surfaces flat, and then it was covered in Aluminium foil to protect the press from the resin. To avoid air trapped in the resin and to make it thin, the press was set at a pressure of 50n/cm².

4.4.2. Ultrasonic mixing machine

By ultrasonic mixing a good dispersion of the nanoclay into the resin can be obtained. This is needed because the nanoclay has a very poor solvability. And the nanomaterial will give negative results if it is not well dispersed. It is called ultrasonic when the frequency outranged the human hearing (>20khz).

4.4.3. Test results / Test Campaign # 2

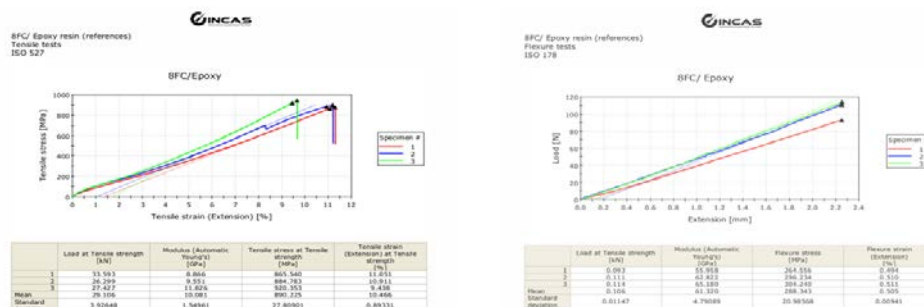


FIG. 13 Test #2 Results of Tensile Test (left), Results of Flexure Test (right) in case of the reference material

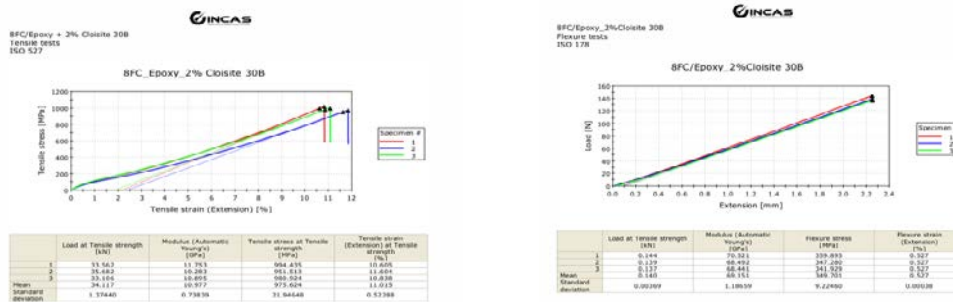


FIG. 14 Test #2 Results of Tensile Test (left), Results of Flexure Test (right) in case of the reinforced material

4.4.4. Analysis of Results and Statistics / Test Campaign # 2

To be sure the results from the test are valid, a statistic study was conducted. The benefit of the machine used to test the results is that it provides a mean and standard deviation. Since in this research two materials were compared, it's useful to know at which certainty conclusions can be made. To calculate this, the means and standard deviations of both test materials is needed. Where σ is the standard deviation. The total standard deviation in this test is 35,43 [mpa]. To make conclusions the interest is in the difference between the means of both materials. This difference is calculated by just subtracting the one from the other. This difference in mean $\Delta\bar{x} = 85,29$ [mpa]. With these numbers the z-value can be calculated. This value is a number of standard deviations within a certain domain. In this case the difference between means. When the $\Delta\bar{x}$ Is divided by σ_{total} A z-value of 2,41 comes out. And following pre-calculated statistics tables this gives a certainty of 0.992024 of 1, so 99,2%. This concludes with a certainty of 99,2% that the cloisite-30b reinforced carbon fiber is stronger than non-reinforced carbon fiber in tensile tests. The same method is used for flexure strength and gave a certainty of 99,6%.

4.4.5. Tensile test results / Test Campaign # 2

Table 4 – tensile test results

Tensile test	Mean tensile strength [mpa]	Standard deviation [σ]
Reference epoxy carbon fiber	890,225	27,809
Cloisite reinforced epoxy carbon fiber	975,624	21,946
Mean difference	85,399	[mpa]
Total standard deviation	35,426	[mpa]
Z-value	2,411	
Certainty	0,992	99,2%

Table 5 - flexure test results

Flexure test	Mean flexure strength [mpa]	Standard deviation [σ]
Reference epoxy carbon fiber	288,343	20,986
Cloisite reinforced epoxy carbon fiber	349,701	9,225
Mean difference	61,358	[mpa]
Total standard deviation	22,924	[mpa]
Z-value	2,677	
Certainty	0,996	99,6%

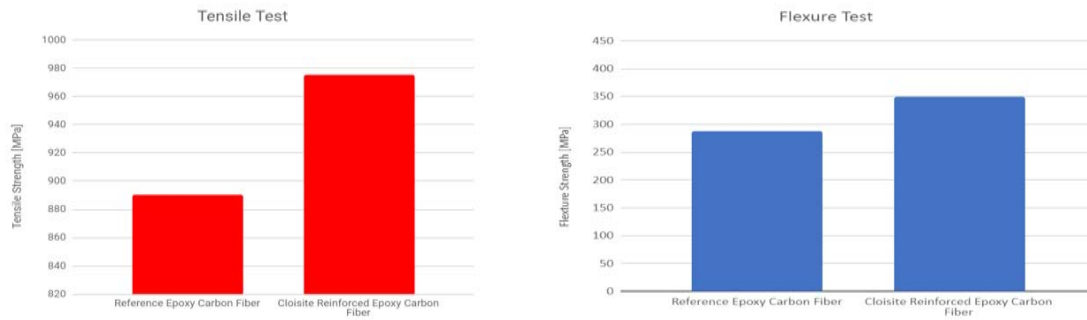


FIG. 15 Test #2 Tensile strength of reference material and cloisite reinforced cf (*left*), Flexure strength of reference material and cloisite reinforced cf (*right*)

5. CONCLUSIONS

5.1. Discussion. Lessons Learned

During the tests and the manufacturing processes of the materials we learned a lot. We noticed for example how important it was to prepare tests. Some of the tabs broke off during the tensile tests, thus some test results were not valid. We experienced that one test is not enough, you need more repeats to be sure the results are valid. Since the product is high-tech, it is hard to find a good marked for it at this moment.

5.2. Further Steps

It is possible to draw better conclusions after a more complex statistics study, like given a certainty that the reinforced material is at least 5% stronger, for example. This is a good subject for further research. Also, to find better ways to cool the mixture with the nano clay and to obtain better measurements, it is worth finding better ways to attach the gripper tabs.

5.3. Final Conclusions

According to the results of the tests, the role of carbon fibers in the epoxy resin-based material is really important in order to improve the mechanical properties (tensile, flexion etc.).

Since better efficiency of materials is always required, one of the most interesting ways to keep improving the mechanical properties of the composite is to find suitable nano-additives, to achieve better toughness, stiffness and even better thermal properties.

The improvements in strength comes with some disadvantages in manufacturing and this with the extra material costs will raise the total costs of the production of the material. For smaller parts its worth to consider using nano-additive reinforced carbon fiber for strength.

Concluding remarks:

- Cloisite 30b improves the mechanical properties of carbon fiber composite – (10 – 20 %)
- Mixing cloisite 30b with the epoxy resin is very time consuming
- Limited working time when using cloisite 30b resin mixture
- Cloisite 30b reinforced mixture is more suited for smaller parts
- The cost of cloisite 30b reinforced cfc is higher than the standard cfc
- Cloisite 30b could increase weight of larger parts compared to standard cfc

Table 6 - advantages and disadvantages of cloisite-30b reinforced material

Name	Costs	Manufacturability	Applications	Strength
Reference	++	++	++	+
Cloisite-30b	-	+/-	+	++

ACKNOWLEDGEMENT

This research was developed within the research partnership between “POLITEHNICA” University of Bucharest, Faculty of Mechanical Engineering and Mechatronics and INCAS - National Institute for Aerospace Research “Elie Carafoli”, through the European Project Semester (EPS) International Programme.

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This research is supported by INCAS - National Institute for Aerospace Research Elie Carafoli, as a beneficiary of the Project - Technological Development Platform for Green Technologies in Aviation and Ecological Manufacturing with Superior Added Value, TGA - TECHNOLOGIES FOR GREEN AVIATION, financed by the Competitiveness Operational Program 2014-2020 (POC), POC/448/1/1/Large R&D Infrastructures, SMIS CODE 127115, Contract of Financing no. 313 / 14.07.2020 funded by Romanian Ministry of Research, Innovation and Digitization.

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INDOOR NAVIGATION: NECESSITY, MECHANISMS AND EVOLUTION

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DOI: 10.19062/2247-3173.2023.24.22

Abstract: Today, GNSS-based solutions are the main technology used in the field of outdoor navigation, which provides good location and a global coverage. The issue arises in densely built-up urban areas, as well as in closed or underground spaces, where the quality of the signal from the satellites can be affected. This is where indoor navigation steps in. Considering these aspects, this paper presents some aspects regarding indoor navigation, starting from the motivation for the appearance of such navigation and presenting several scenarios where indoor navigation can be used. Also, the paper deals with the two main methods and the signal properties suitable for indoor navigation. Finally, algorithms and improvement methods are taken into consideration.

Keywords: indoor navigation, UAV indoor navigation, indoor active location, indoor passive location, 2D/3D indoor navigation

1. INTRODUCTION

Over time, with the development of available techniques and technologies, outdoor navigation has become a very well-developed field. Today, GNSS-based solutions are the main technology used in this field. This provides good location accuracy, global coverage and a very low processing power requirement for the user's device. Problems arise in densely built-up urban areas where the quality of the signal from the satellites can be affected by buildings, as well as in closed or underground spaces where the signal can be completely lost due to the lack of line-of-sight between the satellites and the GNSS receiver. This is where the indoor navigation steps in [1], [2].

This type of navigation is widely used for autonomous devices which are dedicated to specific applications, as well as aid for other navigation systems such as INS/GPS. This problem can also be translated into the continuity of positioning services when switching from one type of navigation to another [3].

2. INDOOR NAVIGATION APPLICATIONS

Technological advances in the area of indoor navigation can spread to several areas of applications. Thus, it finds its use both in the civil and military fields, or as special emergency applications for the rescue crews (personnel). An indoor navigation system could offer advantages in terms of streamlining and coordinating for rescue operations and military operations.

For example, the system can consist of two main components, a personalized device that can be in the possession of each crew member, and a display that is found in the possession of the coordination person of the mission [4].

The navigation devices that are set to be carried and that are subjected to positioning can also be equipped with a variety of sensors, so that they fit as well as possible to the specifics of the respective mission [5], [6].

As previously mentioned, location and position tracking are difficult to do in an environment with tall buildings where distances are short, and the situation can change drastically in a short time. Considering a military operation in such environments, any building is a potential threat, which is why they must be checked room by room by soldiers. Building compartmentalization is often unknown, and in the event of a hazardous situation, an indoor navigation system can increase the situational awareness of the soldiers and also give the operation commander the ability to more effectively coordinate field teams [7], [8].

The benefits of an indoor navigation system increase with the size and complexity of the building or ship in which it is used. These systems can also be used, for instance, in hostage rescue operations where, although an indoor navigation system cannot determine the position of the hostages, it can be useful in ensuring that the intervention forces fully check the buildings or ships where such operations are conducted. Examples of such systems are the Nanohawk and Sparrowhawk produced by the Aeraccess company, or Sewio UWB RTLS produced by the Sewio company [2, 7, 9, 10].

Indoor navigation systems could also be used during firefighting interventions. A personal positioning and indoor navigation system can generate and transmit information of interest to the operation chief. In this type of scenarios, if a firefighter gets lost or injured during the intervention, his location is of critical importance, thus, intervention teams can be dispatched, and with the help of directions provided by an indoor navigation system, they can reach the firefighter that is in difficulty much faster. In addition to this, real-time mapping could also be of interest for scenarios involving large fires where multiple fire crews are involved and coordination becomes more difficult [11], [12].

Other examples of applications can include: law enforcement operations to control crowds, rescue operations or enemy identification in caves or bunkers, route identification in warehouses, locating children etc. [7, 10, 13, 14].

3. METHODS AND SIGNALS USED FOR INDOOR NAVIGATION

Indoor positioning systems can be classified into two categories [15, 16, 17]:

- active positioning systems – that require the tracked person or object to participate actively in the process by carrying an electronic device that sends information to the positioning system;
- passive positioning systems – where the tracked person or object is not required to carry any device that sends information to the positioning system.

Among the examples of active indoor localization system can be listed: Radio-Frequency Identification (RFID), Ultra-wideband (UWB), Bluetooth, Ultrasonic etc. As for the passive indoor localization system can be mentioned: DfP (Device free Passive), physical contact, computer vision, differential air etc. [18, 19, 20].

Most indoor location systems work on an active location basis and the methods generally used for this type of applications are: CoO (Cell of origin), AOA (Angle of arrival) and DOA (Direction of arrival), TOA (Time of arrival), TDOA (Time difference of arrival), RSSI (Received signal strength indicator). The technologies most used in this type of positioning are WLAN (Wireless Local Area Network), UWB (Ultra-wideband),

RFID (Radio frequency identification), ultrasonic technologies, inertial methods or hybrid methods that combine several of the mentioned before [15, 21, 22, 24].

In this paper the focus will be on the active localisation methods.

In the context of indoor navigation systems, CoO is often used as a preliminary step before using more accurate positioning methods such as Wi-Fi triangulation or Bluetooth beacons. The basic idea is to divide the interior space into different cells or zones, each associated with a known reference point or signal source. These reference points can be cellular base stations, Wi-Fi access points, or other wireless transmitters. In [21] a model of CoO is presented. Here, a unique cell for each wireless access point (AP) is determined. The basic idea is that, from the network of access points covering the areas of interest, a single cell is formed, generally in the form of a polygon, on the principle that the signal from this AP is stronger than that of the neighboring APs. This aspect is illustrated in Fig. 1, where the formation of the two cells, 9 and 10, can be observed [21]. Thus, when a device, for example a smartphone, enters a particular cell, it measures the signal strength or other characteristics of the reference point in that cell. By comparing these measurements to a database or pre-existing map of the indoor environment, the system can estimate the initial position of the device.

