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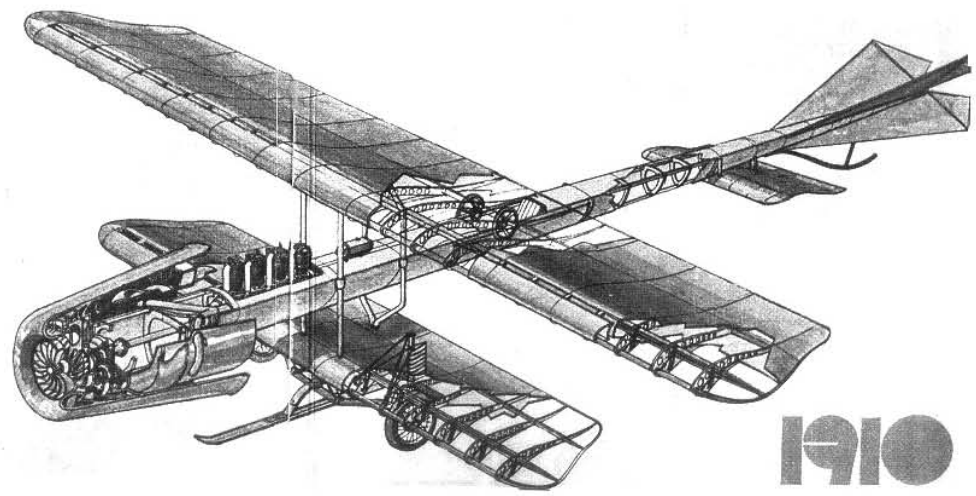

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C O N T E N T S

CONSIDERATIONS ON SEVERE METEOROLOGICAL PHENOMENA FOR AIRCRAFT FLIGHTS IN ROMANIA

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Abstract: *Weather conditions and events have a significant impact on the flight of civil or military manned or unmanned aircraft (UAV/UAS). Adverse and/or dangerous weather conditions force flights to be delayed, diverted, canceled or may cause events with undesirable consequences due to their influence on both aircraft and pilots through biometeorological implications.*

This paper presents meteorological phenomena hazardous to aircraft flight and the human factor from the perspective of methods and instruments used to detect atmospheric and environmental phenomena.

Keywords: *severe meteorological phenomena, detection methods, meteorological instruments, meteorological radar, biometeorological indicators*

Acronims

ATC	*Air traffic control*	*ESWD*	*European Severe Weather Database*
THI	*Temperature humidity index*	*HSI*	*Heat stress index*

1. INTRODUCTION

Hazardous weather conditions and events can significantly influence the evolution of an aircraft on its flight path, causing delays, diversions, cancellations of flights or the occurrence of events with serious consequences.

The most common severe weather phenomena are: severe weather that includes thunderstorms, hail, tornadoes, hurricanes and sandstorms, they can cause severe turbulence, reduced visibility, downdrafts, hail and lightning; ice and sleet deposited on aircraft structural elements can significantly reduce aerodynamic performance and loss of maneuverability, and sleet on the moving surfaces of airport bridges leads to loss of landing gear grip; fog reduces visibility and increases the risk of ground and mid-air collisions of aircraft with other aircraft or ground obstacles.

Adverse weather conditions include: strong winds that can significantly affect the trajectory and speed of the aircraft (increases the take-off/landing distance) or can affect the maneuverability of the aircraft during the flight; turbulence caused by updrafts can cause uncontrolled movements of aircraft sometimes with undesirable consequences; low-visibility clouds can significantly reduce visibility with direct implications for collision risk; heavy precipitation in the form of torrential rain or heavy snow can reduce visibility and affect aircraft flight performance including hydroplaning when landing on airport movement surfaces.

Specialized resources indicate a relevant impact of adverse weather conditions on the human body by quantifying biometeorological indicators with implications for human performance that implicitly affect aircraft performance. Adverse weather conditions can also significantly influence the physical and mental state of pilots with direct and relevant implications on flight safety and performance. The measured biometeorological indices can reveal approaches regarding the implementation of appropriate risk prevention measures. Here is a brief exposition of the most relevant biometeorological index:

- *temperature humidity index (THI), [1]*
- *the wind chill index (wind chill index), [2]*
- *the solar radiation index, [3]*
- *UV index, [4]*
- *thermal stress index / heat stress index (HSI), [5]*

Flying aircraft in adverse/hazardous weather conditions requires careful planning and continuous and constant monitoring of the weather conditions along the flight path. This uses both the consultation of weather maps and forecast charts to identify and avoid risk areas and effective communication with air traffic authorities (ATC) for emergency assistance.

2. CLIMATOLOGICAL ASPECTS OF SEVERE WEATHER IN ROMANIA

Climate data all over the world indicate that incidence of severe weather is gradually increasing in frequency and intensity. As global warming is advancing towards a hotter world, most of the climate variables are significantly changing. These changes imply diverse effects on human society. One of the most affected sectors is aviation where among leading causes of flight delays and accidents are dangerous weather phenomena.

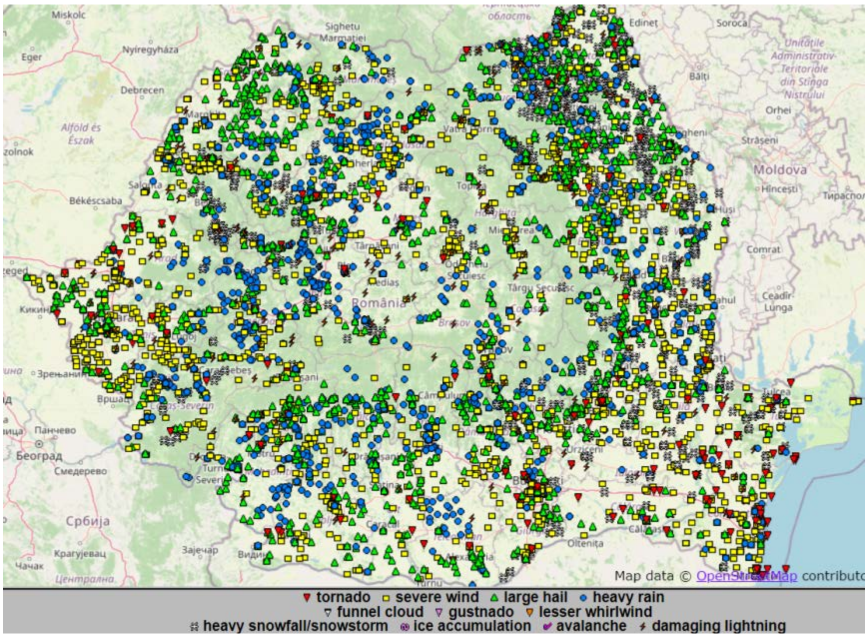


FIG. 1. Severe weather reports in Romania (1994-2023)[6]

European Severe Weather Database (ESWD) operated by European Severe Storms Laboratorycollects relevant information in respect to severe weather in Europe. In Romania, severe weather reports in the last three decades (1994-2023) indicate that northeastern Romania is the most affected area by such weather (Fig. 1).

Eastern Carpathians, Southern Carpathians and Danube Delta had the lowest cases of severe weather reports due to low population density.

Tornadoes reports indicate that the highest frequency of these events was recorded in the southern areas of Romania. The highest numbers of cases with severe winds were reported in western Romania. Extra-Carpathian and Sub-Carpathian regions were the most affected areas by large hail, while the lowest number of cases was reported in southeastern Romania.

The risks of flying through severe weather events which include severe turbulence, wind shear, downbursts, icing, lightning and hail could be extremely dangerous for flight safety [7].Therefore, the avoidance of such events is crucial for flight safety. However, diverting, postponing or flight canceling can result in considerable disturbances and interruption to air traffic.

Even mild weather events related to atmospheric convection or slow-release phenomena such as heat and cold waves, can lead in flight disturbances and delays. Higher temperature maxima at the surface level is significantly decrease air density which impacts the lifting force of the aircraft on the process of taking-off [8]. Civil aviation is highly sensitive to severe weather. Even minor disruption in the flight management plans can induce large interruptions throughout an entire continent [9, 19].

Winter-specific phenomena can also severely affect aircraft flights. For instance, snow can have multiple negative effects on aviation. It can affect visibility through precipitation and increase the risk of fog formation by melting on the surface and increasing the humidity in the lower layer [10]. On the other hand, accumulation of snow on the aircrafts and runways can induce serious delays of flights [11].

3.WEATHER FORECAST TECHNOLOGIES AND TOOLS

The monitoring of dangerous flight phenomena is carried out by terrestrial, aerial and satellite observation systems. In what follows, we present a series of technologies and software tools used to monitor meteorological phenomena for the acquisition of specific data necessary to maintain aircraft flight safety.

3.1. On-board panoramic radar

The on-board panoramic radar is used to find and determine the elements used in air navigation, display the shape of the land surface and a weather regime to display thunderstorm formations according to size and alert level. In the work in front of us, we will refer only to the weather regime, in which the principle of operation is that of primary radar. The transmitting part through the Antenna emits signals of determined duration, wavelength or frequency and power – the desired objective.

Weather radars are generally based on the operating principle centered on the Doppler effect, also applied to electromagnetic waves reflected from a moving target. [12] The radar emits short, high-intensity electromagnetic pulses, and a frequency-Doppler frequency difference occurs between the frequency of the sounding signal emitted and that of the reflected signal (echo) received. The value of this frequency is given by the well-known formula:

$$f_D = \frac{v}{2\lambda},$$

where:

f_D = Doppler frequency, v = radial velocity of the target,
λ = wavelength of the sounding signal emitted

The ranges of wavelengths (λ) most used in meteorological radar technology are in Table 1:

Table 1. [13]

Band	λ=wavelength	f =frequency, $f=\frac{c}{\lambda}$, $c = 3x10^8$ m/s	remarks
W	0.3 ÷ 0.8 cm	35 ÷94 GHz	for middle latitudes
K	0.8 ÷ 2 cm	14 ÷35 GHz	
X	3 cm	10 GHz	
C	5 cm	5 GHz	especially for rain
S	10 cm	3 GHz	

For the pilot the image of the data provided by the radar is essential and the experience and insight of the pilot can make the difference between a dangerous flight and a peaceful one. Below in Fig. 2 we have the weather situation displayed with the dimensions of the thunderstorm formations as indicated by the colors and their danger level, in accordance with the specific characteristics in Table no. 2. [12, 17]

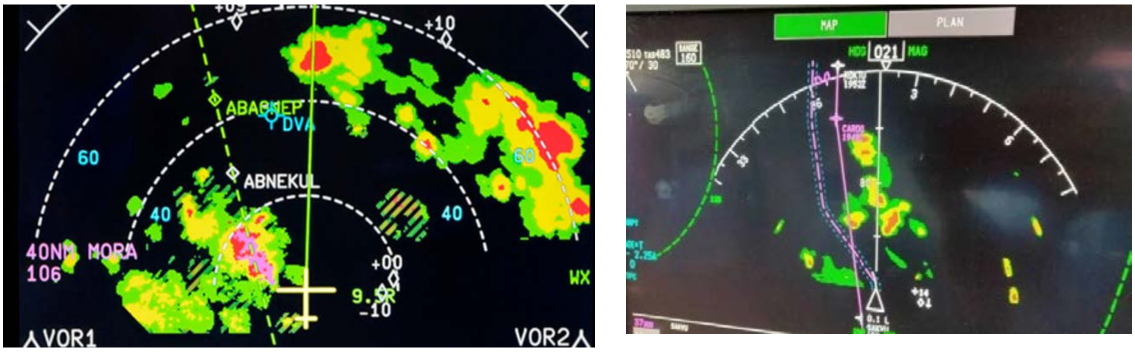


FIG. 2. On-board weather radar indicator [14, 15, 17]

Can be seen the possibility offered by the aerial radar image that the pilot can find solutions to avoid dangerous areas, with minimal deviations from the path.