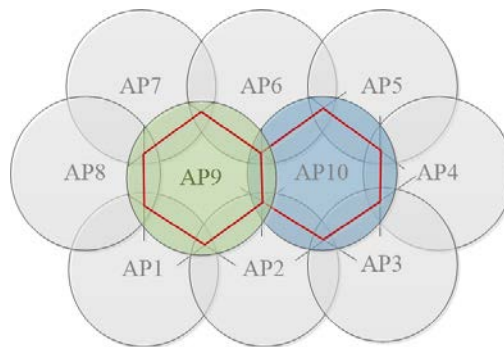


FIG. 1. CoO method – determination of unique cells

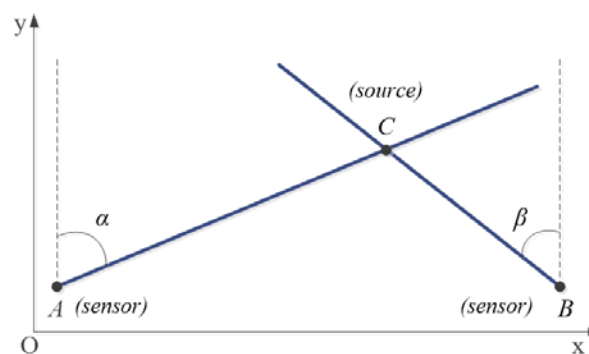


FIG. 2. AOA basic principle

AOA (or DOA – direction of arrival) calculates the angle and the distance from two or more fixed points (signal sources) to a receiver (antennas or sensor arrays) by intersecting the direction lines of the reference points. This information can then be used to determine the position of the receiver (the mobile device) in 2D or 3D. The disadvantages of this method are represented by hardware that tends to be complex and expensive, as well as signal propagation in different paths, which makes the system accuracy decrease. Figure 2 shows a schematic of the AOA method [24, 25, 26, 27, 28].

Unlike the AOA method, which is based on measuring angles, the TOA method is based on distances, or in other words TOA represents the time required for a signal to reach from a transmitter to a receiver. Transmitters are fixed and act as reference points in the system, and the receivers are mobile (attached to the carrier whose position is to be determined). This method is similar to TOF (Time of Flight) which works on the same principle in terms of timing, which means that the time for both are the same. TOF differs from TOA in design, the transmitter being on the carrier and the receivers being fixed. Figure 3 illustrates positioning via TOA analysis. TOA is the most accurate method used in indoor environments, but it is not without disadvantages. One is that the system devices must be very accurate in regard to the timing of the system. This aspect translates into higher hardware costs than other methods [25, 26, 27, 29].

TDOA is similar in operation to TOA. The relative position of a mobile transmitter is determined based on the signal propagation time difference from the transmitter to a multiple receivers (reference points/sensors). In other words, TDOA uses the relative arrival times of the signal at each receiver instead of the absolute time used in TOA. Thus, it is necessary that only the receivers of the system to be synchronized, this resulting in the reduction of the complexity of the equipment used (the transmitter does not need synchronization requirements), without reducing the accuracy of the measurements. Geometrically, a particular TDOA value defines a hyperbola between two receivers on which the mobile device may be located, as it can be seen in Fig. 4 [25, 26, 29, 30, 31].

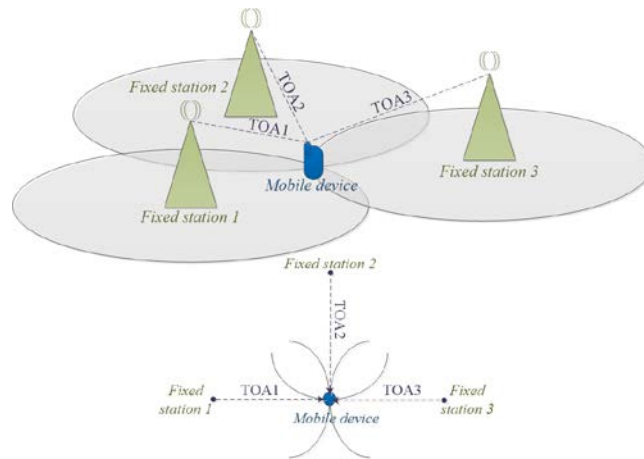


FIG. 3. TOA/TOF basic principle

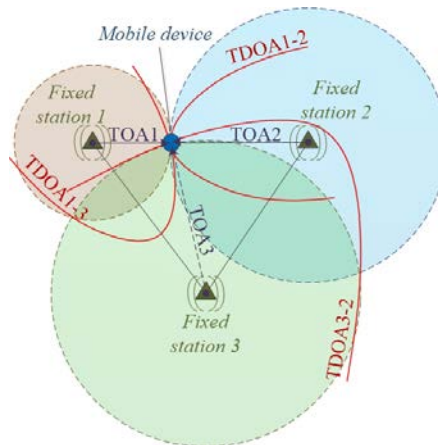


FIG. 4. TDOA basic principle

RSSI can be defined as a measurement of the strength or power level of a received radio signal, typically in wireless communication systems such as Wi-Fi, Bluetooth, or cellular networks. By comparing the RSSI values from multiple reference points, the system can estimate the position of a signal device, like a smartphone, relative to those reference points. This estimation is typically based on the principle that the RSSI decreases with increasing distance between the device and the signal source. Geometrically, the basic principle is the same as with TOA, the difference being that instead of measuring time, the signal strength is measured [23, 24, 32].

Regarding the passive location method, which consists in the fact that the object or person subject to tracking is not equipped with an electronic device, it finds an important applicability in the detection of intruders in an area of interest. Two types of such systems are presented below.

DfP (Device free Passive) focuses on identifying a person's location without the person wearing electronic equipment such as sensors or tags. The principle after it is operating revolves around the fact that a human body is made of approximately 70% water and the resonance frequency of water is 2.4 GHz. The nodes of the system use 2.4 GHz radio frequency and the human body reacts to this by absorbing and attenuating the wireless signal [15].

Physical contact can be also used for indoor localisation systems. The system, based on physical contact, measures changes in capacitance. This analysis is performed using electrodes mounted in the floor. When a person steps on the floor, the capacitance detected by the electrodes changes, thus being able to approximate the person's position. This is a simple and inexpensive method of 2D location estimation [33], [34].

4. POSITIONING ALGORITHMS

Positioning algorithms are working by converting the provided data signal properties into distances and angles, and from there, calculating the position of the tracked object. For example, when the distance between the object and the reference points is estimated, the algorithm intervenes and calculates the position of the object. Each positioning algorithm has its own advantages and disadvantages, so the combined use of several algorithms improves both the accuracy and the performance. The main algorithms used in positioning are triangulation, trilateration, proximity and scene analysis/fingerprinting [25].

Triangulation, uses the geometric properties of the triangle to estimate the position of an object. For 2D estimation, the predetermined distance between the reference points and the measured angles with AoA are used (Fig. 5). With a good precision of AoA and increasing the number of access points, high precision may be obtained [35, 36, 37].

According to Fig. 5 it can be written [35]:

$$\begin{aligned}
 x &= r_a \sin(\alpha) + x_a \\
 y &= r_a \cos(\alpha) + y_a \\
 x &= -r_c \sin(\gamma) + x_c \\
 y &= r_c \sin(\gamma) + y_c
 \end{aligned} \tag{1}$$

Trilateration uses the simultaneous range measurements from at least three reference points at known locations and in contrast with triangulation, does not require the measurement of angles. For 2D estimation a minimum of 3 stations (reference points) are needed [35].

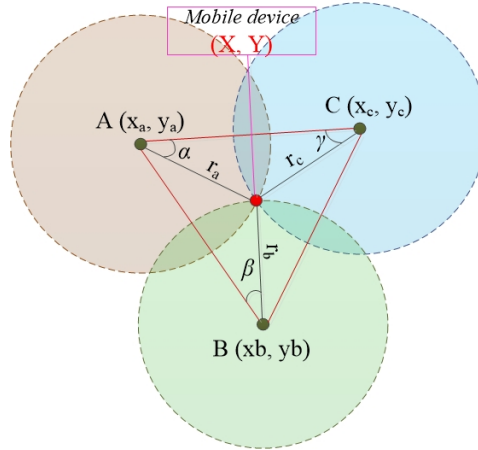


FIG. 5. Triangulation, trilateration - basic geometry

According to Fig. 5 the equation are [35]:

$$\begin{aligned} r_a^2 &= (x - x_a)^2 + (y - y_a)^2 \\ r_b^2 &= (x - x_b)^2 + (y - y_b)^2 \\ r_c^2 &= (x - x_c)^2 + (y - y_c)^2 \end{aligned} \quad (2)$$

The position of the object is determined by using the TOA signal property in order to measure the time it takes for the signal to travel the distance between the transmitter and the receiver. TDOA can also be used in certain system configuration, resulting in a system with the same high accuracy as TOA, but with the disadvantage of greater hardware complexity. The main factors influencing accuracy are the received signal and environmental conditions [25], [38].

The main difference between proximity and triangulation/trilateration is that the proximity technique does not provide an absolute or relative position estimate, instead, it provides a positional information by using an array of antennas whose positions are well known. When a signal from a device is detected, the nearest antenna is used for approximate the position. In the situation where several antennas detect the same device, the one with the strongest signal is used. Position is determined by using the RSSI signal property [25, 35, 39].

Scene analysis gives a position estimation independently of angles or distances. This is done by first collecting information regarding the environment from scenes and then estimating the position of an object by comparing the gathered information with a pre-existing database. It involves a broader analysis of the visual characteristics and features of the indoor environment. It typically includes the use of sensors, computer vision techniques, and machine learning algorithms to interpret visual data captured by cameras or depth sensors. Scene analysis aims to extract relevant information from the environment [25], [35].

The fingerprinting of a location can be done in two stages: offline (training) and online (location). In the offline stage, the environment inside a building is examined and a grid is constructed, which contains the coordinate signal strength of the examined space. In the grid, the points contain the RSSI values for visible access points. The collected grid points and position information are processed in the online phase to obtain the position. The offline stage requires a significant investment of time and effort to build the network that includes the reference points, as well as to update it in the event of changes.

As a result, fingerprinting is a time-consuming, highly complex method that involves high costs [25, 35, 40].

5. IMPROVEMENT METHODS FOR INDOOR NAVIGATION

In order to improve the versatility of indoor navigation systems, different features can be added in order to increase the types of missions. The aids that could be recruited in order to increase performance can include: path planning, map creation or obstacle avoidance (including such technologies, the navigation system may become redundant or autonomous).

Since indoor positioning technologies have become an area of interest, numerous mapping formats and standards have been proposed. The multitude of standards proposed over time led to the need of an analysis of the advantages and disadvantages of each such standard, their interoperability, as well as their applicability in specific situations. Some of the standardized map formats and models used for indoor applications include: Indoor OpenStreetMap (OSM), OGC IndoorGML (OGC – Open Geospatial Consortium, GML – Geography Markup Language-encoding standard) or IFC (Industry Foundation Classes) [41, 42, 43, 44].

The OpenStreetMap project was conceived as a platform built by a community of cartographers who contributed with information about local areas. The project is open source, and the OSM format was initially created for open spaces, later being extended to indoor spaces in a 3D format, with the implementation of an OSM compatible mobile navigation system in 2013 [41], [42].

OGC IndoorGML is based on a cellular spatial model, where each spatial unit is considered a cell that is not-overlapping on another, with the main purpose to reduce information loss during the data conversion process [41], [43].

IFC standard is object-oriented and has a large number of classes dedicated to buildings and even containing information regarding the furniture in the rooms. This aspects make it suitable to provide a precise indoor maps [41], [44].

Path planning is important in the case of an autonomous mission. Path planning algorithms generate trajectories and waypoints that the vehicle needs to pass through. The path is geometric and created from an initial point to a final point [45]. Although, planning does not involve direct command of the controls, a route as detailed as possible can avoid the occurrence of unforeseen situations. For this purpose, indoor navigation systems can use either information from sensors integrated into the system, or information from other external sources [41].

CONCLUSIONS

This paper focuses on indoor navigation aspects, starting with the motivation of the appearance of the this type of navigation. Here are presented the application where it finds its use, thus, various applications are presented both in the military and civil fields, as well as some examples of systems already developed and available on the market. Based on a general classification, active and passive indoor navigation, methods and signals are treated at concept level. The CoO (Cell of origin), AOA (Angle of arrival), DOA (Direction of arrival), TOA (Time of arrival), TDOA (Time difference of arrival) and RSSI (Received signal strength indicator) are the most common active methods and for communication, WLAN (Wireless Local Area Network), UWB (Ultra-wideband), RFID (Radio frequency identification). The RSSI can be categorized as the optimal because it does not require additional hardware, having a lower cost and it is not as

complex as the others. As for the passive methods, which finds an important applicability in the detection of intruders, only two are mentioned and shortly overviewed, the DfP (Device free Passive) and the physical contact. Regarding the algorithm component, this is based on five widely known methods: triangulation (figured here with a 2D example), trilateration (figured with the similar 2D case), proximity, scene analysis and fingerprinting. Among these, trilateration would be preferable due to its low cost, easy implementation and good accuracy. Such systems can be improved through hybridization, on the one hand by the methods already mentioned, or through non-conventional, high tech, but more complex methods such as path planning, map creation or obstacle avoidance. The choice of the optimal system differs from case to case, depending on the application for which it is used.

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AIRCRAFT HYDRO-MECHANICAL NOZZLE VERSUS PNEUMO-HYDRAULIC NOZZLE AS CONTROLLED OBJECTS

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DOI: 10.19062/2247-3173.2023.24.23

Abstract: *The paper makes a comparison between two types of automatic control systems for the opening of the exhaust nozzle as objects subject to automatic control, under the conditions of their use on various types of jet engines for aircraft. Mathematical models of these nozzles are issued and some possible control schemes are described; Matlab-Simulink simulations are performed concerning object(s) step responses for throttle's step input. Some conclusions are drawn and some comments concerning the properties and the quality of the studied systems were also presented.*

Keywords: *exhaust, nozzle, jet-engine, speed, actuator, step input, control.*

1. INTRODUCTION

An exhaust nozzle (EN) for propulsion use is a special conceived device, designed to control the direction and the speed of a fluid flow as it exits a combustion chamber or a turbine [1]. When used on aircraft applications, the EN is also known as propelling nozzle and converts the energy of hot gases into propulsive force (thrust), so the engine becomes a jet engine, according to the classification given in [2].

Jet engines' nozzles accelerate the hot gases flow, depending on engine's power setting, to subsonic, transonic or supersonic velocity. This velocity depends on nozzle's internal shape, as well as on pressure distribution at its entry, respectively at its exit [2], [3].

Nowadays used nozzles have convergent or convergent-divergent (de Laval) shape, according to its purpose; convergent nozzles can only ensure subsonic exhaust velocities, at most sonic velocities, while de Laval nozzles can accelerate gas flow within their divergent sections to supersonic velocities ([2], [3], [4]).

In terms of their exhaust area, nozzles may have a fixed geometry, or they may have variable geometry ([2], [3]); variable geometry assures different exit areas, in order to control the operation of the engine [5]. This kind of nozzle is mandatory when the jet engine is fitted with an afterburner, for supersonic flights. When a jet-engine with afterburning is equipped with a de Laval nozzle, the variable area is its throat; however, for high supersonic flight speeds (when high nozzle pressure ratios are obtained), nozzles might have variable area divergent sections too ([2], [3]).

Most of nowadays in use propulsion nozzles are convergent. If nozzle's pressure ratio is above the critical value, the nozzle will choke [1] and the expansion to atmospheric pressure takes place downstream (in the jet wake) and the propulsion force is weaker, based on the imbalance between the exhaust area static pressure and the atmospheric pressure ([1], [2]).