Table 2. [12]

Level display	Category the storm	Remarks
Magenta	Extreme	Severe turbulence, large hail, electrical discharges, widespread wind gusts (blizzards) and turbulence
	Intense	Severe turbulence, electrical discharges, areas with squalls, possible hail
Red	Very strong	Possible severe turbulence, electric shocks.
	Strong	Severe turbulence, possible electric shocks.
Yellow	Moderate	Light to moderate turbulence possible with electrical discharges
Green	Low	Light to moderate turbulence, possibly with electrical discharges
Black		

The weather regime presents a series of information, such as:

a) Determination and analysis in space of the shapes, types, consistency of cloud formations, their location and their cataloging as a level of danger to the flight;

b) Makes it possible to discover other aircraft flying in the forward area, ensuring risk assessment in preventing approaches;

c) Provides the possibility of displaying the relief with the determination of the safety height in the high regions.

The safety of flying in the area with radar echoes depends on the intensity of the echoes, the distance between them, and the capabilities of the aircraft and the experience of the pilot. Weather radars are constantly developing, they practically determine the concentration of humidity, therefore the pilot must have thorough knowledge of meteorology because atmospheric disturbances do not only come from the area of increased humidity in the form of rain / hail, but also from the strong currents that I take care forms within these stormy formations.[14]

Below is an unpleasant situation with potentially catastrophic consequences of a transport aircraft interacting with a hail formation.

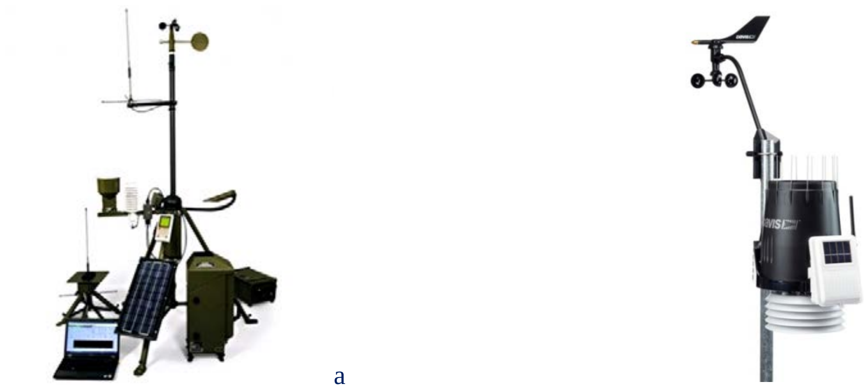
Austrian Airlines Flight OS434 (Fig. 3) sustained considerable hail damage while on approach to land. The aircraft was caught in a severe storm, which resulted in damage to the outer skins and especially the cone. [16]

FIG. 3. Austrian Airlines Mayday after severe hail damage [5]

In conclusion, the weather radar is an electronic device used to locate types of precipitation (rain, snow, sleet, etc.), to determine their trajectories and to predictably calculate the future position and intensity of atmospheric phenomena.

3.2.Automatic weather stations

The best-known technologies and analysis tools are automated weather stations that collect online data on a range of atmospheric parameters such as: temperature, precipitation, wind speed, humidity, atmospheric pressure, cloud ceiling and lightning presence, as examples Vaisala TacMet MAW 201M (Fig. 4a) and Davis Instruments Vantage Pro2 (Fig. 4b). [21, 22]

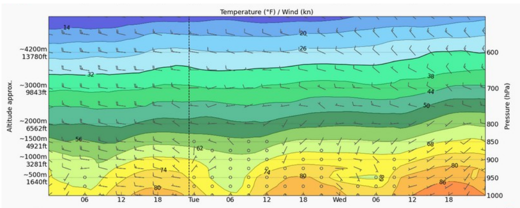


a b

FIG. 4. Automatic weather stations

Offers a free online tool for providing weather information and forecasts on: temperature, precipitation, wind speed and direction, cloud cover, humidity, visibility and air quality. The services offered can be accessed from a number of IT platforms with various operating systems by individuals, legal entities, specialists, meteorologists and researchers who need detailed specialized meteorological data for analysis and research activities. The features of the data provided are: high-resolution data, long-term forecasts, customized data, graphical visualizations. [18]

A series of exposures regarding data specific to the aeronautical field, data valid for the Brașov region are recorded in Fig. 5. and Fig. 6.



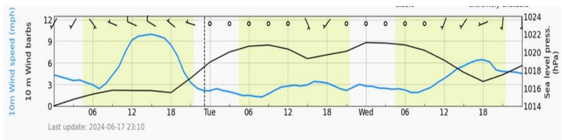


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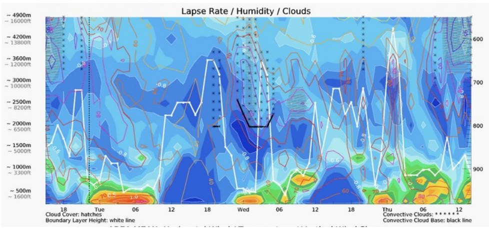
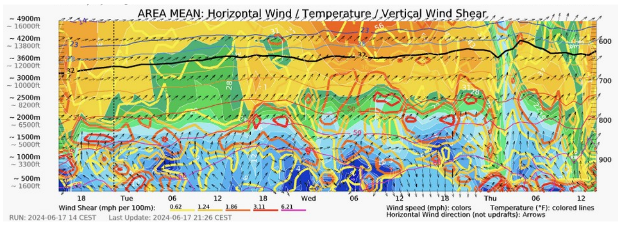
FIG.5. Meteorological data –Meteoblue, a. wind-temperature, b.pressure





a b

FIG.6. Meteorological data –Meteoblue, a.laps rate/humidity/clouds, b. horizontal wind/temperature/vertical wind shear

This online software provides relevant data on meteorological phenomena in the area of interest necessary for specific flight activities.

3.4.Offline software. Supercell Wx

Supercell Wx is a freeware, open source tool used to view live NEXRAD level 2 and level 3 data and severe weather alerts. It displays continuously updating weather data overlaid on responsive maps, providing the ability to monitor weather events using reflectivity, velocity and other products. The software tool also provides extended functionality such as weather reports and specific lightning data see Fig. 7.

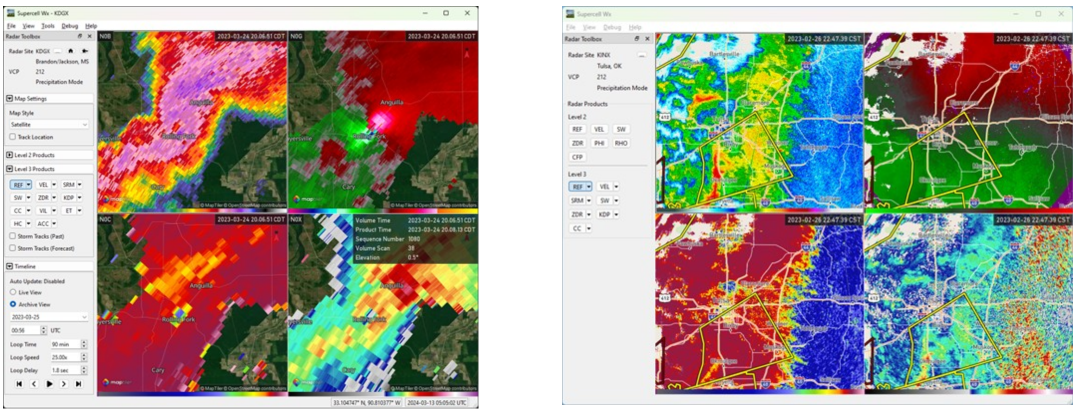


FIG. 7. Supercell Wx, [20]

Data visualization for NEXRAD level 2 offers over 200 graphic and numerical products, including: reflectivity, wind profile, storm velocity, tornado vortex, velocity display, hail index, icing level, hydrometeor classification, [20]

4. CONCLUSIONS

The factors that contribute to aviation accidents can be classified into four categories, such as: human errors / the human factor through lack of relevant training or experience, technical failures can increase the risk of an accident, unpredictable weather conditions that can be difficult to forecast can put pilots in dangerous situations, inadequate procedures and regulations necessary to manage aeronautical activities can favor the risk of accidents.

Lessons learned may focus on the following aspects: the importance of aircrew training, the need to equip aircraft and ground systems with advanced weather forecasting equipment for detailed and up-to-date data, the implementation of procedures and regulations, the development of early warning systems for the occurrence of hazardous weather conditions and cultivating a culture of safety in aviation.

For future studies, it is considered to focus on the statistical analysis of aeronautical accidents caused by dangerous meteorological phenomena, multicriteria analysis classified by types of aircraft and types of phenomena.

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GENERATIVE AI IMPACT FOR GENERATION OF A DUAL CLOCK FIFO UVM TESTBENCH

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Abstract: *The rapid evolution of generative AI technologies has brought transformative changes to the field of testbench generation, significantly enhancing the efficiency and accuracy of hardware and software testing. Traditional testbench development is a labor-intensive process, often requiring substantial manual effort to simulate various scenarios and edge cases. This article explores the impact of generative AI on UVM testbench creation, examining its benefits, challenges, and future potential in the verification and validation domains. Key use cases are also discussed, highlighting how AI-driven testbench automation can streamline design verification, reduce time-to-market, and improve product reliability across industries. The example used is for a dual Clock FIFO Device Under Test (DUT).*

Keywords: *UVM-Universal Verification Methodology, Generative AI-Artificial Intelligence, FIFO-First In First Out, Testbench*

1. INTRODUCTION

In this digital era, technology continues to evolve and innovate at an accelerated rate. Among the many advancements, Artificial Intelligence (AI) stands out as a particularly prominent and transformative trend. The most popular Generative Artificial Intelligence (GenAI) model is ChatGPT which is a chatbot and virtual assistant developed by OpenAI and launched on November 30, 2022 [1]. Based on Large Language Models (LLMs), it enables users to refine and steer a conversation towards a desired length, format, style, level of detail, and language. AI is revolutionizing various industries, from healthcare and finance to entertainment and transportation, by enabling more efficient processes, enhancing decision-making, and creating new opportunities for innovation. As AI technology progresses, it promises to shape the future in unprecedented ways, making it a key focus for researchers, developers, and businesses worldwide.