Most of subsonic engines have nozzles of a fixed size because the changes in engine performance with altitude and subsonic flight speeds are acceptable with such architecture. However, high performance subsonic engines (e.g. multi-spool engines) and all supersonic engines employ variable architecture [2], consisting of a series of moving, overlapping petals (flaps) which build a nearly circular nozzle cross-section ([2], [3]), because of afterburner's requests, to prevent adversely affecting the operation of the jet-engine.

The nozzle opening control is carried out by various methods and is provided by control equipment based on various principles (mechanical, hydraulic, pneumatic, electrical or combinations thereof), generically called exhaust nozzle's control units (ENCU). The decision is taken by the engine designer in correlation with the designer of the aircraft that the engine is going to equip. Consequently, it is important that the decision be taken considering as many aspects as possible, including the behavior of the aircraft-engine-nozzle assembly as an object subject to automatic control and to estimate the advantages and disadvantages of using a certain type of exhaust nozzle.

2. PROBLEM FORMULATION

The paper intends to make a comparison between two types of automatic control systems for the opening of the exhaust nozzle as objects subject to automatic control, under the conditions of their use on various types of jet engines for aircraft. In fact, the direct comparison between the two types of ENCU cannot be always relevant; it is important to compare the effects of using each ENCU in an embedded control architecture of the same jet-engine, be it single-spool single-jet engine, double-spool single-jet engine or low by-pas turbofan.

The ENCU embedding into engine's control system entails some consequences concerning some modifications of engine's behavior as controlled object, such as its time constant, its settling time after a step input and its static error(s).

This paper aims to highlight such changes and formulate conclusions about the advantages and disadvantages of using a certain ENCU within the control structure of a jet engine, even from the pre-design stage.

The first studied ENCU is hydro-mechanical-type (HMEN), as presented in [6], while the second one is pneumatic-hydraulic-type (PHEN presented in [7]), both ENCUs being used by aircraft jet engines with variable exhaust opening area.

The way in which these two controllers behave in the engine assembly is obviously different and, for their choice in the pre-design phase, a study is necessary to highlight how the engine would behave as an object subject to control under the conditions of ENCU embedding with the other controllers of the engine.

3. HYDRO – MECHANICAL - TYPE ENCU

A hydro-mechanical ENCU with complex structure and operation is the one studied in [6], depicted in Fig.1. In fact, this is a tracking (a "follower") system, which provides an opening of the exhaust nozzle depending on the position of the engine throttle (in other words, with respect to the power lever angle PLA).

The described ENCU operates with respect to the throttle's position (assured by the 1-lever rotation angle θ , equal to the PLA). Nozzle's flaps have profiled outer contours (as seen in Fig 1, position 32). When the actuator's rod (26) moves, it presses its 30-roll on this contour, determining nozzle flaps' opening.

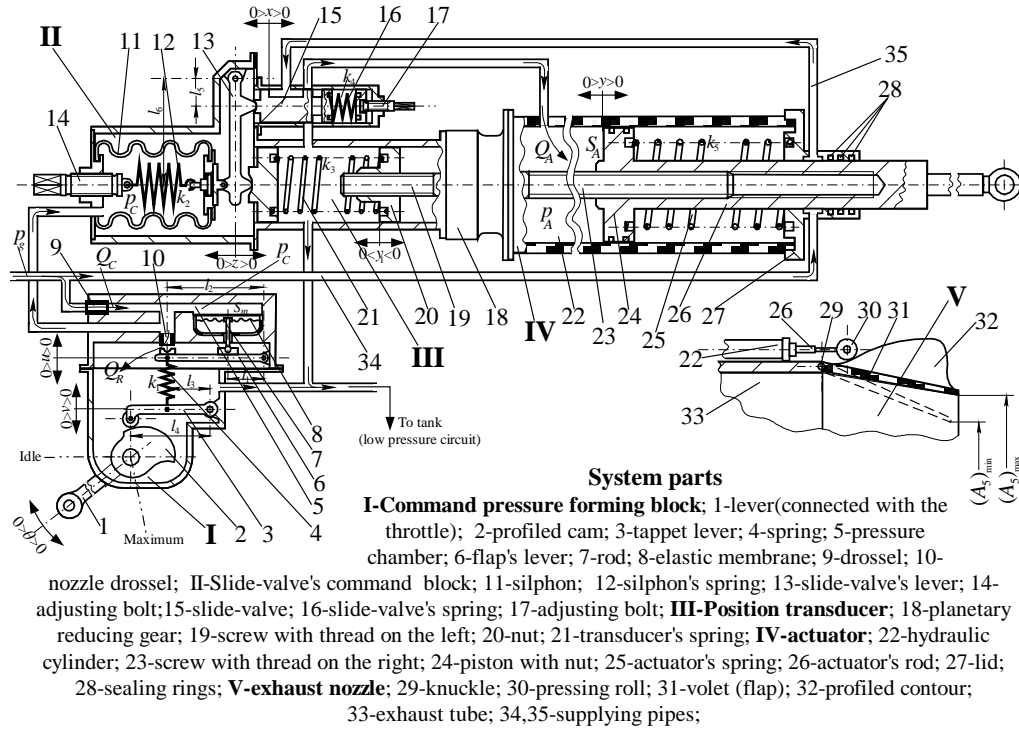


FIG. 1 Hydro-mechanical ENCU's constructive and operational diagram [6]

Nozzle's opening log law $A_5 = A_5(\theta)$, determined by considerations of engine's gas-dynamics, is provided through 2-cam profile, which is connected to ENCU's lever. In fact, the gas-dynamics of the jet-engine imposes, at each engine regime (at each position of the throttle and at each spool speed), a certain value of the nozzle opening, and the cam profile is built in such a way as to realize the law thus determined; this is why it is said that the opening of the exhaust nozzle follows the position of engine's throttle, so ENCU is a tracking system.

Hydro-mechanical ENCU's linear adimensional simplified mathematical model was determined in [6], based on non-linear motion equations, linearised using finite differences method and brought to an adimensional form by favorable dividing. After Laplace transformation applying, one had obtained ENCU's mathematical model's usable form, which consists of the following equations:

$$\bar{v} = k_{\theta} \bar{\theta}, \quad (1)$$

$$\bar{u} = k_{uc} \bar{p}_C - k_{uv} \bar{v}, \quad (2)$$

$$\bar{p}_C = k_u (\tau_u s + 1) - k_{gp} \bar{p}_g, \quad (3)$$

$$\bar{x} = k_{xc} \bar{p}_C - k_{xy} \bar{y}, \quad (4)$$

$$\bar{p}_A = k_{gA} \bar{p}_g + k_x \bar{x} - \tau_y s \bar{y}, \quad (5)$$

$$\bar{y} = \frac{k_{yA}}{T_y^2 s^2 + 2\omega_0 T_y s + 1} \bar{p}_A, \quad (6)$$

together with $\bar{A}_5 = k_{5y} \bar{y}$ - the adimensional equation of the nozzle's opening. The above-used coefficients of the mathematical model have the form presented in [6]. Based on these equations, ENCU's block diagram with transfer functions was built and depicted in Fig. 2.

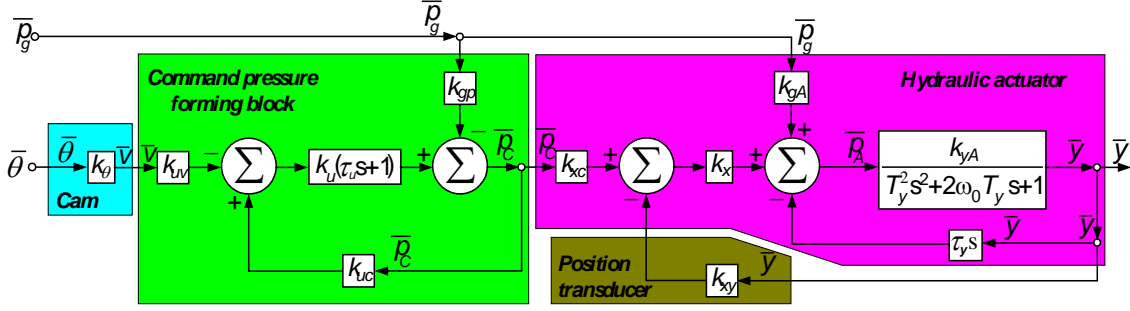


FIG. 2 Hydro-mechanical ENCUs block diagram with transfer functions [6]

One may observe that ENCUs has two inputs: the power lever angle (PLA) $-\theta$, as well as the supplying hydraulic pressure $-\bar{p}_g$. However, as far as the hydraulic pump is driven by the engine's spool and is assisted by a constant pressure valve, one may assume that \bar{p}_g is nearly constant and its behavior as input becomes irrelevant, so ENCUs transfer function, determined based on its mathematical model, is:

$$H_{\theta}(s) = \frac{\tau_{u\theta}s + \rho_{\theta}}{(\tau_{yA}s + 1)(\tau_{uA}s + 1)}, \quad (7)$$

where the coefficients' expressions are $\tau_{yA} = \frac{k_5 k_{yA} \tau_y + \xi}{k_5 (1 + k_{yA} k_x k_{xy})}$, $\tau_{uA} = \frac{k_u k_{uc} \tau_u}{k_u k_{uc} - 1}$,

$$\tau_{u\theta} = \frac{k_{yA} k_x k_{xc} k_u k_{uv} k_{\theta} \tau_u}{(k_u k_{uc} - 1)(1 + k_{yA} k_x k_{xy})} \text{ and } \rho_{\theta} = \frac{k_{\theta} - k_{yA} k_{gA} k_x k_{xc} k_{uc} k_{uv}}{(k_u k_{uc} - 1)(1 + k_{yA} k_x k_{xy})}, \text{ as presented in [6].}$$

A particular form of the model, for an ENCUs belonging to a VK-1A-type engine, is the one used in [6] for quantitative evaluation:

$$\bar{A}_5(t) = \frac{0,0712 \times (0,0422s + 0,1025)}{(0,1474s + 1)(0,6376s + 1)} \bar{\theta}(t). \quad (8)$$

4. PNEUMATIC – HYDRAULIC – TYPE ENCUs

This type of ENCUs (presented and studied in [7]) consists of three main parts: I – the exhaust nozzle, II – the hydraulic actuator (with inner rigid feedback) and III – the pneumatic pressure ratio transducer (with flow rate corrector).

As Fig. 3 shows, the variable exhaust nozzle is equipped with overlapping petals (1), which have the outer contour (2) designed to assure nozzle's opening law, as the engine's operating gas-dynamic conditions request ([3], [10]). Hydraulic actuator's rod (6), equipped at the free end with a pressing roller (4), interacts, during its movement, with the outline of the petals and forces them to overlap more or less, leaving a smaller or a larger nozzle opening (between extreme positions of $A_{5\min}$ and $A_{5\max}$). The actuator's slide-valve (10) is commanded by the pressure ratio transducer's rod (16), in order to assure the gas-dynamic conditions behind the turbine as to maintain constant the turbine pressure drop (constant pressure ratio P_3^*/P_4^* , where P_3^* and P_4^* are hot gases total pressures before/behind the turbine).

The pressure transducer has two active chambers - one for P_4^* and the other one for the reference pressure P_R , separated by an elastic metallic membrane (15); it has also two variable fluidic resistances – one for the supply (20) and the other for the discharge (17), meant to assure the reference pressure value. However, as long as burned gas temperature T_3^* at turbine's inlet is high, one uses instead of P_3^* the air pressure behind the compressor P_2^* ($P_3^* = \sigma_{cb}^* P_2^*$, where $\sigma_{cb}^* < 1$ is the total pressure loss coefficient inside the combustor) to protect the pressure transducer; one may also use another smaller air pressure signal, from an intermediate stage of the compressor, to avoid the excessive mechanical charge of transducer's membrane. Transducer's flow rate corrector (18) operates similarly to the transducer, but it has as inputs air pressures before and behind engine's compressor; it has two pressure chambers (for air pressure in front of the compressor and for the correction pressure), an elastic membrane (19) and two variable fluidic resistances (21 and 22). The 22-resistance is an adjustable-one, and serves to set the suitable correction pressure value, during the program of testing and adjustment operations on ground testing rig, before ENCU enters service.

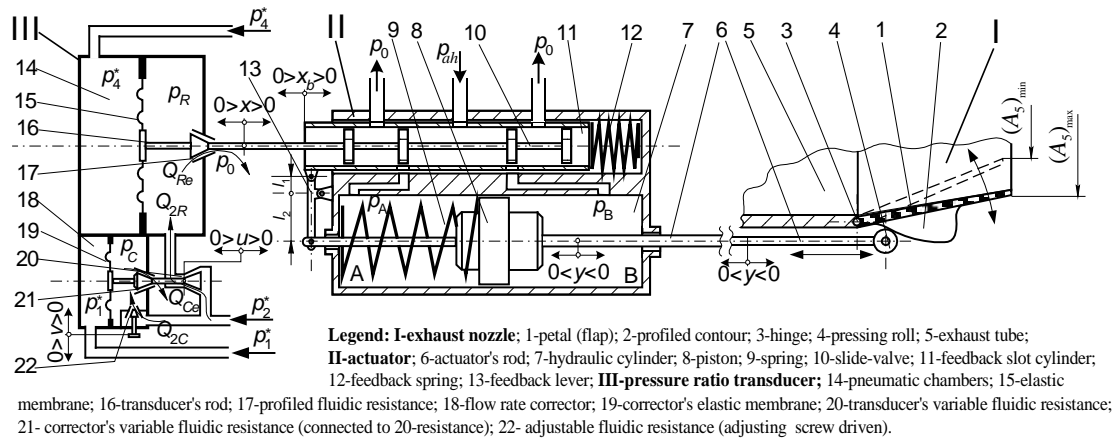


FIG. 3 Pneumatic – hydraulic ENCU constructive and operational diagram [7]