The semiconductor industry is not unaffected by this trend either. A key question arises: can we leverage GenAI to make the work of engineers easier? By integrating GenAI into semiconductor design and manufacturing processes, engineers can potentially streamline complex tasks, improve precision, and accelerate innovation. GenAI algorithms can assist in optimizing chip design, predicting failures, and enhancing the overall efficiency of production. As the industry continues to embrace GenAI, we may witness significant improvements in both the quality and speed of semiconductor development, ultimately driving further advancements in technology.

We decided to evaluate ChatGPT's and BingAI's ability to write and verify a Dual Clock FIFO module. Microsoft introduced Bing Chat in February 2023 as a revolutionary web search tool and users' "copilot for the web." This AI-powered chatbot version of the Bing search engine is designed for use with the Microsoft Edge browser and requires a Microsoft account [2]. Bing AI, offers a comprehensive range of search services, including web, video, image, and map search capabilities, all developed using ASP.NET [3]. However, we discovered that there are limited online resources available for UVM verification and its components, which constrained their ability to fully develop a comprehensive verification environment. We needed to make several adjustments to ensure a functional environment free of compilation errors. ChatGPT successfully generated RTL code without syntax or compilation issues, but we identified areas where functionality needed improvement. This experience highlighted the potential of GenAI like ChatGPT and BingAI in assisting with code generation but also underscored the importance of resource availability in hardware development projects.

2. FIFO DUAL CLOCK

A Dual Clock FIFO (First-In-First-Out) module is a type of memory buffer that allows for the storage and retrieval of data between two systems operating at different clock frequencies. It is commonly used in digital systems to handle data transfer between components that do not share the same clock domain. In implementing the FIFO module, we decided to use two pointers for reading and for writing. Based on the values of these pointers, we also generate the empty and full signals to indicate the status of the FIFO buffer.

The read pointers help in tracking the current position from which data should be read, as well as the next position to be read. Dual-pointer method ensures accurate data retrieval and helps prevent errors that may arise from concurrent read operations. The write pointer, on the other hand, tracks the position where new data should be written [4]. This pointer-based approach not only simplifies the management of the FIFO but also enhances its efficiency by providing clear indications of its state. By accurately maintaining and comparing the read and write pointers, we ensure reliable data flow and effective buffer management in the FIFO module.

To determine whether a FIFO is full or empty, some form of mathematical manipulation or comparison of the write and read pointers is necessary. The challenge arises because these pointers are generated in two separate clock domains, meaning that one or both pointers must be synchronized with the opposite clock domain before performing any mathematical or comparison operations to ensure accuracy and safety. A good method for passing pointers between clock domains is to use a gray-code counter for the two FIFO pointers. In a binary counter, multiple bits may change simultaneously when counting up or down, which can create issues when sampled by a slower or unsynchronized clock domain. Gray code counters solve this problem by ensuring that only one bit changes at a time between successive values, minimizing the risk of metastability and making it easier to synchronize between clock domains [5]. A high-level overview of the proposed dual clock shared buffer is illustrated in Fig. 1.

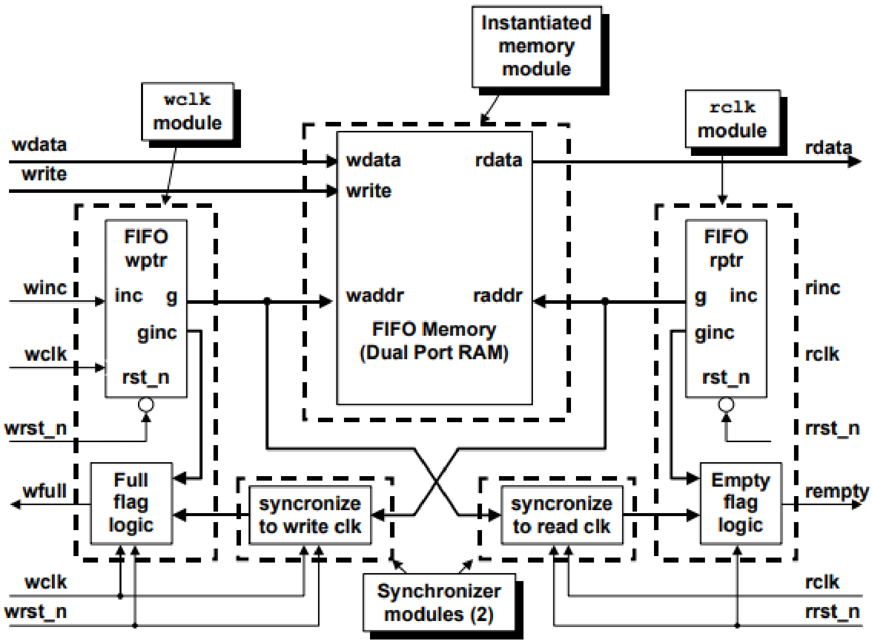


FIG. 1. FIFO Block Architecture (source:[5])

An important problem in systems lacking a single global timing reference is synchronization. The timing relationship between a signal and a clock generally falls into one of five categories :

• synchronous; the signal and the clock are perfectly aligned. Every signal transition occurs precisely with the clock edge, ensuring consistent timing across the system. This alignment facilitates easy data transfer and coordination between different parts of the system.

• mesochronous; the signal and the clock share the same frequency but maintain a constant phase difference. This means that while they operate at the same speed, their transitions are offset by a fixed amount of time. This constant phase difference can be managed through Phase-Locked Loops (PLLs) or delay elements to ensure proper synchronization.

• plesiochronous; the signal frequency is close to but not identical to the clock frequency. This slight difference results in a varying phase difference over time, necessitating sophisticated synchronization techniques. Buffering and elastic storage elements are often used to accommodate the variations and prevent data loss or misalignment.

• periodic; the signal has a repetitive nature but lacks a defined relationship to the clock. Although the signal repeats at regular intervals, it is not synchronized with the clock edges.

• asynchronous; the signal is completely independent of the clock, with transitions occurring at arbitrary times. This lack of timing correlation presents significant challenges for synchronization. Techniques such as handshake protocols and asynchronous FIFOs are employed to manage data transfer and maintain integrity across different clock domains [6].

Metastability is a fundamental issue that arises when interfacing asynchronous blocks. It occurs when registers do not receive a stable input signal near the active edge of the clock signal, leading to unpredictable behavior and potential system failures [7].

Metastability-free operation depends on ensuring that the receiver does not read the signal until a sufficient amount of time has passed, allowing the signal to stabilize and preventing incorrect or unpredictable behavior. This safe time period ensures the signal has fully transitioned to a stable state before being sampled by the receiving system [4]. To mitigate this problem, we decided to use Gray code pointers to synchronize the clocks. This technique helps in minimizing the risk of metastability by ensuring that only one bit changes at a time when pointers are updated, thereby providing a more stable transition and reliable data transfer between different clock domains.

3. UVM METHODOLOGY

The Universal Verification Methodology (UVM) is a standardized methodology for verification that focuses on reusability. By utilizing predefined classes and objects, it provides a consistent approach to building verification environments, making it easier to reuse components and ensure compatibility across different projects. UVM streamlines the process of developing, deploying, and maintaining verification systems, improving overall efficiency and flexibility in the verification process [8].

To validate the proposed concept, an HDL (Hardware Description Language) design specification is prepared, and a small team of HDL designers is assigned to the project. This team is responsible for implementing a digital system based on a Finite State Machine (FSM) following a detailed specification. Once each task is completed, the design is automatically validated using the proposed UVM methodology, and a performance evaluation of the validation process is conducted [9].

The figure below illustrates the complete structure of the Universal Verification Methodology.

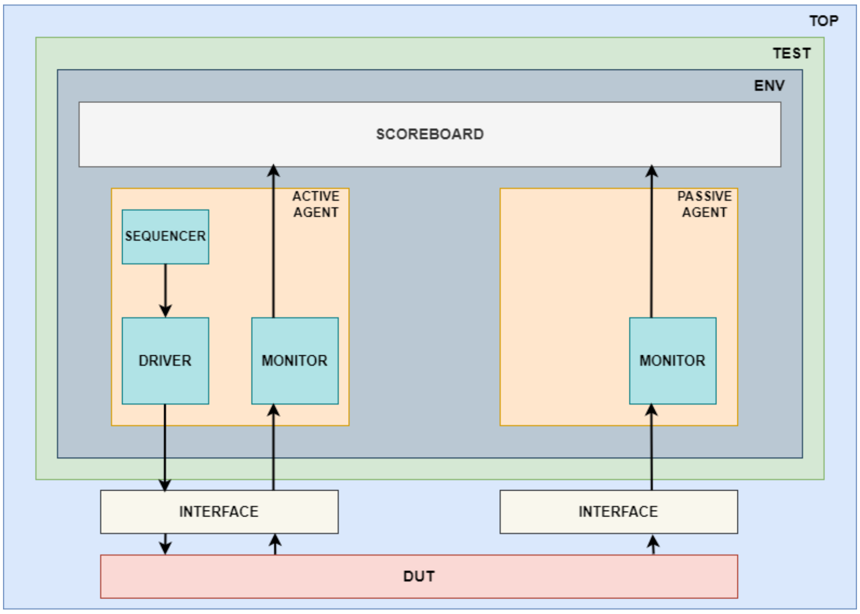


FIG. 2. Structure of UVM

In this diagram, two Agent classes are created. One of the agents is designated as active and the other one is passive. The agent serves as a container that bundles key verification components like Driver, Monitor, and sometimes a Sequencer. It can operate in active mode (driving signals to the DUT and monitoring outputs) or passive mode (only monitoring outputs).

The agent coordinates communication with the DUT and helps manage the flow of data. DUT (Design Under Test) : This is the hardware or system being tested.

The Driver converts high-level transactions (stimulus) into low-level signals that are applied directly to the DUT's pins. It is responsible for generating appropriate signal sequences based on the input provided by the verification environment, typically through a virtual interface. The Monitor observes the signals exchanged between the DUT and other system components. It captures the DUT's outputs and pass them to the Scoreboard.

A virtual interface abstracts the physical signal details of the DUT, providing a high-level interaction layer for components like Driver and Monitor. It connects the testbench to the DUT, allowing Driver to apply signals and Monitor to observe DUT behavior.

The DUT's behavior is verified against expected outputs under various test scenarios driven by the verification environment. The test environment is the overall setup in which the verification of the DUT takes place. The scoreboard is a verification component used to track and compare the expected outputs of the DUT against its actual outputs. It collects data from the Monitor and compares the observed results to a reference model or expected values to identify mismatches or errors. The top refers to the highest level of the testbench hierarchy. It integrates the entire verification environment and connects it to the DUT. It's responsible for instantiating the DUT, agents, and test environment, and configuring them to run simulations. The Coverage Model tracks which parts of the DUT's functionality and scenarios have been tested and ensures that all critical aspects of the design are exercised and validated during verification. It can be instantiated within the agent classes [10].

4. USING GENERATIVE AI

ChatGPT:

In initial attempt at generating a functional testbench and RTL was unsuccessful because we didn't receive the Verilog code for the required files. Instead, it generated a skeleton and provided the following response regarding the difficulties of generation: "Building a UVM testbench is a detailed and iterative process. It's crucial to have a solid understanding of the UVM methodology and SystemVerilog. Due to the complexity and the need for iterative development and debugging, it's recommended to start with basic functionality and gradually add features and checks."

In response, we revised our requirements and requested each component in more detail. This led to the generation of some code, but it contained numerous compilation errors. These included misspelled variable names, an improperly configured reset (active low), incorrect signal assignments from the interface, and an improper sequence—data randomization should have occurred between start_item and finish_item. Additionally, the parameter in the clocking block of the interface needed to be removed.

After addressing these issues, we achieved our first version of a functional environment and a running test. However, the test revealed that the DUT was not functioning correctly, as the empty and full signals were not asserted and deasserted at the appropriate times (see Fig 3). From this point, we began developing a more complex and accurate verification module using UVM methodology with the help of ChatGPT and BingAI.

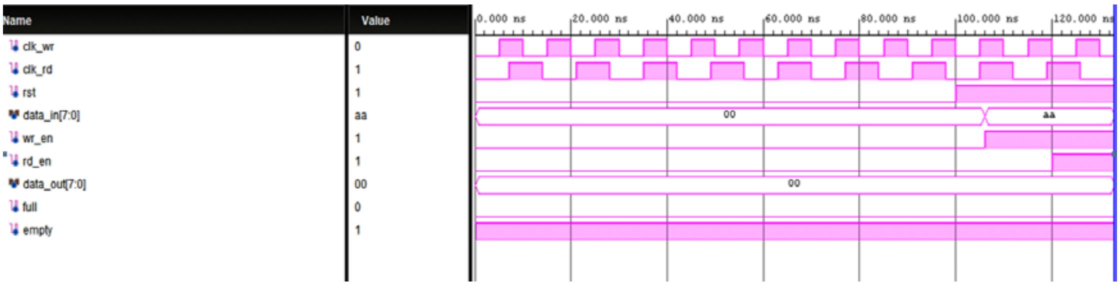


FIG. 3. First successful test

We began by attempting to fix the DUT, focusing on resolving the issues with the empty and full signals. We asked the AI to modify the code, and the proposed solution involved creating a counter that increments during write operations and decrements during read operations. When the counter reaches 16, the full signal is asserted, and when it reaches 0, the empty signal is asserted. While this approach worked, it was not suitable for the design, as it is not synthesizable.

We also encountered challenges with pointer synchronization. After multiple iterations, during which we had to explain in detail how to modify the conditions and specify which pointers to include, we finally succeeded in developing a proper DUT module. Once the DUT was fixed, we started creating more complex sequences and tests, while also making corrections to other components. In the driver, we added a reset condition, and in the monitor, we included all the signals from the interface in the item. Additionally, we created a coverage file and, most challenging of all, a scoreboard file. Finally, we achieved some well-functioning tests. An example is shown in Fig. 4, where we successfully simulated read and write operations.

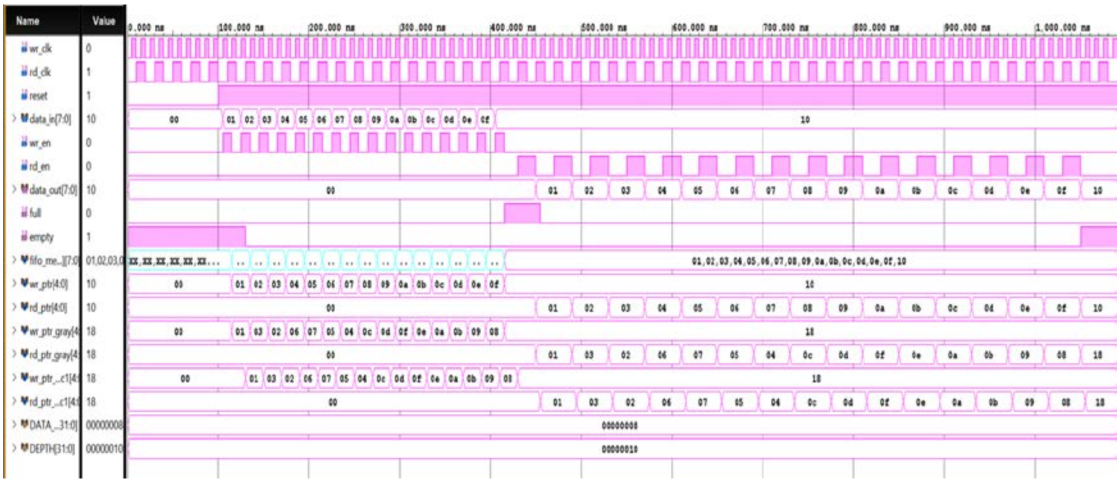


FIG. 4. Write all Read all test

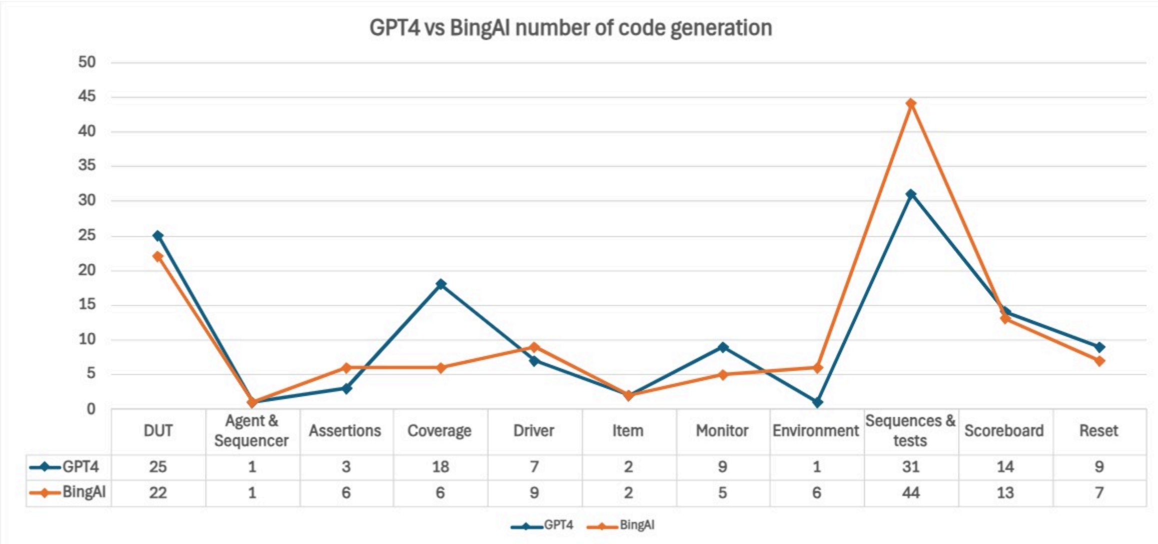
BingAI:

The next step in our process was to attempt developing the same environment using Bing AI. This time, we decided to build upon the basic environment initially generated by ChatGPT, which had several issues and wasn't functioning correctly. By using Bing AI, we aimed to address these problems and enhance the environment's functionality, hoping to achieve a more robust and reliable solution. The experience we have gained from using ChatGPT in the past has been put to good use this time. We better understood how to ask the right questions, which references to include and when to provide them.

This knowledge allowed us to communicate more effectively with AI, which sometimes led to more accurate and relevant results. The most challenging part, similar to those encountered when using ChatGPT, was generating of the scoreboard. This task requires extensive knowledge, including a detailed understanding of the design's specifications, architecture, and behavior. Additionally, it necessitates the ability to manage various test scenarios, including corner cases, and requires thoughtful planning to ensure that these tests cover all potential issues and accurately reflect the intended functionality of the design.

What have we learned:

After generating the DUT and Verification Environment using two large language models—ChatGPT-4 and Bing AI—we compared the number of code generations produced by each model. The graph, in Fig. 5, illustrates the number of code iterations generated by ChatGPT-4 and Bing AI for each component of the verification environment.



	DUT	Agent & Sequencer	Assertions	Coverage	Driver	Item	Monitor	Environment	Sequences & tests	Scoreboard	Reset
GPT4	25	1	3	18	7	2	9	1	31	14	9
BingAI	22	1	6	6	9	2	5	6	44	13	7

FIG. 5. Comparison between the number of code generations for each model

• Communication is key – we learned how to ask the right questions to get the desired answer

• The references are important - there needs to be background on a topic to generate correctly

• In a single question, all the requests need to be clearly and explicitly stated. For instance, the AI won't be able to generate the desired code if we refer to something that was mentioned above in the same conversation.

• Once we knew what the correct prompt was, after several trials with ChatGPT, we were able to use that from the beginning when we generated the code with Bing AI.

• Even if we specified that we wanted the signals to be assigned in separate "always" blocks, if we added a new signal, the generative AI did not take into account this requirement anymore.

5. CONCLUSION

Using generative artificial intelligence to generate design and verification code has enormous potential, offering opportunities to speed up the development process and reduce human error.

GenAI can automate repetitive tasks, generate quick solutions and explore complex scenarios that might be difficult to cover manually. However, there will always be a need for an engineer to verify the accuracy and validity of the information generated. Engineers bring a deep understanding of context, the ability to identify design subtleties and nuances, and are essential to ensuring that the results provided by AI are accurate, relevant, and compliant with industry specifications and standards. In essence, AI can be a powerful tool, but human supervision remains crucial to the ultimate success of any engineering project.

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THE USE AND ADAPTATION OF ANTI-AIRCRAFT ARTILLERY AGAINST DRONES

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Abstract: *In the context of the rapid development of drone technology and their increasingly frequent use in modern conflicts, the adaptation and use of anti-aircraft artillery against drones has become a priority for armed forces around the world. This article explores the possibilities of modifying and adapting anti-aircraft artillery systems, initial designed to combat large aircraft, so that they become effective against drones of different sizes, speeds and flight altitudes. Thus, the adaptation of classic anti-aircraft artillery systems is analyzed by improving the detection systems, by using projectiles with proximity warheads as well as the integration of advanced sensors and I.A. algorithms to detect, intercept and combat the drones. The article highlights the technical and tactical challenges associated with adapting these systems, including the limitations of conventional air defense systems against drones*

Keywords: *drones, anti-aircraft artillery, proximity warhead, artificial intelligence …*

1. INTRODUCTION

In recent years, the use of UAVs has increased significantly, both for commercial and military purposes. They are often small, maneuverable and capable of flying at low altitudes, posing a unique challenge to traditional air defense systems. These characteristics make them difficult to detect and intercept. Also, the low cost of drones compared to the price of anti-aircraft missiles raises questions about the economic efficiency of air defense systems. This has created new challenges for air defense forces, which must develop and adapt strategies to counter the threats they represents.