ENCU's simplified mathematical model, as determined in [7], consists of linearised adimensional equations of pressure ratio's transducer with flow rate corrector (the pneumatic component), of hydraulic actuator and, obviously, of nozzle's opening:

$$\bar{p}_C = \frac{1}{\tau_c s + 1} [k_{2C} \bar{p}_2^* - k_{uC} (\tau_u s + 1) \bar{u}], \quad (9)$$

$$\bar{p}_1^* - \bar{p}_C = \frac{1}{k_{pu}} \bar{u}, \quad (10)$$

$$\bar{p}_R = \frac{1}{\tau_R s + 1} [k_{2R} \bar{p}_2^* + k_{uR} \bar{u} - k_{xR} (\tau_x s + 1) \bar{x}], \quad (11)$$

$$\bar{p}_4^* - \bar{p}_R = \frac{1}{k_{px}} \bar{x}, \quad (12)$$

$$\bar{y} = \frac{1}{\tau_s s + \rho_s} \bar{x}, \quad (13)$$

$$\bar{A}_5 = k_{yA} \bar{y}, \quad (14)$$

with the notations explained in [7]:

$$\begin{aligned} \tau_s &= \frac{S_p y_0}{\mu_b x_0} \sqrt{\frac{\rho_h}{p_{ah} - p_0}}, \quad \rho_s = \frac{k_{e9} y_0}{2S_p \sqrt{p_{ah} - p_0}} + \frac{y_0}{x_0} \frac{l_1}{l_2}, \quad k_{yA} = \frac{y_0}{A_{50}} \left(\frac{\partial A_5}{\partial y} \right)_0, \quad \tau_R = \frac{\beta V_{R0}}{k_{pR}}, \\ \tau_x &= \frac{S_{mR}}{2k_{Rx}}, \quad k_{2R} = \frac{k_{R2} P_{20}^*}{k_{pR} P_{R0}}, \quad k_{xR} = \frac{k_{Rx} x_0}{k_{pR} P_{R0}}, \quad k_{px} = \frac{S_{mR} P_{R0}}{k_{e1} x_0}, \quad k_{pR} = \frac{A_{170} K_a}{\sqrt{T_{20}^*}}, \quad k_{R2} = \frac{A_{22} K_a}{\sqrt{T_{20}^*}}, \\ \tau_C &= \frac{\beta V_{C0}}{k_{pC}}, \quad k_{Rx} = \frac{\pi K_a P_{R0}}{2\sqrt{T_{20}^*}} \tan \alpha [x_0 \tan \alpha - (d_2 - d_1)], \quad k_{2C} = \frac{k_{C2} P_{20}^*}{k_{pC} P_{C0}}, \\ k_{C2} &= \frac{A_{21} K_a}{\sqrt{T_{20}^*}}, \quad k_{uC} = \frac{k_{Cu} u_0}{k_{pC} P_{C0}}, \quad \tau_u = \frac{S_{mC}}{2k_{Cu}}, \quad k_{pu} = \frac{S_{mC} P_{C0}}{k_{e2} u_0}, \quad k_{pC} = \frac{A_{c0} K_a}{\sqrt{T_{20}^*}}, \\ k_{Cu} &= \frac{\pi K_a P_{C0}}{2\sqrt{T_{20}^*}} \tan \alpha_2 [u_0 \tan \alpha_2 - (d_4 - d_3)], \quad k_{uR} = \frac{\pi K_a P_{R0}}{2\sqrt{T_{20}^*}} \tan \alpha_3 [u_0 \tan \alpha_3 - (d_6 - d_5)], \\ \chi_a &- \text{air's adiabatic exponent, } R_a - \text{air's gas constant, } K_a = \sqrt{\frac{\chi_a}{R_a} \left(\frac{2}{\chi_a + 1} \right)^{\frac{\chi_a + 1}{\chi_a - 1}}}. \end{aligned} \quad (15)$$

Based on the above-presented model, the ENCU's block diagram with transfer functions was built up and depicted in Fig. 4.

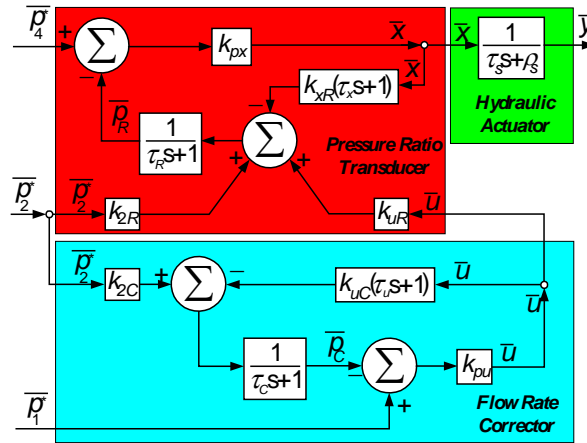


FIG. 4 Pneumatic-hydraulic ENCU block diagram with transfer functions

ENCU has three inputs (the pressure in front of the compressor p_1^* , behind the compressor p_2^* and behind the turbine p_4^*) and one output (actuator's rod displacement y). In terms of p_1^* , it brings the influence of the aircraft (and engine) flight regime, so, for constant flight regime $\bar{p}_1^* = 0$ its influence becomes irrelevant; the other ENCU's inputs are, in fact, aircraft engine's outputs, so ENCU brings another feedback inside engine's mathematical model.

5. AIRCRAFT ENGINE CONTROL ARCHITECTURE

Any aircraft jet engine has its own control system, more or less complex, depending on its architecture, its level of performance and its specific field of use. The embedding of an ENCU into a certain control architecture depends on its own operational properties (such as its inputs parameters, which often are other engine's outputs).

An aircraft jet-engine, as controlled object, is a MIMO system ([5], [9], [11]), whose control parameters (inputs) are: the fuel flow rate (for the basic engine and for the afterburning, if operational) and the nozzle's opening. Other inputs may appear, for example if the engine is fitted with thrust augmentation system through coolant injection, when the coolant flow rate may become an input parameter too.

However, from pilot's point of view, the engine is a SISO, which has a single input – the power lever angle (throttle's position) and a single output – the thrust. So, any control architecture must use sub-controllers, which must give the level of the main inputs (fuel flow rate and nozzle opening) with respect to engine's throttle position (PLA).

ENCU's embedding into a control architecture is formally depicted in Fig. 5.

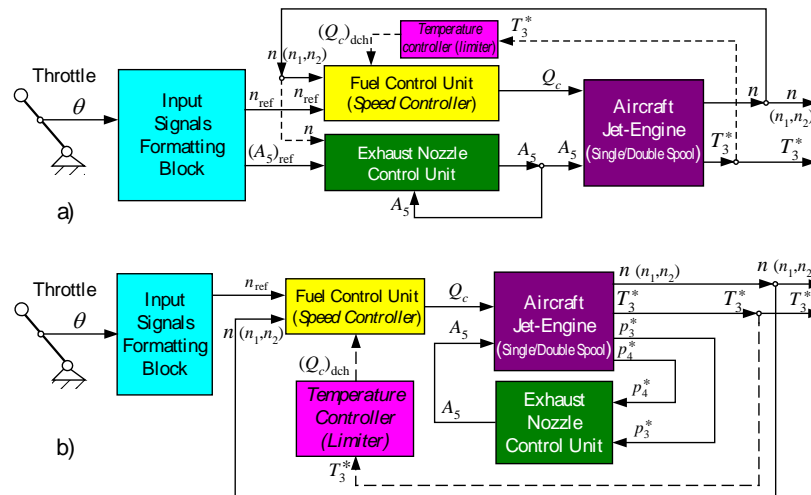


FIG. 5 Jet-engine's embedded control architecture

The hydro-mechanical ENCU's embedding is much more simple, as Fig. 5.a) shows, because it is necessary only a simple signal forming block for the tracking of PLA – θ , while the pneumatic-hydraulic ENCU's embedding is more complex, as Fig. 5.b) shows, because of the presence of the pressure intakes for the input pressures (p_2^* and p_4^*), which are, in fact, engine's secondary outputs.

Along with the nozzle controllers, there must be also fuel flow rate controllers (fuel control units – FCU), which, as shown in [11], have effects both on the engine speed(s), as well as on the temperature of the combustion chamber. The operating principles of any FCU are based on the control of the engine speeds, having these as quantities used in the control loops (thereby creating internal feedbacks).

The speed control is based on the fact that the thrust of a jet-engine is always proportional to its spool rotational speed and, as long as the thrust is impossible to be correctly measured and inserted into a control loop, the spool speed can successfully replace the thrust, being a relevant and easily measurable parameter ([9], [10]). Consequently, control units embedding has different complexity levels; for example: a two-spool jet-engine's FCU has the fuel pump driven by the high-pressure shaft, while the speed transducer is connected to the low-pressure shaft, which makes of both engine's speeds important controlled parameters (as Fig. 5 highlights).

One has chosen for the study a FCU similar to the one described and studied in [5] designed for a double spool jet engine consisting of: a main fuel pump (driven by the high pressure spool), a hydraulic-type actuator (fitted with rigid feedback) and a speed transducer (driven by the low-pressure spool). This model of FCU may be used for turbofans too.

Following equation is describing the mathematical model of the FCU and in Fig. 6 is depicted FCU's block diagram with transfer functions:

$$\bar{Q}_c = k_{pn} \bar{n}_2 - \frac{k_{py} k_{es}}{\tau_s s + \rho_s} \bar{n}_1 + \frac{k_{py} k_u k_{u\theta}}{\tau_s s + \rho_s} \bar{\theta}, \quad (16)$$

which may be used for quantitative determinations in the following form

$$\bar{Q}_c(t) = 0.5 \bar{n}_2(t) - \frac{0.274 \bar{n}_1(t) - 0.782 \bar{\theta}(t)}{0.114s + 0.815}. \quad (17)$$

It must be stated that, for single-spool jet-engines, the fuel pump and the speed transducer are driven by the engine's shaft through engine's gear, so they both have the same rotational speed; consequently, for such an FCU $\bar{n}_1 = \bar{n}_2 = \bar{n}$ and its mathematical model becomes:

$$\bar{Q}_c = \frac{(k_{pn} \tau_s s + k_{pn} \rho_s - k_{py} k_{es}) \bar{n} + k_{py} k_u k_{u\theta} \bar{\theta}}{\tau_s s + \rho_s}, \quad (18)$$

$$\text{or } \bar{Q}_c(t) = \frac{(0.057s + 0.1335) \bar{n}(t) + 0.782 \bar{\theta}(t)}{0.114s + 0.815}. \quad (19)$$

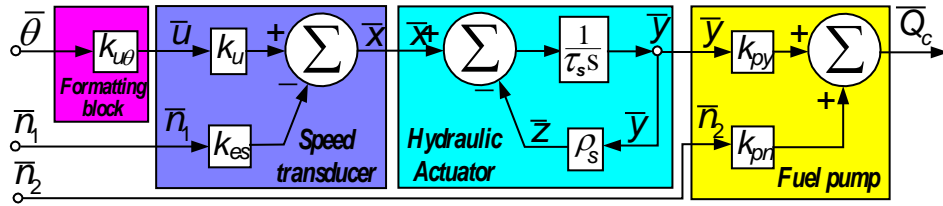


FIG. 6 Block diagram with transfer functions of the fuel control unit [5]

Whatever the architecture of the jet-engine control system, there must also exist an auxiliary control unit to limit the combustor temperature to an admissible value (as Fig. 5 shows), which, however, also acts on the fuel's mass flow rate (through the additional discharge $(Q_c)_{dch}$ flow), so it will somehow be integrated into the FCU.

Both embedded control systems depicted in Fig. 5 were studied for three types of jet engines: a) a single-spool single-jet engine (SJE); b) a two-spools single-jet engine (TJE); c) a low by-pass turbofan (also a two-spools engine, TFE).

For quantitative determinations one has used for each one of the above-presented engines the equations established in [5] and [11], as follows:

$$\text{-for SJE: } \bar{n}(t) = \frac{1.2606 \bar{Q}_c(t) + 0.476 \bar{A}_5(t)}{2.0859s + 5.1015}, \quad (20)$$

$$\bar{T}_3^*(s) = \frac{(1.3799s + 2.3888) \bar{Q}_c(t) + (0.339s + 1.211) \bar{A}_5(t)}{2.0859s + 5.1015}, \quad (21)$$

$$\text{-for TJE: } \bar{n}_1(t) = \frac{(0.061s + 0.174) \bar{Q}_c(t) + (0.027s + 0.118) \bar{A}_5(t)}{0.1395s^2 + 0.761s + 1.227} \quad (22)$$

$$\bar{n}_2(t) = \frac{(0.102s + 0.351) \bar{Q}_c(t) + 0.1081 \bar{A}_5(t)}{0.1395s^2 + 0.761s + 1.227}, \quad (23)$$

$$\bar{T}_3^*(t) = \frac{(0.04s^2 + 0.0217s + 0.198)\bar{Q}_c(t) + (0.054s + 0.223)\bar{A}_5(t)}{0.1395s^2 + 0.761s + 1.227}, \quad (24)$$

$$\text{-for TFE: } \bar{n}_1(t) = \frac{(0.208s + 0.341)\bar{Q}_c(t) + (0.274s + 0.242)\bar{A}_5(t)}{0.414s^2 + 4.181s + 3.377} \quad (26)$$

$$\bar{n}_2(t) = \frac{(0.294s + 0.514)\bar{Q}_c(t) + (0.412s + 0.366)\bar{A}_5(t)}{0.414s^2 + 4.181s + 3.377}, \quad (27)$$

$$\bar{T}_3^*(t) = \frac{(0.018s^2 + 0.194s + 0.285)\bar{Q}_c(t) + (0.382s + 0.436)\bar{A}_5(t)}{0.414s^2 + 4.181s + 3.377}. \quad (28)$$

It can be seen that the influence of the exhaust nozzle opening is different for each type of engine, so incorporating the ENCU into the control system is more complex the more complex the engine design.

6. COMPARISON BETWEEN CONTROL SYSTEMS' BEHAVIORS

Embedded control systems' quality was estimated studying their step responses. For comparison, any studied jet-engine was considered, alternately, as fitted with both types of nozzle (hydro-mechanical HMEN and pneumo-hydraulic PHEN). Any engine has, in fact, a single input (see Fig. 5), which is the PLA-parameter $\bar{\theta}$, so one has considered for study PLA step input (assumed as a sudden throttle displacement, from idle to maximum). One has also neglected the other possible input parameter \bar{p}_1^* , which, otherwise, gives the influence of the flight regime.

As main output parameters one has selected engines' spool rotational speed parameters (\bar{n} for the single spool single-jet engine SJE, while for double spool engines TJE and TFE - \bar{n}_1 - low pressure spool speed and \bar{n}_2 - high pressure spool speed); a relevant secondary output parameter was also considered for study – the combustion chamber's temperature parameter \bar{T}_3^* .

For quantitative determinations one has used the formulas (8), (18) and (19) to (28). Simulation results are graphically depicted in Fig. 7 – for SJE, in Fig. 8 – for TJE, while in Fig. 9 – for TFE. Figures a) are reserved for engines' speed(s) behaviors, while figures b) show temperatures' behaviors.