Anti-aircraft artillery systems, originally designed to intercept aircraft and missiles, are now being evaluated and adapted to meet the following new challenges:

- Small dimensions and low radar cross section: Drones are much smaller than fighter planes and helicopters, and the effective reflection surface is reduced, which makes them difficult to detect for the radars of the air defense units.

- Flying at low altitudes: Many drones operate at extremely low altitudes, below the level detected by conventional air defense radar systems, allowing them to avoid detection until it is too late to be intercepted [1].

- Drone swarms: One of the modern tactics is the use of drone swarms, a form of attack where multiple drones are used simultaneously to overwhelm air defense systems.

- High operating costs: Using an expensive missile to destroy a small, low-cost drone is not financially sustainable in the long term [2, 3].

2. THE ADAPTATION OF CLASSIC ANTI-AIRCRAFT ARTILLERY AGAINST DRONES

The role of anti-aircraft artillery against drones is a crucial component of modern air defense. By adapting traditional systems and integrating new technologies, the growing threats posed by drones can be effectively countered. As drone technology continues to advance, so will the methods and tools to neutralize this versatile and persistent threat, ensuring that air defense systems remain robust and adaptive in the face of new challenges. To deal with the threats posed by drones, classic air defense systems have been modernized or adapted, improvements have been made that allow them to be used successfully:

1. Improvement of detection systems: Traditional air defense radars are designed to detect aircraft with a large radar cross section flying at medium and high altitudes. Small drones are difficult to see on traditional radars. Thus, radar systems have been updated to be able to detect smaller and faster objects. Among the adaptations brought to the detection systems are:

- Specialized radars with machine learning algorithms to distinguish drones from other airborne objects, able to detect small drones and differentiate between them and other airborne objects such as birds [4].

- Optical and infrared detection systems that work well against drones that have low radar signatures.

- Passive detection systems such as acoustic microphones or vibration sensors to identify approaching drones without relying on radar [5].

2. Proximity warhead-equipped fragmentation projectiles: Unlike conventional munitions, which require a direct impact to destroy the target, these projectiles are designed to detonate when they are at an optimal distance from the target, without the need for physical contact . Fragmentation projectiles, equipped with proximity warheads, represent an effective solution adapted to the new requirements of modern anti-aircraft combat, especially in the context of combating drones. This technology significantly increases the chance of success against small and fast targets such as drones, as controlled explosions generate a shower of shrapnel that can more easily hit and neutralize moving objects.

Fragmentation projectiles equipped with proximity warheads are equipped with sensors that detect proximity to the intended target. These sensors can be of various types, such as radar or optical, and are able to determine the optimal moment for detonation so that the fragments are scattered in a cone of explosion in the direction of the target. This directed explosion increases the chances that fragments from the detonation will hit and damage critical components of the drone, such as the propulsion systems, electronics, or physical structure.

One of the major advantages of this technology is that it does not require extreme precision in projectile trajectory. Given that small drones are difficult to track and intercept with conventional ammunition, which requires direct contact, the proximity warhead allows drones to be neutralized even if the trajectory of the projectile is not perfectly aligned with the target. This makes projectiles much more effective in scenarios where drones are maneuvering quickly and at low altitudes.

One of the most important uses of this technology is to combat drone swarms. A drone swarm is a relatively new tactic in military conflicts, where dozens or even hundreds of small drones are launched simultaneously to overwhelm defense systems. The combination of the large number of targets and their small size makes intercepting individual drones a difficult task for traditional air defenses.

Proximity warhead projectiles, however, are ideal for this type of threat. Instead of trying to hit each drone individually, a single fragmentation projectile can detonate in the middle of the swarm, scattering fragments that can hit multiple drones at once. The extended range of the fragments thus provides greater destruction capacity over a wide area, increasing the chances of neutralizing a significant number of drones with a small number of projectiles. This feature is essential to counter overwhelm tactics and ensure more efficient use of defense resources [6].

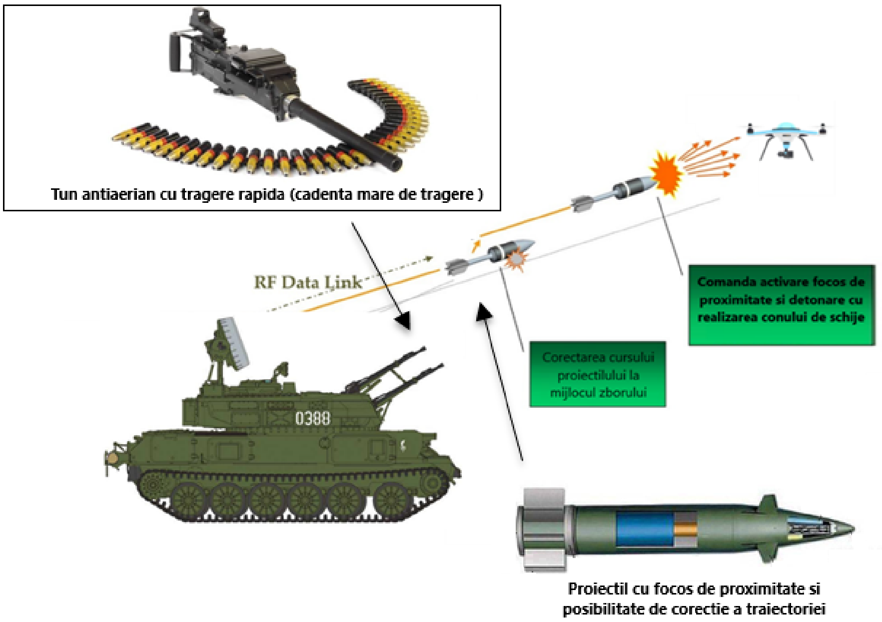

FIG. 1. Graphical representation of an anti-aircraft artillery system with multiple detection possibilities that uses guided projectiles equipped with proximity warheads to combat drones [7]

3. Automated Sighting Systems: Many modern anti-aircraft artillery systems are equipped with automatic targeting technologies. They can quickly calculate a drone's trajectory and adjust the firing angle to effectively intercept it. Such systems eliminate human errors and significantly increase reaction speed [8]. Automated sighting systems for anti-aircraft artillery, combine various advanced technologies to ensure effective detection, tracking and neutralization of drones. These systems rely on the integration of advanced radars, electro-optical sensors and artificial intelligence algorithms (AI) to speed up the identification and reaction processes. AI can learn from past data to improve the effectiveness of targeting systems, adapting to new drone use tactics. AI is also used to predict drone behaviour based on previous movement patterns, thus adapting the aiming strategy. Advanced AI systems can quickly analyse data from sensors, optimizing reaction time and significantly reducing the likelihood of false alarms [9].

Automation allows these systems to act independently without human intervention during the attack. This reduces response time and enables quick reactions in critical situations. The ability to detect and neutralize targets in seconds is critical in the context of swarm attacks, where reaction speed is vital.

These automation technologies lead to the following anti-drone capabilities:

- Quickly classify flying objects and distinguish between drones, birds or other aircraft.

- Automatically calculate the trajectory and speed of the drone, anticipating its movements.

- Optimizing the target engagement process, recommending quick actions based on drone type and potential danger.

4. Integration with other defense systems: To effectively combat drones, anti-aircraft artillery is often integrated with other systems, such as anti-aircraft machine guns or short-range surface-to-air missiles or directed energy lasers. Within this integrated system, artillery can be used to eliminate drones that escape initial interception by other defensive systems.

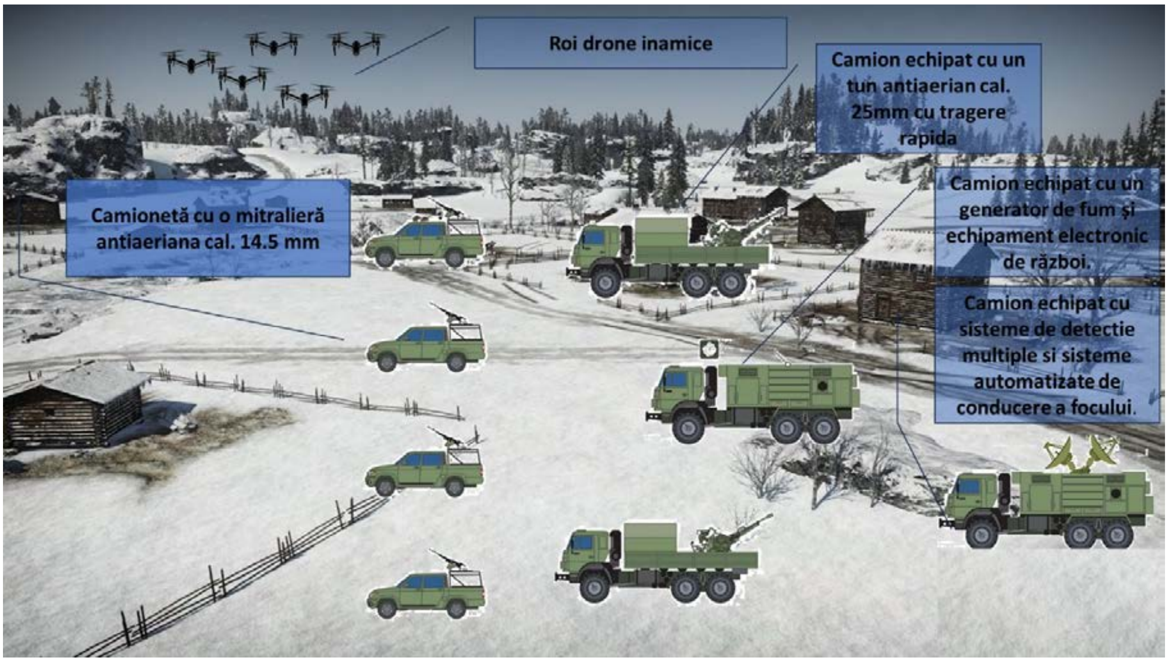

FIG. 2. Graphical representation of a multi-layer anti-aircraft artillery system with possibilities to combat drones [10]

3. THE LIMITS OF CLASSIC ANTI-AIR ARTILLERY SYSTEMS AGAINST DRONES

Despite all the progress made, the use of classic anti-aircraft defense systems against drones also has certain limits:

- High Ammo Consumption: Since drones are small and fast, it is necessary to fire a large number of projectiles to ensure a hit. This makes the use of anti-aircraft artillery relatively expensive.