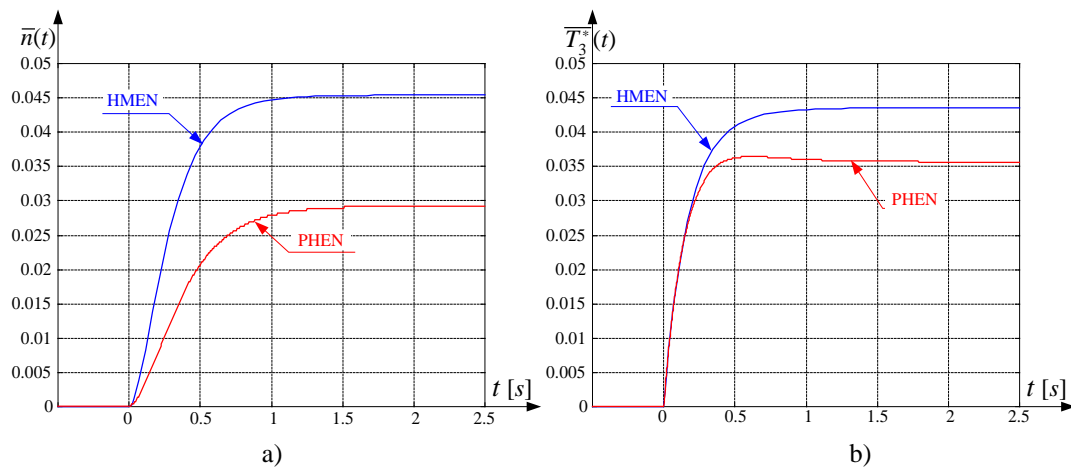


FIG. 7 Step responses of speed and temperature parameters for a single-spool single-jet engine SJE

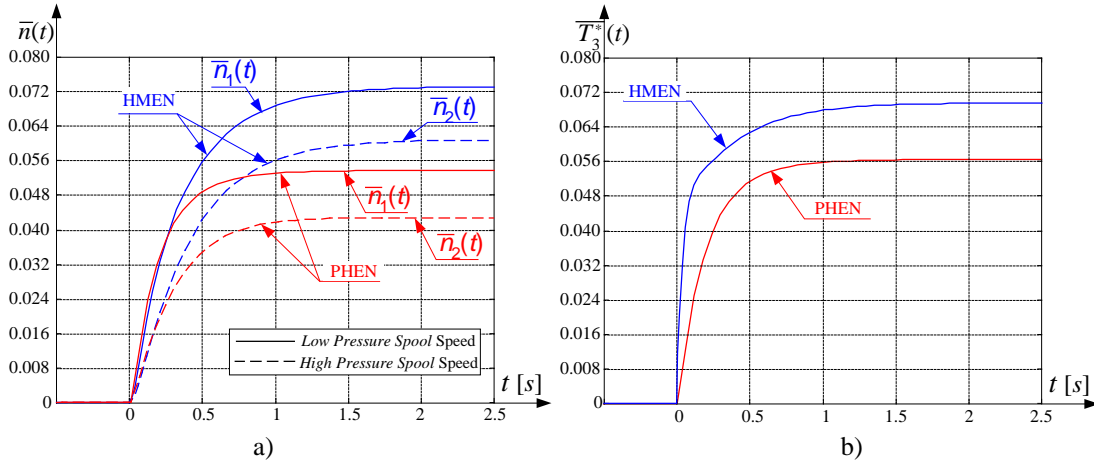


FIG. 8 Step responses of speed and temperature parameters for a two spools single-jet engine THE

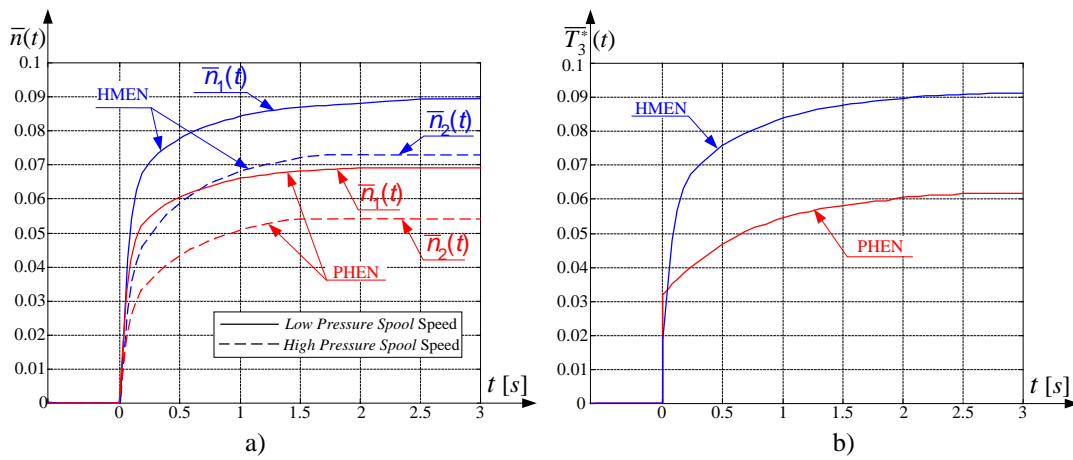


FIG. 9 Step responses of speed and temperature parameters for a low by-pass turbofan TFE

CONCLUSIONS

As all above-presented figures show, whatever the engine and whatever the nozzle version, the embedded control systems ensure asymptotically stable behavior of the engines, with settling times and static errors of acceptable values. However, there are certain differences between the behavior of the two types of equipment (from static error and settling times values point of view), which, highlighted, lead to conclusions regarding which nozzle controller is recommended for a certain type of jet-engine.

One has studied two different ENCUs as part of embedded control systems for different jet-engines (single-spool or twin-spool single-jet aircraft engines).

For a SJE, the use of HMEN produces higher values of the static errors (both for the speed and for the combustor's temperature parameters) than PHEN, but lower settling times values. In addition, the use of PHEN produces a small initial temperature overshoot (as Fig. 7.b) shows), which could be a disadvantage, although the subsequent stabilization is still asymptotic. A possible cause might be the presence of the pneumatic equipment.

As for both twin-spool engines (TJE and TFE), figures 8 and 9 show for all studied parameters similar behaviors. For the two-spool single-jet engine (TJE), fig. 8 shows that, from spools' speed point of view, HMEN offers smaller static errors (5.4% for n_1 and 4.8% for n_2) than PHEN (9% for n_1 and 6.8% for n_2) and smaller settling times (1.5 s,

smaller than 2 s); combustor temperature parameter has smaller static error for PHEN (5.6%) than for HMEN (7%), but near same settling times (around 1.5 s).

For the low-bypass turbofan (twin-spool-type too), figures 9 prove high similarity to TFE from spool speeds point of view, but higher static errors and settling times. For \bar{n}_1 HMEN offers 9% static error and 2.6 s settling time, while for \bar{n}_2 - 7% static error and 1.7 s settling time, comparing to PHEN, where \bar{n}_1 has 6.8% static error and 1.8 s settling time and

\bar{n}_2 has 5.4% static error and 1.4 s settling time; temperature parameter has, in both cases, initial sudden increases (smaller for HMEN), but asymptotic stabilization, with 9.2% static error for HMEN and 6.3% for PHEN and similar settling times (2.7 s for HMEN and 2.5 s for PHEN).

As a final conclusion, it can be stated that PHEN offers better performance than HMEN to the engine it equips, especially for twin-spool engines, these becoming faster when accelerating and stabilizing at values of the controlled parameters closer to those assumed by design and calculation.

However, the final decision belongs to the engine designer, who must also take into account the aspects of efficiency and reliability in operation and, last but not least, the benefit/cost ratio, as well as the aspects related to maintenance.

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CONSIDERATIONS FOR OPTIMIZING THE FLIGHT PERFORMANCE OF miniUAVs

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DOI: 10.19062/2247-3173.2023.24.24

Abstract: Unmanned aerial vehicles benefit from a series of mature technologies that transform them into data acquisition, processing and dissemination tools with high levels of impact on areas of interest and great utility for users.

The paper exposes the stages of analysis regarding the upgrade process of UAV (ATM-1) from the variant of equipping a target aircraft to a superior variant that can be used for data collection, from areas of interest, in the form of static or dynamic images. The proposed variant has implications both on the air vector balance and on the performance of use due to the new onboard equipment.

Keywords: ATM-1, aerodynamic performances, autopilot, XFLR5 freeware

Symbols and acronyms

AGL	Above Ground level	LLT	Lifting line theory
AoA	Angle of Attack	LOS	Line of Sight
BEC	Battery Eliminator Circuit	MAC	Main Aerodynamic Chord
BLOS	Beyond Line of Sight	PDB	Power Distribution Board
C_b, C_d, C_m	Aerodynamic coefficient	Rx / Tx	Receiver / Transmitter
C2	Command and control	VLM	Vortex Lattice Method
ESC	Electronic Speed Control	XFLR5	Xfoil low Reynolds
FPV	First Person View		

1. INTRODUCTION

The paper focuses on the aerodynamic aspects of the upgrade process applied to an aircraft by exposing the stages of analysis applied to an UAV (ATM-1) from the variant of equipping a target aircraft to a superior variant that can be used for sampling data from areas of interest, in the form of static or dynamic images. The proposed aerodynamic variant has implications both on the balance of the air vector and on the performance of use due to the new onboard equipment.

NATO UAS CLASSIFICATION						
Class	Category	Normal Employment	Normal Operating Altitude	Normal Mission Radius	Primary Supported Commander	Example Platform
Class II (> 600 kg)	Strike/Combat**	Strategic/National	Up to 65,000 ft	Unlimited (BLOS)	Theatre	Reaper
	MALE	Strategic/National	Up to 65,000 ft	Unlimited (BLOS)	Theatre	Global Hawk
	MALE	Operational/Theatre	Up to 45,000 ft	Unlimited (BLOS)	JTF	Heron
Class I (150 kg-600 kg)	Tactical	Tactical Formation	Up to 18,000 ft AGL	200 km (LOS)	Brigade	Hermes 450
Class I (< 150 kg)	Small (<15 kg)	Tactical Unit	Up to 5,000 ft AGL	50 km (LOS)	Battalion, Regiment	Scan Eagle
	Mini (<15 kg)	Tactical Sub-unit (manual or hand launch)	Up to 3,000 ft AGL	Up to 25 km (LOS)	Company, Platoon, Squad	SkyLark
	Micro** (<66 J)	Tactical Sub-unit (manual or hand launch)	Up to 200 ft AGL	Up to 5 km (LOS)	Platoon, Squad	Black Widow

a b
FIG. 1 UAV classification, a. civilian classification, b. NATO classification [1]

A series of specialized paper [1, 11, 12] offer classifications according to relevant criteria such as: total mass, flight duration/distance or from the point of view of use, the most relevant classifications are shown in Fig. 1.

The study stages include aspects of: description of the miniUAV variants (ATM-1 and ATM-1AP /autopilot); the XFLR5 freeware tool; comparative 2D (airfoil) and 3D aerodynamic analyzes of proposed aerodynamic concepts.

2. RESOURCES

2.1. Target drone performances.

The ATM-1 target aircraft (see Fig. 2) is based on a simple monoplane aerodynamic concept with a mid-wing, classic wing and fixed wing landing gear. Its construction is modular for both easy containerized transport and minimal time for operation in the areas of interest (pre-assembled fuselage and engine with tail-planes and landing gear, two half-planes).

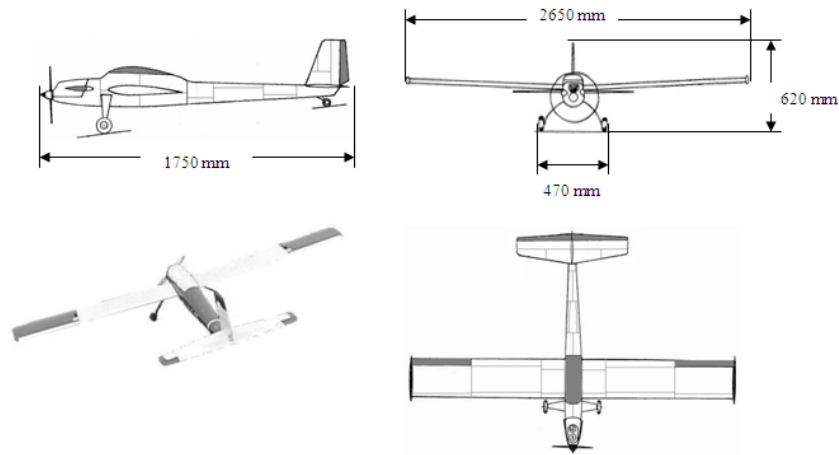


FIG. 2 Target ATM -1 [2]

The main characteristics and flight performance, in the basic version, are highlighted in Table 1.

Table 1 ATM-1 features [2, 8]

Features	Value	Features	Value
Span / Length	2650 mm / 1750 mm	Flight autonomy	0,6 h
Chord	300 mm	Flight distance	2800 m
Wing area	0,78 m ²	Ceiling	2800 m
Total weight	8 kg	Engine	26 cm ³ / 1,7 CP

2.2. ATM 1N target drone. Upgrade proposal.

For an upgrade process with a relevant performance increase, we propose a series of equipment (propulsion and radio electronics) that generate the values of new constructive characteristics highlighted in Table 2, [3, 4, 5, 8, and 9].

Table 2 Equipment and features proposal for ATM-1AP

Features	Value	Features	Value
Span / Length	2650 mm / 1750 mm	Autopilot	Pixhawk PX4
Wing area	0,78 m ²	Meteo sensor	uRad monitor A3
Total weight / payload	7 kg / 4kg	C2 system	FR Sky Taranis
Combustion engine	26 cm ³ / 2,95 CP	FPV camera	Fixed / mobile

Upgrade equipment has minimal aerodynamic implications due to forward resistance but involves centering optimizations depending on the flight range (fuel reserve). Figure 2 provides a global view of the connections and system elements on board the ATM-1AP/autopilot UAV.

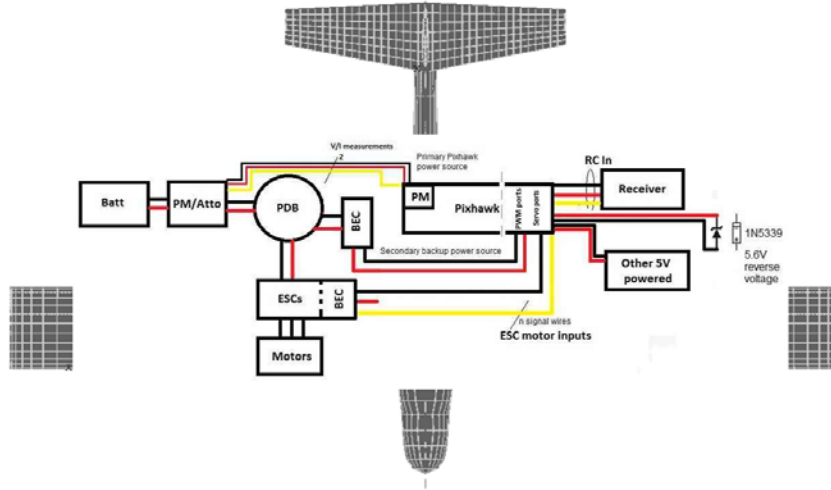


FIG.2 ATM-1AP connection diagram, [7]

2.3. Method and tools analysis

To support the upgrade process, we used the XFLR5 freeware tool that offers geometric parameterization and aerodynamic analysis modules, the latest version containing numerical calculation modules, the most relevant being: 2D design and analysis mode (aerodynamic profiles) and 3D design and analysis mode (wing, aircraft). It should be noted that these numerical analyzes are specific to the speeds and no. Low Reynolds based on LLT (lifting line theory), VLM (vortex lattice method) and 3D panel calculation methods. [6, 8].

3. PERFORMANCES ANALYSIS

3.1. Purpose, objectives and conditions of analysis

The purpose of the numerical multicriteria analysis focuses on determining the implications of the upgrade process on the overall performance of the UAV. The pursued objectives want the quantification of the analyzed parameters according to the selected analysis conditions. The analysis matrix provides a series of relevant cases for this type of miniUAV, according to Table 3.

Table 3 The analysis matrix

UAV type	2D Analysis	3D Analysis	Mass and balancing
ATM-1	yes	yes	no
ATM-1AP	yes	yes	yes

3.2. 2D and 3D aerodynamic analyzes

a. 2D analyzes

The 2D aerodynamic analyzes are focused on the numerical simulations of the profiles used in the compared construction variants, see fig. 3, under the conditions selected from table 4.

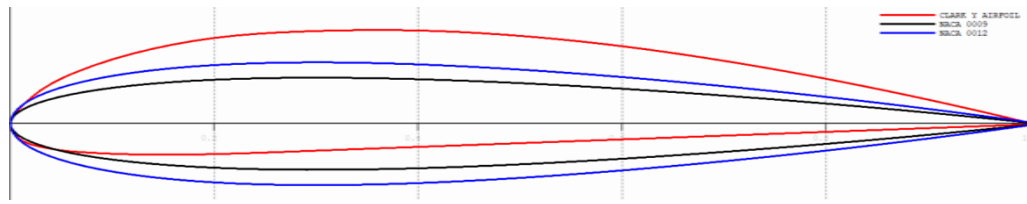


FIG. 3 The airfoils [10]

The relevant aerodynamic parameters in Fig. 4-7 (and Appendix 1) were determined by considering the viscosity effect and according to the analysis conditions in Table 4.

Table 4 The 2D analysis conditions

Condition	Value	Condition	Value
Speed	20 m/s	Iteration	100
Nr. Reynolds	400000	AoA	-15° to 15°

Figure 4 shows the variation of the lift coefficient (C_l) as a function of the angle of attack (AoA) for the analyzed profiles, due to the curvature the Clark Y profile has the highest C_l value for a fixed AoA (ex. 10°) but also a forward resistance (C_d) at the same AoA (ex.10°), see figure 5.

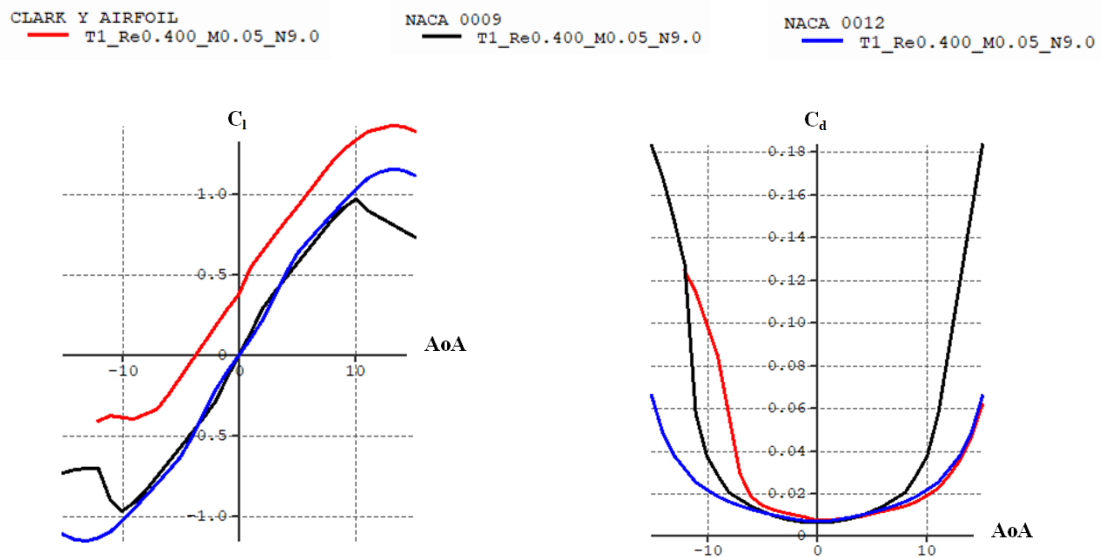


FIG. 4 C_l vs AoA

FIG. 5 C_d vs AoA

According to figure 6 we observe similar values of C_m for the symmetric profiles NACA 0009 and NACA 0012 and high values of C_m for Clark Y, values read in the range $AoA = -10^\circ \div 10^\circ$. Figure 7 shows the variation of C_l/C_d ratio vs AoA (gliding ratio) or gliding rate with high values for the Clark Y profile.

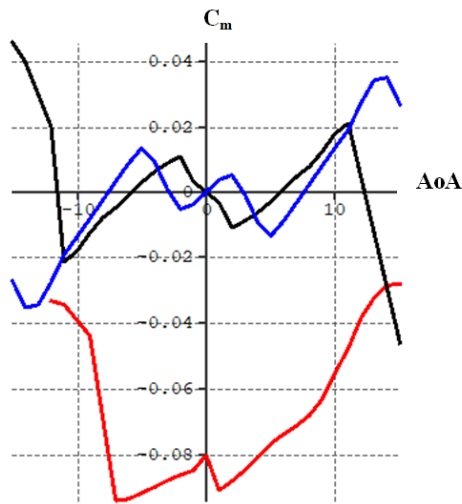


FIG. 6 C_m vs AoA

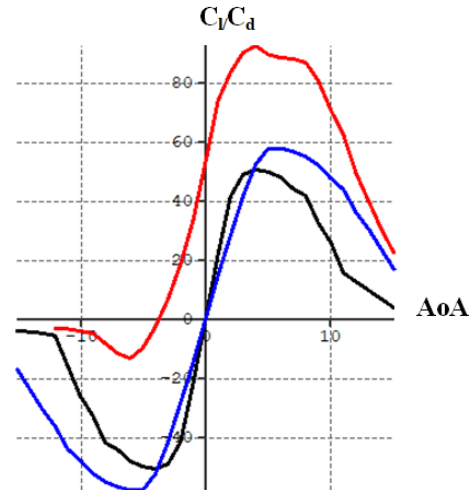


FIG. 7 C_l/C_d vs AoA

b. 3D analyzes

The values of the global geometry are similar to the ATM-1 variant, (see figure 8), the geometric configuration that was used for the initial numerical simulations, with the FPV camera nacelle mounted on the ventral side on the vertical axis passing through the leading edge of the wing. The 3D analysis conditions are recorded in Table 5.

Table 5 The 2D analysis conditions

Conditions	Value	Conditions	Value
Polar type	Fixed speed	Iterations	100
Speed	20 m/s	AoA	-15° to 15°
Type analysis	VLM	Nr. Reynolds	400000
Boundary conditions	Dirichlet		

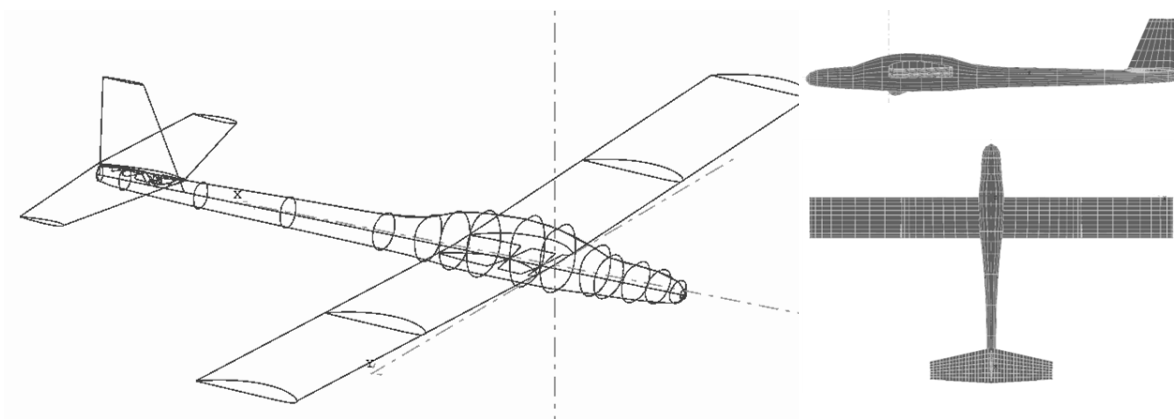


FIG. 8 ATM-1AP upgrade

In the graphs in Fig. 9-12, a series of variations of the numerical values of the aerodynamic coefficients can be observed depending on the angle of attack (AoA). In Fig.9, as expected, implications on the increase in forward resistance (C_d -AoA) and according to Fig. 10 implications on the pitching moment (C_m -AoA) are revealed.

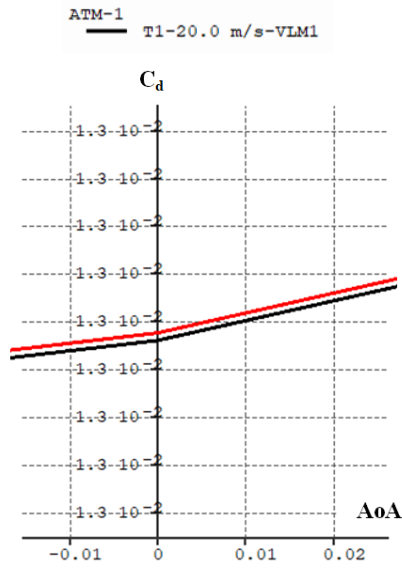


FIG. 9 C_d vs AoA

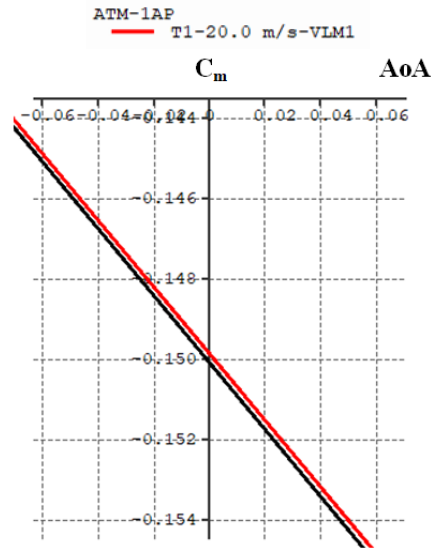


FIG. 10 C_m vs AoA

The presence of the FPV nacelle indicates a minimal influence for the roll coefficient (Fig. 11) and the yaw moment variation is maximum around the value $AoA=10^\circ$ (Fig. 12).

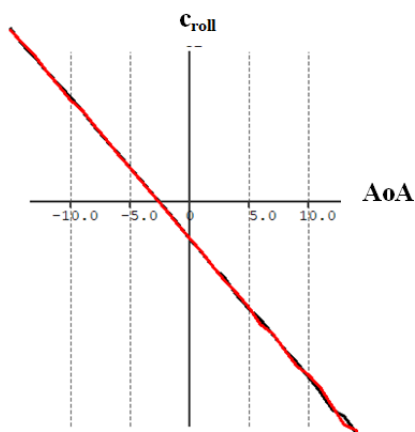


FIG. 11 C_{roll} vs AoA

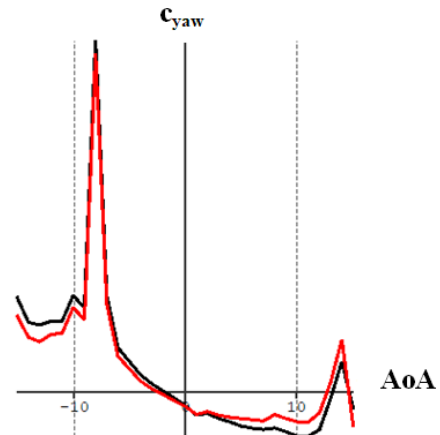


FIG. 12 C_{yaw} vs AoA

c. Balancing

The mass estimate for the onboard equipment is highlighted in Table 6.

Table 6 The mass estimate (kg)

Nr. crt.	Elements	ATM-1	ATM-1AP
1	Wing	2,2	2,2
2	Fuselage	2,3	2,3
3	Horizontal tail	0,3	0,3
4	Vertical tail	0,2	0,2
5	Engine	1,7	1
6	FPV camera	0	0,05
7	Autopilot + receiver	0,3	0,1
8	Fuel	1	1
9	Battery	0	0,25
	Total	8,0	7,40

The arrangement of the masses on the air vector can be seen in figure 11, and the numerical data in annex 3. When arranging the masses of the equipment, both the availability of the volumes of the front fuselage (for the tank) and of the rear fuselage for the autopilot were taken into account.

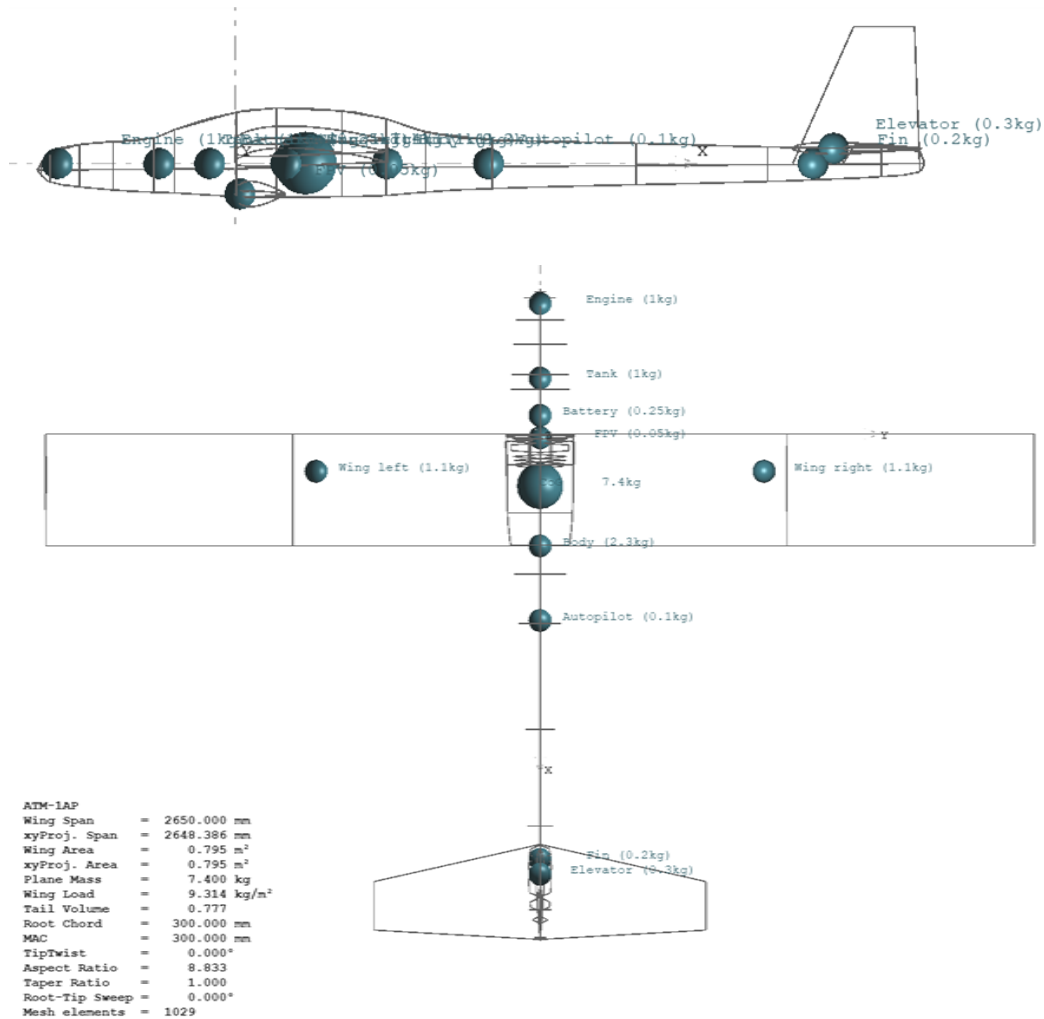


FIG. 11 ATM-1AP balancing

CONCLUSIONS

The implications of the ATM-1 UAV upgrade process require multiple iterations on aerodynamic and centerline optimization. The paper presented an aerodynamic optimization and centering cycle, which can form a foundation for completing the upgrade approach. Accurate digital reproduction of the geometry and layout of the inertial values can converge to results similar to those of the experimental stages. Mounting the FPV camera nacelle on the ventral side has minimal implications on aerodynamic performance, however an optimization of stability through the layout of the equipment is considered.