- Complex coordination: Integration of anti-aircraft artillery systems with other defensive systems requires complex coordination and a very short reaction time.

- Limited capabilities against swarms of drones: An attack with a swarm of drones can overwhelm classic anti-aircraft systems, not being able to deal with the large number of targets in a short time. Most traditional anti-aircraft systems are not designed to target multiple targets simultaneously on such a large scale, making them vulnerable to a saturation attack.

- Disadvantages in urban and forest environments: In urban areas or with varied terrain, such as forests, drones can maneuver much more easily, and fixed radars have difficulty detecting them. Complex environments offer many obstacles and natural camouflage, allowing drones to infiltrate and pose a serious threat.

- Mobility restrictions of anti-aircraft defense systems: Classic defense systems are often stationary or have reduced mobility. Drones, on the other hand, are highly maneuverable and can move quickly out of range of these systems. A possible solution is the integration of classic systems with modern solutions. Classic air defense systems are increasingly integrated with new anti-drone defense technologies such as jamming systems, directed energy lasers and defensive drones. This multi-layered approach provides a more comprehensive defense tailored to both classic and modern threats.

- Jamming and electronic warfare systems: These are used to disrupt communication between drones and their operators, causing them to crash or land in a controlled manner.

- Laser systems: High power lasers can destroy drones by focusing energy on their critical components such as engines or cameras.

- Defensive Drones: Drones can also be used as an active countermeasure against other drones, either through controlled collisions or by placing nets to capture them [11].

CONCLUSIONS

Adapting classic anti-aircraft artillery to counter drone threats has become an essential component of modern air defense. As the use of drones increases in military operations, traditional systems must evolve to meet the technical and economic challenges these devices pose. The integration of advanced technologies, such as high-frequency radars, optical and infrared systems, proximity warhead missiles and automatic targeting systems, significantly improves the ability of anti-aircraft artillery to intercept drones, even in complex scenarios such as drone swarms.

One of the key aspects of modernizing anti-aircraft artillery is economic efficiency. The low cost of drones compared to anti-aircraft missiles calls for a more affordable strategy, which can be achieved by using proximity warhead missiles capable of destroying multiple drones at once. In addition, the implementation of artificial intelligence technologies and machine learning algorithms facilitates the detection and tracking of targets, minimizing errors and increasing the speed of reaction.

Although advances in anti-aircraft artillery have significantly improved defense capabilities against drones, there are still important limits. Intercepting large numbers of drones, especially in drone swarm scenarios, remains a challenge, and high ammunition consumption makes artillery-only air defenses difficult to sustain over the long term.

Also, coordination of artillery with other defensive systems, such as electronic jamming and high-powered lasers, is essential for a complete and effective defense.

In conclusion, to maintain a robust and adaptable defense in the face of technological evolution of drones, a multi-layered approach is required, combining modernized anti-aircraft artillery with new defensive technologies. This approach enables the military to effectively respond to both conventional and emerging air threats, ensuring an effective and sustainable air defense.

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THE NEED TO BUILD AND OPERATE A MOBILE MODULE FOR ENSURING ENERGY AUTONOMY FROM SUSTAINABLE SOURCES (MAES)

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Abstract: *The mobile module for ensuring energy autonomy from sustainable sources (MAES) can solve the problem of power supply in remote areas, providing a flexible and sustainable solution, especially for military applications. Based on renewable sources, MAES ensures energy autonomy, reducing dependence on fossil fuels and minimizing environmental impact. By integrating solar panels, batteries, and smart energy management systems, MAES can provide electricity for a wide range of equipment and applications, from communications and surveillance and security systems to electric vehicles. Its portability and resilience make it ideal for field operations, and unlike generator sets, its silent operation provides thermal and acoustic masking conditions. The adoption of the MAES can enable the armed forces to operate more efficiently, more discreetly and in a more sustainable way.*

Keywords: autonomy and energy independence, thermal and acoustic masking, flexibility, portability, resilience, green energy, critical infrastructures.

MOTTO *"Energy and persistence conquer all things."*
Benjamin Franklin

1. INTRODUCTION

In a world marked by climate change and increasing demand for energy, finding sustainable and efficient energy solutions is a global priority [1]. MAES is one such solution, offering a viable alternative to conventional energy sources.

MAES is a portable, solar-powered electricity storage system that can provide electricity in remote areas or in emergency situations. Composed of photovoltaic panels, batteries and one or more inverters (depending on the destination and size of the load), this system converts solar energy into usable electricity, providing energy autonomy from a clean and (theoretically) unlimited energy source. Its availability, portability and flexibility are ensured by the location of the photovoltaic system on a semi-trailer, towable according to any type of vehicle equipped with a towing system.

According to Eurostat, in chapter 4.2.2. Energy from renewable energy sources in the National Integrated Energy and Climate Change 2021-2030 [2], Fig. 1 highlights the evolution of electricity production from renewable energy sources between 2005 and 2017, by source type. By adopting the MAES in Romania and beyond, in line with Goal7: Affordable And Clean Energy of Romania's Sustainable Development Strategy 2030, it can be reduced dependence on fossil fuels, reduce greenhouse gas emissions and help protect the environment [3][4].

In addition, MAES offers a flexible and scalable solution that can be adapted to a wide range of applications, from powering military equipment to supporting isolated communities.

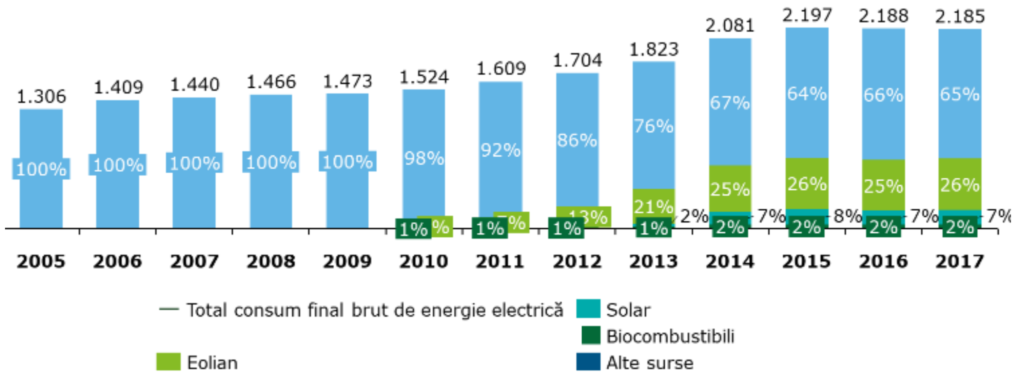

FIG. 1. Evolution of electricity production from renewable energy sources between 2005 and 2017

2. COMPONENTS AND OPERATION OF THE MAES

MAES is an innovative solution for generating and storing electricity, based on renewable sources. Its efficient operation is ensured by a complex interaction between several key components.

Photovoltaic panels are the fundamental element of the system, directly transforming solar radiation into electricity through the photovoltaic effect. Solar cells, the basic units of panels, are made up of semiconductor materials, such as silicon, that generate an electrical voltage when exposed to photons. The efficiency of a photovoltaic panel, i.e. its ability to convert solar energy into electricity, is influenced by factors such as the type of solar cells (monocrystalline, polycrystalline, amorphous), the operating temperature and the angle of incidence of solar radiation. Monocrystalline cells, for example, offer the highest efficiency, but they are also the most expensive.

The electricity produced by photovoltaic panels is stored in batteries, which act as **energy reservoirs**. The most used batteries in photovoltaic systems are lithium-ion batteries, appreciated for their high energy density and long lifespan. The energy storage capacity in a battery is influenced by factors such as electrochemical chemistry, physical size, and operating conditions. A battery management system (BMS) is essential for monitoring battery health and optimizing charging and discharging processes.

The inverter plays a critical role in converting direct electricity (DC) generated by photovoltaic panels and stored in batteries into alternative energy (AC), which is the form of energy used in most electrical applications. The type of inverter used (on-grid, off-grid, hybrid) depends on the system configuration and the specific requirements of the user. Conversion topologies such as MPPT (Maximum Power Point Tracking) and PWM (Pulse Width Modulation) are used to optimize the inverter's energy efficiency.

The Energy Management System (EMS) is the brain of the MAES system, coordinating and optimizing the operation of all components. EMS monitors real-time solar energy production, energy consumption, battery charge status, and adapts system parameters to maximize efficiency and ensure safe and reliable operation. Advanced control algorithms, such as MPPT and self-consumption maximization algorithms, are implemented in EMS to optimize the use of generated energy.

The interconnection of all these components into a coherent system allows for the efficient conversion of solar energy into usable electricity.

Photovoltaic panels capture solar energy, batteries store it, the inverter converts it into alternating current, and the energy management system coordinates the entire process. All these deliverables wherever the beneficiary's interests require it, in conditions of increased mobility in terms of the placement of the MAES on a semi-trailer type mobile platform that also allows the optimal orientation of the panels towards the solar source.

3. ADVANTAGES AND BENEFITS

MAES represents a significant paradigm shift in the energy field, offering a viable and sustainable alternative to conventional energy sources. These systems, mainly based on solar energy, are designed to operate independently of the electricity grid and classic generator sets, thus ensuring an autonomous and reliable energy source.[5]

One of the most important advantages of the MAES is **the energy independence** it offers and implicitly operational availability. By eliminating dependence on centralized power grids, these systems allow access to electricity even in isolated or hard-to-reach areas. Appropriately sized to the consumption requirements of the beneficiary, MAES can provide energy 24/7 (**UPS function**).

In addition, MAES contributes significantly to the **reduction** of greenhouse gas emissions, thus aligning itself with the global Sustainable Development Goals.

Resilience is another key feature of ESAM systems. They ensure continuity of power supply, even in extreme conditions such as natural disasters or grid outages. Also, **the long-term costs** associated with using MAES are significantly lower compared to those of conventional energy sources, due to reduced energy bills and maintenance costs [6].

The versatility of the MAES is another important aspect. They can be adapted to power a wide range of applications, from street lighting systems to industrial equipment. In rural areas, MAESs can be used for drinking water supply, public lighting, communications, and other critical infrastructure. In the industrial sector, these systems can power equipment in isolated areas or with limited access to the grid.

All these benefits can make a significant contribution to the military sector, offering flexible and efficient energy solutions. These systems allow armed forces to operate in remote areas without being dependent on existing energy infrastructure, thus ensuring increased operational autonomy.

The mobility and compact dimensions of MAESs make them ideal for quick transport and installation in different locations, offering flexibility in carrying out operations. Also, the resistance to attacks and modular configurations that allow redundancy make these systems a safe and reliable choice in hostile environments.