The optimal arrangement of the equipment determines the maximization of the UAV flight performances, correlated with the balancing limits determined by the fuel consumption or the release of some mass elements necessary for the missions in the areas of interest.

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Annex 1. 2D analysis. Aerodynamic coefficients.

Calculated polar for: NACA 0009												Calculated polar for: CLARK Y AIRFOIL											
1 Reynolds number fixed						Mach number fixed						1 Reynolds number fixed						Mach number fixed					
alpha	Cl	CD	Cl/D	Cm	Cm0	alpha	Cl	CD	Cl/D	Cm	Cm0	alpha	Cl	CD	Cl/D	Cm	Cm0						
-15.000	-0.7397	0.12038	6.1470	0.1700	0.0000	-15.000	-0.7397	0.12038	6.1470	0.1700	0.0000	-15.000	-0.7397	0.12038	6.1470	0.1700	0.0000						
-12.000	-0.7183	0.11975	6.0856	0.1698	0.0000	-12.000	-0.7183	0.11975	6.0856	0.1698	0.0000	-12.000	-0.7183	0.11975	6.0856	0.1698	0.0000						
-9.000	-0.7012	0.11954	6.0486	0.1697	0.0000	-9.000	-0.7012	0.11954	6.0486	0.1697	0.0000	-9.000	-0.7012	0.11954	6.0486	0.1697	0.0000						
-6.000	-0.6879	0.11950	6.0341	0.1697	0.0000	-6.000	-0.6879	0.11950	6.0341	0.1697	0.0000	-6.000	-0.6879	0.11950	6.0341	0.1697	0.0000						
-3.000	-0.6780	0.11950	6.0300	0.1697	0.0000	-3.000	-0.6780	0.11950	6.0300	0.1697	0.0000	-3.000	-0.6780	0.11950	6.0300	0.1697	0.0000						
0.000	-0.6710	0.11950	6.0260	0.1697	0.0000	0.000	-0.6710	0.11950	6.0260	0.1697	0.0000	0.000	-0.6710	0.11950	6.0260	0.1697	0.0000						
3.000	-0.6669	0.11950	6.0220	0.1697	0.0000	3.000	-0.6669	0.11950	6.0220	0.1697	0.0000	3.000	-0.6669	0.11950	6.0220	0.1697	0.0000						
6.000	-0.6650	0.11950	6.0180	0.1697	0.0000	6.000	-0.6650	0.11950	6.0180	0.1697	0.0000	6.000	-0.6650	0.11950	6.0180	0.1697	0.0000						
9.000	-0.6656	0.11950	6.0140	0.1697	0.0000	9.000	-0.6656	0.11950	6.0140	0.1697	0.0000	9.000	-0.6656	0.11950	6.0140	0.1697	0.0000						
12.000	-0.6674	0.11950	6.0100	0.1697	0.0000	12.000	-0.6674	0.11950	6.0100	0.1697	0.0000	12.000	-0.6674	0.11950	6.0100	0.1697	0.0000						
15.000	-0.6701	0.11950	6.0060	0.1697	0.0000	15.000	-0.6701	0.11950	6.0060	0.1697	0.0000	15.000	-0.6701	0.11950	6.0060	0.1697	0.0000						

Annex 2. 3D analysis. Aerodynamic coefficients.

NACA name: 4415												Plane name: 4415											
1 Reynolds number fixed						Mach number fixed						1 Reynolds number fixed						Mach number fixed					
alpha	Cl	CD	Cl/D	Cm	Cm0	alpha	Cl	CD	Cl/D	Cm	Cm0	alpha	Cl	CD	Cl/D	Cm	Cm0						
-15.000	-0.7397	0.12038	6.1470	0.1700	0.0000	-15.000	-0.7397	0.12038	6.1470	0.1700	0.0000	-15.000	-0.7397	0.12038	6.1470	0.1700	0.0000						
-12.000	-0.7183	0.11975	6.0856	0.1698	0.0000	-12.000	-0.7183	0.11975	6.0856	0.1698	0.0000	-12.000	-0.7183	0.11975	6.0856	0.1698	0.0000						
-9.000	-0.7012	0.11954	6.0486	0.1697	0.0000	-9.000	-0.7012	0.11954	6.0486	0.1697	0.0000	-9.000	-0.7012	0.11954	6.0486	0.1697	0.0000						
-6.000	-0.6879	0.11950	6.0341	0.1697	0.0000	-6.000	-0.6879	0.11950	6.0341	0.1697	0.0000	-6.000	-0.6879	0.11950	6.0341	0.1697	0.0000						
-3.000	-0.6780	0.11950	6.0300	0.1697	0.0000	-3.000	-0.6780	0.11950	6.0300	0.1697	0.0000	-3.000	-0.6780	0.11950	6.0300	0.1697	0.0000						
0.000	-0.6710	0.11950	6.0260	0.1697	0.0000	0.000	-0.6710	0.11950	6.0260	0.1697	0.0000	0.000	-0.6710	0.11950	6.0260	0.1697	0.0000						
3.000	-0.6669	0.11950	6.0220	0.1697	0.0000	3.000	-0.6669	0.11950	6.0220	0.1697	0.0000	3.000	-0.6669	0.11950	6.0220	0.1697	0.0000						
6.000	-0.6650	0.11950	6.0180	0.1697	0.0000	6.000	-0.6650	0.11950	6.0180	0.1697	0.0000	6.000	-0.6650	0.11950	6.0180	0.1697	0.0000						
9.000	-0.6656	0.11950	6.0140	0.1697	0.0000	9.000	-0.6656	0.11950	6.0140	0.1697	0.0000	9.000	-0.6656	0.11950	6.0140	0.1697	0.0000						
12.000	-0.6674	0.11950	6.0100	0.1697	0.0000	12.000	-0.6674	0.11950	6.0100	0.1697	0.0000	12.000	-0.6674	0.11950	6.0100	0.1697	0.0000						
15.000	-0.6701	0.11950	6.0060	0.1697	0.0000	15.000	-0.6701	0.11950	6.0060	0.1697	0.0000	15.000	-0.6701	0.11950	6.0060	0.1697	0.0000						

Annex 3. Balance export data.

```
# Mass & Inertia breakdown.
# x y z is location of item's own CG.
# Ixx... are item's inertias about item's own CG.
#
# x,y,z system here must be exactly the same one used in the .avl input file
# (same orientation, same origin location, same length units)
#
# mass      X      Y      Z      Ixx      Iyy      Izz      Ixy      Ixz      Iyz
# 0          0      0      0      126      1.75e+14      31.1      0      0      0
# 0          42.2      -4.04e-15      -60      0      0      0      0      0      0
# 0          1.23e+03      7.7e-14      30      0      0      0      0      0
# 0          1.23e+03      -1.60e-13      3025      0      0      0      0      0
# 1          -350      0      0      0.000      0.000      0.000      0.000      0.000      0.000
# 1          -150      0      0      0.000      0.000      0.000      0.000      0.000      0.000
# 0.25      -50      0      0      0.000      0.000      0.000      0.000      0.000      0.000
# 1.1      100      600      0      0.000      0.000      0.000      0.000      0.000      0.000
# 1.1      100      -600      0      0.000      0.000      0.000      0.000      0.000      0.000
# 0.05      10      0      -60      0.000      0.000      0.000      0.000      0.000      0.000
# 0.3      1.18e+03      0      30      0.000      0.000      0.000      0.000      0.000      0.000
# 0.2      1.18e+03      0      0      0.000      0.000      0.000      0.000      0.000      0.000
# 2.3      300      0      0      0.000      0.000      0.000      0.000      0.000      0.000
# 0.1      500      0      0      0.000      0.000      0.000      0.000      0.000      0.000
```

STUDY ON THE IMPACT OF AIRCRAFT AGE ON FLIGHT SAFETY FOR A MEDIUM COURIER TURBOPROP AIRPLANE

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DOI: 10.19062/2247-3173.2023.24.25

***Abstract:** This paper introduces the connection between old aircraft and flight safety as well as the present state and potential futures for managing old aircraft. Age can be managed in two ways: retiring the aircraft and buying a newer one, or properly sustaining aging aircraft through additional and targeted maintenance. To do this, manufacturers, maintainers, operators, and owners must work together with regulators. A good way to guarantee proper maintenance is through continuing airworthiness programs and supplemental inspection programs. While the effects of aging on an aircraft can be detrimental to safety, they can be reduced with proper maintenance. If the operators follow the maintenance programs, current and future maintenance programs will operate as a preventative strategy to lessen the safety risk associated with aging aircraft.*

***Keywords:** aviation, critical parts, flight safety, turboprop aircraft, maintenance, reliability*

1. INTRODUCTION

This study looked at present and potential strategies for guaranteeing the flight safety in front of aging aircraft as well as to reveal the relationship between aging aircraft and flight safety. Existing research on aircraft age was analyzed in light of safety, reliability, and statistical information. [1]

The age of an airplane cannot be determined by a single factor. The chronological age, the number of flight cycles and the number of flying hours all affect how old is an aircraft. The fact that different aircraft components age differently based on these factors makes figuring out the aircraft's age much more difficult. Certain aging processes, including fatigue, are brought on by cyclic or recurrent loading. Aircraft wings, pressurized sections, and other structural components will become fatigued as a result of flight cycles. Other processes, such degradation, corrosion, and wear, will take place over time. [2] These aging mechanisms pose a serious safety risk if they are not controlled.

Given the aforementioned factors, it is challenging to compare transport aircraft between each other. To determine if an aircraft is old, all of these variables must be taken into account. Other elements may also have an impact on how quickly aircraft age. These include the type of the aircraft operations, like the tactical flights with high maneuverability requirements, the operating environment and the maintenance on the entire system life-cycle. [3]

2. HISTORICAL ACCIDENT RELATED TO AIRCRAFT AGE

Since the age and operating histories of the aircraft became available, MIT International Center for Air Transportation (ICAT) did a historical analysis of aircraft accidents occurring between 1959 and 2012 for transport aircraft with an MTOW larger than 60,000 lbs. According to the data, there is no relationship between the likelihood of fatal accidents and aircraft age up to 27 years old. The fatal accident rate did somewhat increase above this age, but due to the older aircraft generations' short operational lifespan, the accident rate data is not statistically significant. [4]

Worries about the safety of aging air transport aircraft due to corrosion, fatigue, or Widespread Fatigue Damage (WFD) increased following the dramatic in-flight catastrophic decompression of Aloha Airlines Flight 243 in 1988. As it approached cruise altitude, the Boeing 737-200 aircraft experienced an explosive decompression. The cabin skin and supporting structure of the cabin separated from the airplane by around 5.5 meters, which caused the decompression. Despite suffering severe structural damage, the aircraft made a safe landing. One flight attendant, however, was fatally hurt during the decompression when she was swept from the aircraft. [5]



FIG. 1 Aloha Airlines flight 243 [5]

The aircraft which was involved in the disaster, was 19 years old and made 89,680 takeoffs and landings with an average flying length of 25 minutes. The majority of the aircraft's operational life had been spent flying between the Hawaiian Islands, subjecting it to an extremely corrosive environment. The design of one particular joint (or skin splice) utilized in the fuselage's construction was another factor. In addition to riveting, the junction was cold-bonded with an epoxy-impregnated scrim fabric. Instead of passing the pressure loads through the rivets, the cold bonding was intended to distribute them uniformly over the joint.

Due to this tragic catastrophe, industry became aware of the dangerous interaction between corrosion and fatigue and were launched a series of researches and regulations with the aim of diminishing the possibility of a new case.

3. ANALYSIS OF THE RELATIONSHIP BETWEEN FAILURES AND AGE FOR A MEDIUM COURIER TURBOPROP AIRPLANE

It is required to separate the aircraft into its systems in order to assess its overall reliability. The systems of an aircraft can then be divided into subsystems and then components. As an airplane ages, its various parts perform in a different way. As a result, each of these components' dependability needs to be evaluated separately. [8]

Component reliability can be predicted during design or determined from in-service failure data. It is vital to ascertain how the components interact to construct the system after each component's reliability has been proven. Knowing the system and the component failure rates is necessary for this process, which can be highly complicated. The wear-out phase begins as an aircraft reaches the end of its useful life. As components will have variable failure rates throughout this period, establishing reliability will be significantly more difficult. [9]

The components of an airplane are also regularly upgraded and replaced when they become worn out. Another component will now have the chance to reach the end of its useful life. This component will thereafter be changed or have its lifespan increased. When further extending the aircraft's life becomes uneconomical, the cycle of upgrading and replacing components will stop.

Fatigue and corrosion are the two main mechanisms that cause aircraft to age. In addition to the wiring, flight controls, powerplants, and other components, these operations typically have an impact on the structure of the aircraft. It is possible for corrosion and fatigue to operate separately or in tandem. In comparison to either process acting alone, the combination between corrosion and fatigue can accelerate aging.

Corrosion is a way that metal breaks down over time. Corrosion usually hurts the structure of an airplane, but it can also hurt electrical connectors and wires that control flight. [10]

A small fracture that appears at a site of high stress, such as a hole, notch, or flaw in the material, usually serves as the starting point for fatigue, also known as wear out. The crack will then deepen when further loads are applied. If the crack is not found and fixed, it will gradually enlarge to a critical size and fail at loads far below the material's initial strength.

The number of flight cycles, the number of flying hours, and the relationship between repetitive loading and fatigue crack propagation are all related to fatigue-induced aging. The majority of structural components, including the wings, fuselage, and engine(s), are among the aircraft parts that are prone to fatigue. [11]

For pressurized aircraft, flying sector length affects fatigue. Due to pressurisation, an aircraft structure expands as it climbs and contracts as it descends, causing fatigue. Thus, pressurisation cycles matter more than pressurisation time.