The MAES is **scalable**, which means that a consumer's need for increased power can be met by connecting multiple units in parallel. In this way, an adequate amount of modules can be deployed in the field that provide adequate resource management. Through the use of renewable energy sources, MAESs contribute to reducing the carbon footprint of military operations, aligning with global efforts to combat climate change. In addition, the low operating and maintenance costs make these systems a profitable long-term investment.

MAESs **significantly improve the living conditions of** military personnel, ensuring a stable supply of electricity to bases, camps and checkpoints, even in the most remote areas. These systems also allow personal electronic equipment to be charged, facilitating communication and morale boosting.

In the field of special operations, MAESs offer discreet and efficient solutions, being able to power specialized equipment such as drones and surveillance systems. The ability to operate in **silent mode (thermal and phonic masking)** is essential for missions that require discretion.

4. PRACTICAL APPLICATIONS OF MAES SYSTEMS

MAES can cover a wide range of applications in various sectors, thus demonstrating the versatility and efficiency of these technologies.

In the military field, MAESs can be an autonomous and reliable source of energy in areas of operations, often remote and with limited infrastructure. These systems can power communications equipment, charging stations for drones and electric vehicles, as well as lighting systems in areas of operations. The mobility and strength of MAESs make them ideal for use in harsh environments.

In areas affected by natural disasters or armed conflicts, MSEAs can play a key role in providing electricity for essential services. Mobile hospitals, refugee centres and rescue operations can benefit from the energy provided by these systems, thus ensuring access to drinking water, lighting and communications, even in extreme conditions.

The events industry has widely adopted MAESs as an environmentally friendly and efficient alternative to diesel generators. These systems can power stages, lighting systems, audio equipment, and other facilities needed to organize outdoor events. MAESs significantly reduce noise and polluting emissions, contributing to the organization of more sustainable events.

In rural areas, where access to the electricity grid is limited or non-existent, MAESs offer a viable solution for electrification. These systems can power drinking water pumps, irrigation systems, refrigerators for food storage, and support the development of small local businesses, thus helping to improve the living standards of rural communities.

5. CONCRETE EXAMPLES OF USE CASES

Systems with characteristics similar to MAES have demonstrated remarkable versatility, being successfully implemented in a variety of contexts and sectors. Here are some concrete examples that illustrate the impact of these systems:

Following catastrophic events such as earthquakes, hurricanes or armed conflicts, the MAESs have proven to be a quick and efficient solution for the supply of electricity in the affected areas. For example, in the aftermath of the earthquake in Haiti, MAESs were used to power mobile [7] hospitals, refugee centers, and communication systems, thus ensuring the survival and recovery of affected communities.

In many rural areas, far from conventional power grids, MAESs have provided electricity, lightingband other strictly necessary appliances, greatly improving the quality of life [8]. For example, in isolated communities, these systems powered water pumps, street lighting, and made it possible for small local businesses to develop.

Industries, especially those in remote areas or with limited access to the electricity grid, have benefited significantly from the implementation of MAES. For example, in the mining industry, these systems powered drilling and lighting equipment in underground mines, reducing costs and environmental impact.

MAESs have also found applications in the transport sector. Charging stations for electric vehicles, especially in rural areas or national parks, are often powered by MAES systems, contributing to the development of infrastructure. Ships and ferries can also be equipped with MAES systems to reduce emissions while stationary in ports.

In the field of education, MAESs have facilitated access to technology and knowledge in remote areas.

Schools and universities in developing countries have benefited from these systems to power computers, laboratories, and other educational equipment.

Also, in the field of scientific research, MAESs have been used to power measuring instruments and laboratory equipment in remote areas or in extreme conditions.

Ecotourism hotels and resorts have adopted MAESs to reduce their carbon footprint and provide a more sustainable experience for customers. These systems can power the rooms, restaurants, swimming pools and other facilities of the accommodation units.

The examples presented clearly demonstrate the versatility and impact of EAW systems in different sectors. From providing electricity in disaster-affected areas, to supporting economic development in rural communities and facilitating scientific research, ESMs play a key role in the transition to a more sustainable and equitable energy future.

6. TECHNICAL, ECONOMIC, LEGAL AND ENVIRONMENTAL CONSIDERATIONS FOR THE IMPLEMENTATION OF MAES SYSTEMS

The correct sizing of a MAES system is very important to ensure an adequate and efficient power supply. This involves a careful assessment of energy consumption, the availability of renewable resources (sun, wind) and the site-specific climatic conditions. Factors to consider include:

- **Energy consumption**: the power required to power electrical equipment and appliances is evaluated.
- **Renewable resources:** The energy potential of available renewable sources, such as solar radiation and wind speed, is analysed.
- **Climatic conditions:** Seasonal variations in energy resources and the impact of weather conditions on the performance of the system are considered.

The investment costs for a MAES system include the purchase and installation of components, such as solar panels, wind turbines, batteries, and inverter. Operating costs are related to maintenance, component replacement, and auxiliary power consumption. The lifespan of the components of a MAES system can vary significantly, from a few years for batteries to decades for solar panels. Maintenance costs are influenced by the complexity of the system and the operating conditions.

MAES systems have a significant positive impact on the environment, helping to reduce greenhouse gas emissions and promote the use of renewable energy. However, it is important to assess **the impact of these systems throughout their entire life cycle,** from component production to disassembly and recycling.

- **Production:** The production of solar panels and wind turbines involves energy consumption and greenhouse gas emissions. However, the energy generated by these systems over their lifetime quickly offsets these initial emissions.
- **Operation:** During operation, the MAES systems do not produce direct emissions of pollutants.
- **Disassembly and recycling:** At the end of their life, MAES components must be properly disassembled and recycled to minimize environmental impact.

The implementation of the MFA systems is significantly influenced by the legal and political framework. Regulations on renewable energy and energy efficiency vary from country to country, but generally encourage the development and use of these technologies.

- **Renewable Energy and Energy Efficiency Regulations:** These regulations set national targets for renewable energy production, provide financial incentives for investment in ESAM systems, and promote energy efficiency in different sectors.
- **Financing and incentive programs:** Governments and financial institutions offer a variety of financing programs and incentives to support the implementation of MAES systems, such as low-interest loans, grants, and green certificates.

The successful implementation of an ESAM system requires a detailed analysis of technical, economic, legal and environmental aspects. Through careful planning and evaluation of the specific factors of each project, significant benefits can be achieved in terms of energy autonomy, cost reduction and environmental protection.

CONCLUSIONS

The mobile module for ensuring energy autonomy from sustainable sources (MAES) represents a strategic solution for the military sector, offering a series of advantages that can transform the way operations are carried out in the field.

The ability of these systems to generate electricity in isolated areas, without being dependent on infrastructure, makes them indispensable in remote missions or in conflict zones. The MAES ensures increased energy autonomy, reducing vulnerability to attacks on conventional power grids and thus increasing operational resilience. In addition, by using renewable sources, these systems contribute to reducing the carbon footprint of military activities, aligning with global efforts to protect the environment. Investments in the development and implementation of the MFA are essential to modernize the armed forces and enable them to meet the complex challenges of the 21st century.

This innovative technology not only improves operational efficiency, but also helps boost troop morale by providing increased comfort in conflict zones. Therefore, it is imperative that the authorities pay particular attention to the promotion and implementation of the MFA within military structures, recognizing the transformative potential of this technology.

In conclusion, MAES represents a strategic investment with a positive impact on both military efficiency and the environment. By adopting this technology, the armed forces can become more agile, more sustainable and better prepared to face the challenges of the future.

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METHODS AND TOOLS USED TO INVESTIGATE INTERACTION BETWEEN AEROSOLS AND CLOUDS

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Abstract: *The interaction between aerosols and clouds is a relevant factor in global, regional and local climate change. The scientific community is trying to provide relevant theoretical and experimental benchmarks on aerosol loading, cloud formation patterns and trends. Aerosol–cloud interactions play a vital role in global climate change and are associated with one of the greatest uncertainties. In recent decades, due to its unique geographical location, the North Indian Ocean (NIO) has been gaining significant attention among scientific communities. Deep understanding of aerosols and their interaction with clouds in this region is very important both regionally and globally.*

The paper provides both an overview of the most used methods and tools used in experimental approaches in the field, as well as an analysis methodology regarding aerosol-cloud interaction scenarios.

Keywords: *clouds, aerosols, 4D sniffer, uRAD monitor, meteorological survey, interferometer, radiometer*

Acronyms

ACTRIS	*Aerosol, clouds, and gases research infrastructure*	*AOD*	*Aerosol optical depth*
AERONET	*Aerosol RObotic NETwork*	*LARSS*	*Laser Airborne Remote Sensing Signal*
LIDAR	*Light detection and ranging*	*NIO*	*North Indian Ocean*
UEFISCDI	*Executive Agency for Higher Education, Research, Development and Innovation Funding*		

1. INTRODUCTION

1.1. General considerations

The interaction between aerosols and clouds is a relevant factor in global, regional and local climate change. The scientific community is trying to provide theoretical and experimental benchmarks on aerosol loading, cloud formation patterns and their trends. Clouds, together with aerosols, contribute the greatest uncertainty to terrestrial energy and hydrological calculations [1, 2, 3, 4]. Aerosols act directly on cloud properties due to their influence on internal cloud processes. [4, 5], see Fig. 1.

Research shows progress in understanding both the microphysics of aerosols that contribute to the activation of cloud nuclei [5, 6, 9] and the transport phenomena that allow the supply of aerosols far from the source areas (Euro-Atlantic) [7, 8].

At the same time, numerical simulations have demonstrated the impact of aerosols (such as mineral dust) on cloud processes as a function of concentration and the chemical composition of the atmosphere [10, 11, 12].

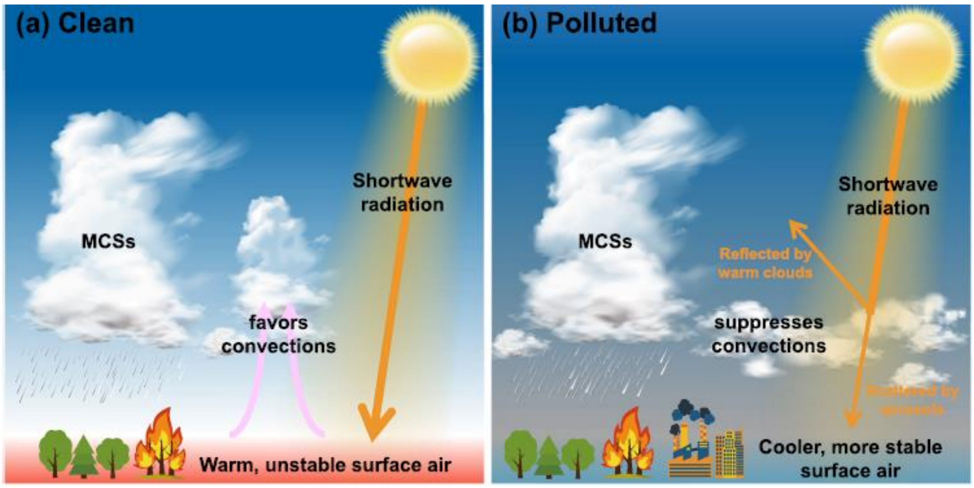


FIG. 1. Anthropogenic impact of aerosols, [3]

General approaches on aerosol-cloud interactions are transposed in a series of scientific papers from 2016 Jiwen Fan et all [13], from 2021 Wehbe [14], from 2023 Hamish Gordon [15], Michibata et all [16], satellite-based estimates of the radiative forcing of aerosol-cloud interaction Hailing Jia et all [17] or the evaluation of the stability of the aerosol-cloud interaction index by simulating radar or LIDAR signals (LARSS) C.M. Zambrano et all [18].