In order to find out the connection between failures and age for the subject turboprop medium courier aircraft, I analysed during two years of operating, 2018 and 2019, two airplanes, generically named as Aircraft A and Aircraft B. In this period, each aircraft flew about 1400 hours.

I prepared a centralized situation and I noticed a total number of 308 defects, of which 170 for aircraft A and 138 for aircraft B. During the study it was found that most of the defects were observed by the pilots during the flight, namely 190, of which 94 on aircraft A and 96 on B, while on the ground, the technical team of the aircraft found 118, 76 at aircraft A and 42 at aircraft B.

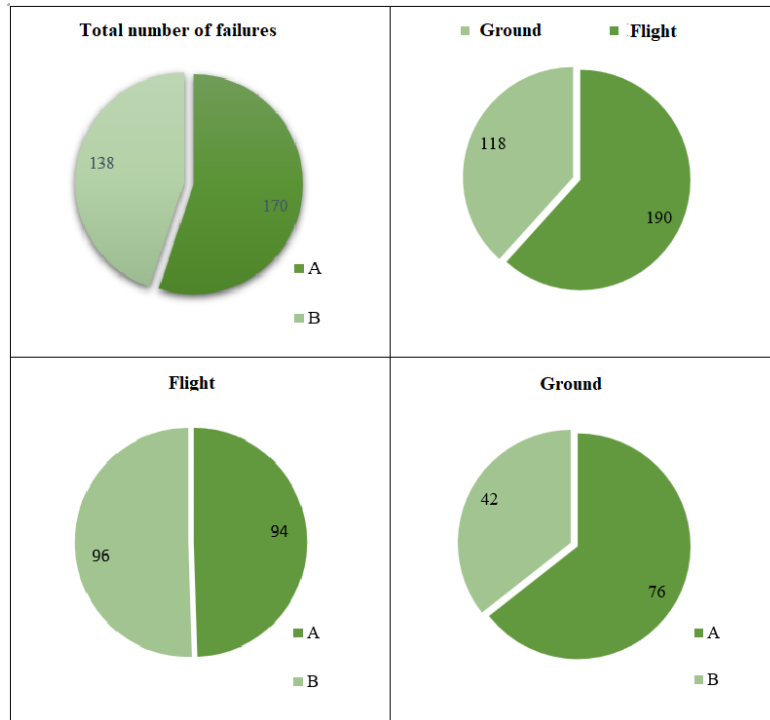


FIG. 2 Classification of defects

Out of the total of failures, were identified 21 system malfunctions, found mainly in the fuel correction and control system (TD), the negative torque detection system (NTS), but also in auxiliary equipment installed on the aircraft (lighting systems , door locks, etc.), 15 defects caused by open circuits or imperfect contacts, 15 defects due to clogging of filters or systems, 10 situations of pressure loss due to loss of tightness in the case of shock absorbers on the landing gear, parts of the entire hydraulic installation, or the parking brake, 10 situations of pressure loss due to loss of tightness in the case of shock absorbers on the landing gear, parts of the entire hydraulic installation, or the parking brake, 9 situations in which the deposits of impurities caused defects in the brake blocks, the air conditioning system and in the transmitter of the quantity of oil from the engine.

And, the most crucial information to be observed is that material failure, probably because of fatigue, accounts for 235 out of 308 incidents of faults, which suggests that the age of the aircraft may be a contributing factor. [12]

In the following paragraphs, I will classify the defects by system categories and explain the causes of their occurrence, the effectiveness of the failure detection methods and the possible ways to reduce the failure rate.

3.1. Failures of aircraft structure components

Out of a total of 54 incidents, 26 of the structure's components failures were discovered during the preliminary flight preparation (Fig. 3, a). It should be emphasized how effective are the preventive maintenance and monitoring system.

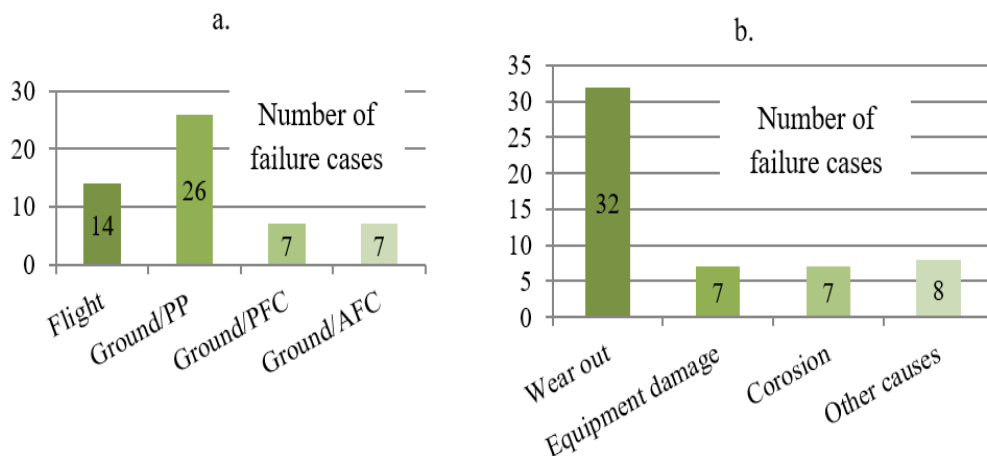


FIG. 3 Data associated to structure components failures – place/ type of preparation where these were discovered (a), causes (b)

According to 32 out of 54 cases (Fig. 3, b), fatigue is the primary cause of problems, most likely as a result of aging and vibrations that impact the cell and its aggregates. In most circumstances, the system monitoring techniques currently in use are adequate to identify errors before they materialize. In some cases, the defects are caused by the relatively low reliability of the parts, but this can be increased by replacing them with other components more reliable and lead to a decrease in the frequency of defects, even involves additional costs.

3.2. Failures of aircraft engine components

The charts (Fig. 4, a, b) show that the majority of failures happened during the flight and were primarily brought on by clogging of the injectors and filters (from the lubrication system, fuel, and hydraulics), which supports the idea that preventive maintenance and monitoring systems in technical systems of the engine type are not carried out to their full potential. Another crucial element is component wear, which is partly expected given their age and the stress of strong vibrations and temperatures inside/outside the engine, which have a significant impact on them.

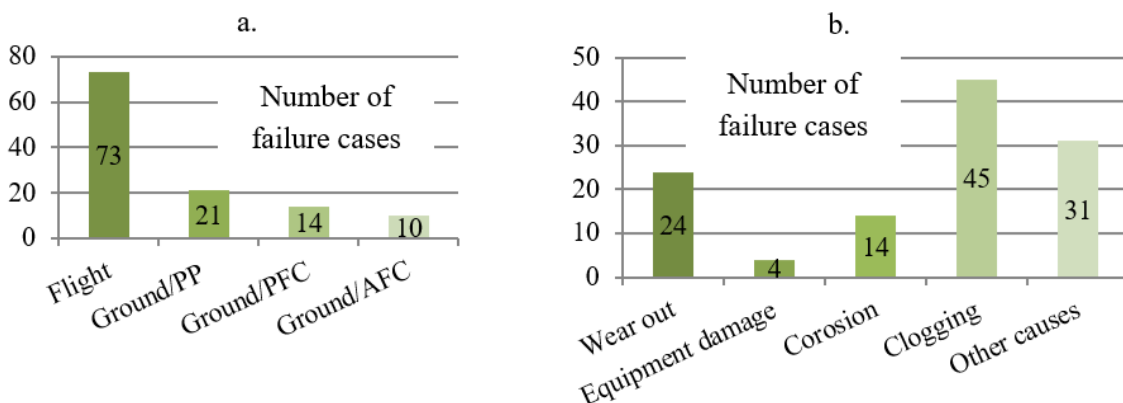


FIG. 4 Data associated to engine components failures – place/ type of preparation where these were discovered (a), causes (b)

Similar to the analysis for structural technical systems, the analysis for engine-type systems necessitates the identification of components with a high risk of failure and their replacement with others more reliable in order to assure adequate maintenance.

By applying predictive and statistical detection techniques, creating databases with flaws detected in the operation and highlighting the development of new defects, preventative measures will be simplified in order to lower the likelihood of failure.

3.3. Failures of aircraft radio components

When examining the factors that contribute to failures, it can be seen in Fig. 5 that wear accounts for the vast majority of issues, accounting for a higher percentage than other specializations. Given their age, radio parts are susceptible to vibrations with large amplitudes and prolonged exposure.

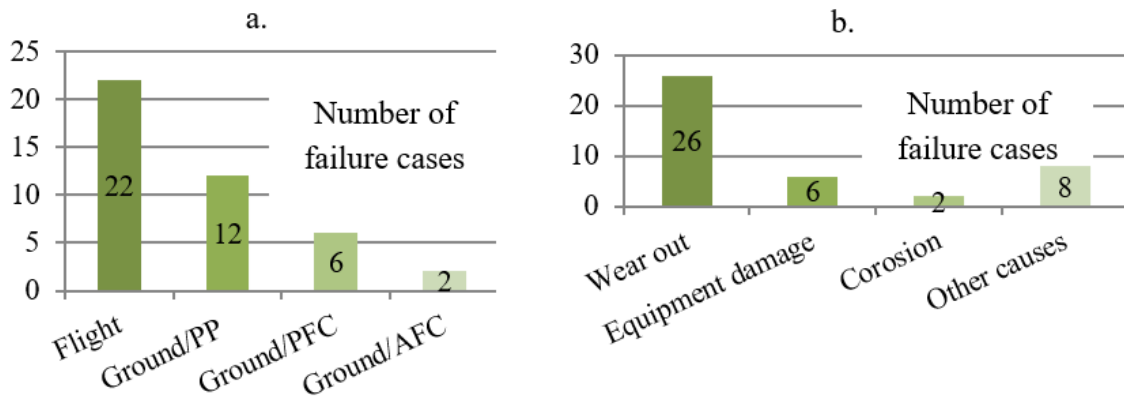


FIG. 5 Data associated to radio components failures – place/ type of preparation where these were discovered (a), causes (b)

The rule of improvement is upheld for the aircraft radio components as well, optimizing them by lowering the frequency of failures in most circumstances. This can be affected by locating the aggregates that are vulnerable to damage, wear, corrosion, moisture, etc. and by replacing them with others that have higher reliability. In order to be able to recognize the components with poorer dependability in the structure of the aggregates, detection methods can also be improved by specializing maintenance personnel.

3.4. Failures of aircraft special systems

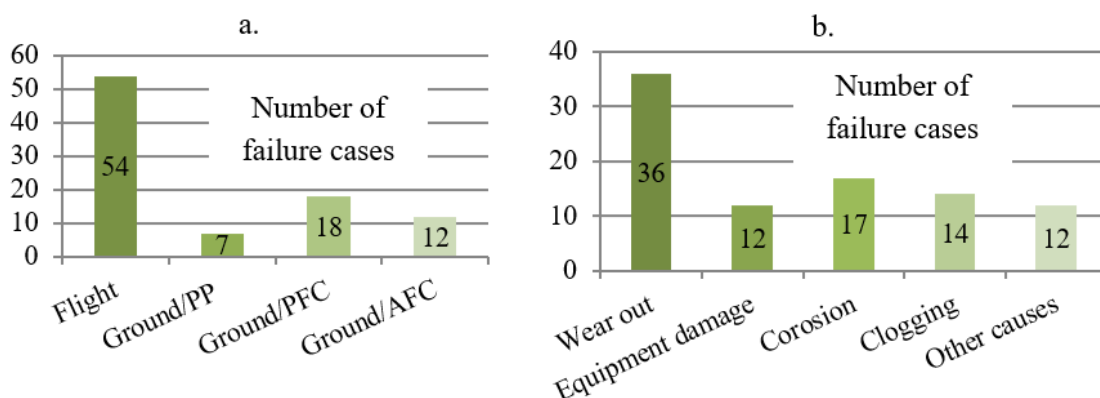


FIG. 6 Data associated to special systems failures – place/ type of preparation where these were discovered (a), causes (b)

The chart (Figure 6) shows that approximately 60% of the problems were discovered during flight, which is similar to the outcome for radio-type systems since some aggregates, like the wing and empennage deicing installation, don't begin operating until the aircraft is in the air. Preventive maintenance and the monitoring system are effective, as about a third of the faults were found during initial setup and pre-flight inspection. Therefore, streamlining preventive measures is required to lower the incidence of inflight failures.

Once more, wear is the primary cause of failures, especially given the age of the aircraft and its aggregates. Appropriate actions can be taken to impact this by identifying the aggregates that are most susceptible to wear or corrosion and replacing them with more current ones and more advanced technically.

CONCLUSIONS

At the beginning, aircraft were made to meet structural airworthiness standards for an indefinite amount of time. But at the end of the 20th century, several accidents led to an international effort to deal with problems caused by old airplane structures. The reviews that followed found a number of places where structural maintenance programs needed to be improved to make sure that older planes could still fly.

Ensuring that an aircraft's structural integrity is maintained throughout its service life is fundamental in controlling aviation safety. Maintaining an aircraft requires, beside the corrective unscheduled maintenance necessary to restore the original state of a defective system, also regularly scheduled maintenance. This type of maintenance involves investigating the structure for fatigue and corrosion, replacing life-limited components, and fixing general wear and tear. Depending on national or international requirements for a specific aircraft, maintenance schedules will vary.

Also, because age increases the complexity of an aircraft's maintenance, additional maintenance will be required in areas where fatigue or environmental deterioration has been observed to be greater than anticipated. This extra maintenance can be included in Supplementary Inspection Programmes, that should be implemented once an aircraft reaches a predetermined number of flights or hours. This programmes include additional maintenance duties and are a component of the manufacturer's maintenance guide, that specifies where to check for cracks, the equipment to be used, and the frequency of inspections.

Finally, managing aging aircraft can be accomplished in two ways: additional maintenance programmers or retirement. If maintenance programs are selected, they must be comprehensive and take into account the effects of aging on the specific aircraft model. As presented in the main part of the article, the existing preventive and corrective maintenance methods used for the subject aircraft, were sufficient to detect faults before they occur, in most of the situations. But it is important to remember that as an aircraft ages, the danger of a catastrophe rises alongside the increasing costs of maintenance.

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Correction notice for conference Proceedings AFASES 2022

Article title: NORD ATLANTIC CYCLONES TRACKS IN EUROPE AND THEIR INFLUENCE OVER AMOUNT OF PRECIPITATION RECORDED IN ROMANIA (1985-2015)

Authors: Vlad-Alexandru ILIE, Adina-Eliza CROITORU, Titus-Cristian MAN

DOI: 10.19062/2247-3173.2022.23.27

In the original article the authors are incorrectly listed. This has now been corrected as shown below:

Article title: NORD ATLANTIC CYCLONES TRACKS IN EUROPE AND THEIR INFLUENCE OVER AMOUNT OF PRECIPITATION RECORDED IN ROMANIA (1985-2015)

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