1.2. Application of aerosol data analysis

Numerical data analysis can highlight the complex phenomena associated with aerosols, the main applied areas are:

a. environmental quality management and monitoring with the identification of aerosol concentration and pollution sources through online monitoring, generation of predictive models and issuing policies for assessing and combating pollution [19, 20];

b. climate change research (atmospheric radioactive behavior) with the quantification of the impact of aerosols on local, regional and global temperature, the role of aerosols on precipitation and climate modeling [21, 22];

c. public health by assessing the risk and impact of exposure to different types of aerosols, identifying disease outbreaks and developing public health intervention policies [23, 24];

d. agricultural productivity by predicting crop yields based on aerosol-related factors (air quality and climate), pest and disease control, optimizing irrigation activities based on aerosol-based meteorological models [25, 26];

e. atmospheric chemistry by analyzing the chemical composition of aerosols and their generating sources, studying kinetic reactions and understanding the role of aerosols in acid rain [27, 28];

f. environmental monitoring by assessing ecosystem health and biodiversity, soil and water quality [29, 30];

g. renewable energy by assessing the potential impact of aerosols on alternative (renewable) energy sources, air pollution control and energy (efficiency) optimization [31, 32];

h. transport through visibility monitoring (aerosol concentration monitoring), vehicle emissions (emission reduction technologies) and specific infrastructure design, [33, 34];

i. urban planning through land use planning, urban greening (increasing air quality in urban areas) and urban transport (sustainable transport modes), [35, 36];

j. natural disasters through monitoring and forecasting of wildfires (aerosol analyses) volcanic eruptions (impact of volcanic aerosols on air quality) and forecasting of dust storms and their effects on the environment [37, 38].

2. METHODS AND INSTRUMENTS USED IN THE ANALYSIS OF AEROSOL-CLOUD INTERACTION

2.1. Method

Aerosol-cloud interactions are a complex and dynamic field of atmospheric science with significant implications for global climate. To better understand these processes, researchers use a wide range of methods and instruments, both on the ground and in the atmosphere.

Ground-based data acquisition is achieved using terrestrial aerosol monitoring networks using photometers (light intensity), snow gauges, spectrometers (chemical composition); weather stations (atmospheric parameters), weather radar (three-dimensional images of atmospheric parameter distributions), and LIDAR (vertical profile measurement of clouds and aerosols), Fig. 2. [39, 40, 41]

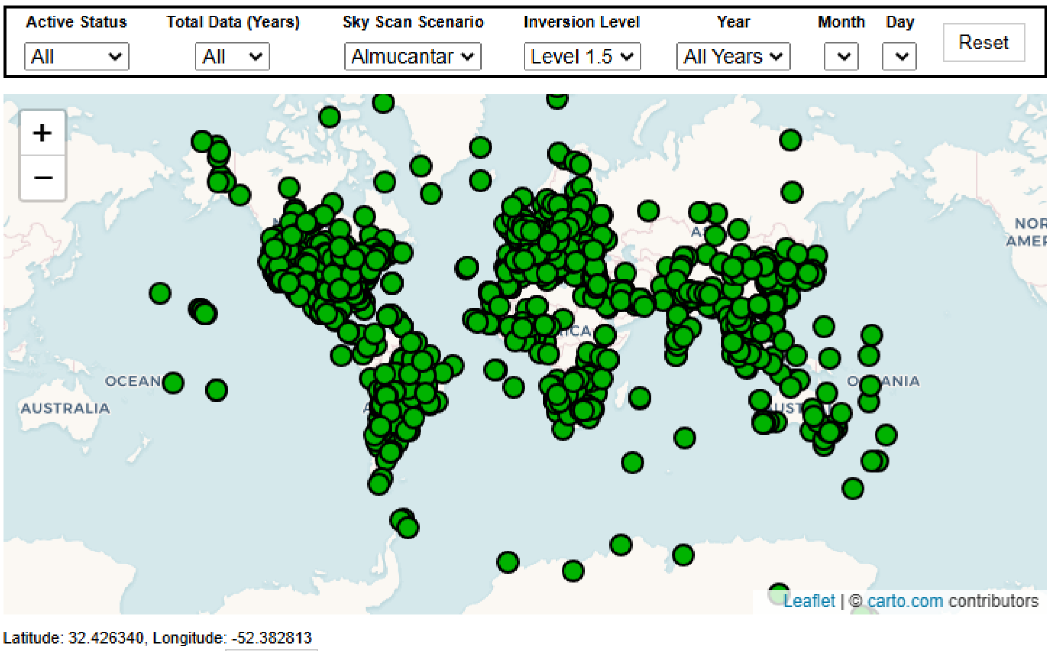


FIG. 2. AERONET data display interface [39]

Atmospheric data acquisition can be instrumented with:

a. weather balloon-type atmospheric probes for measuring vertical profiles of temperature, pressure and humidity (and aerosol concentration);

b. research aircraft (or UAVs), equipped with dedicated sensors for direct atmospheric or in-cloud measurements (aerosols, electrical parameters, water droplets):

c. satellites equipped with radiometers or LIDAR, providing high-resolution global-scale images of aerosols and clouds. [42, 43]

2.2. Instruments

The acquisition and processing of data on aerosol-cloud interaction can be achieved with a series of specific instruments with operating performances proportional to the acquisition and operating cost (accuracy, data resolution), here are some examples:

a. uRADMonitor (web and network data), is a fixed automatic monitoring station (can also be mounted on UAV), the data being exported to the uRADMonitor network, see Fig. 3 and 4. [44, 45]

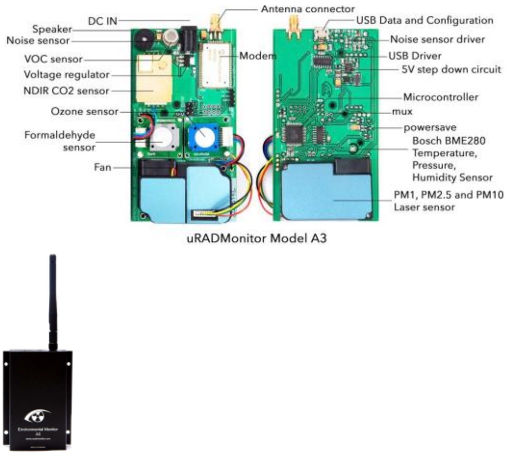


FIG.3. uRAD monitor

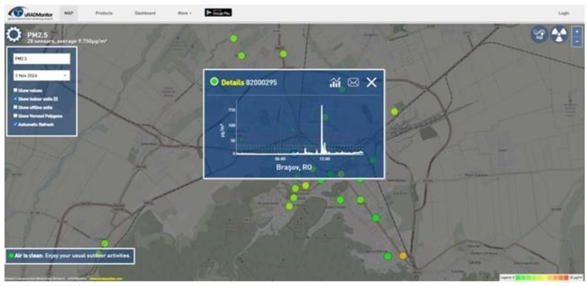


FIG.4. Web interface URAD monitor

b. Polarization-sensitive LIDAR (with two wavelengths) for monitoring vertical profiles of aerosols and clouds (e.g. ceilometu LIDAR), see Fig. 5. [46, 47]

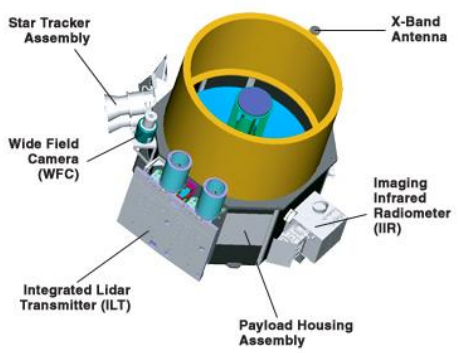


FIG.5. LIDAR – CALIOP [47]

FIG.6. Radiometer [48]

c. spectral radiometer (photometer), which operates on the principle of measuring solar radiation at certain wavelengths, see Fig. 6. [48]

d. modular aerosol monitoring systems, which can measure the degree of radioactive contamination of the air due to radioisotopes of particles in the air [49]

3. SOFTWARE FOR AEROSOLS DATA ANALYSYS

Data analysis can generate relevant results regarding the management of the phenomena underlying aerosol-cloud interaction, here are a number of software options that can be used:

a. R – opensource software tool that provides a statistical computing environment based on extensive libraries for data manipulation and visualization, it contains aerosol-specific packages OpenAir and dataMaid, [50] *b. Python*, can be used for data analysis, machine learning and web development, based on a number of popular libraries (NumPy, Pandas, Matplotlib) or aerosol-specific libraries (AerosolPy, MetPy) [51]

c. MATLAB, is a commercial software based on a mathematical computing environment (matrix and numerical analysis and integration with Simulink) that contains aerosol-specific modules such as Aerosol Toolbox or Meteorology Toolbox, [52].

d. ArcGIS, is a software tool for analyzing and visualizing spatial data (grouping, interpolation, geostatistics), it can integrate aerosol data with other spatial data: meteorological, georeferencing, population, see Fig. 7 [53].

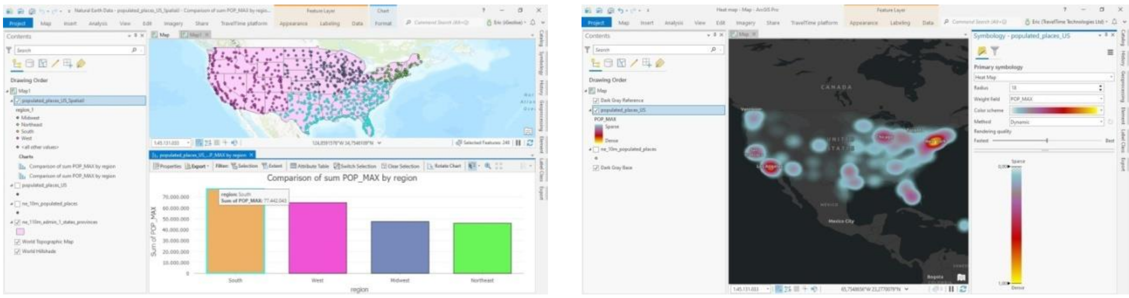
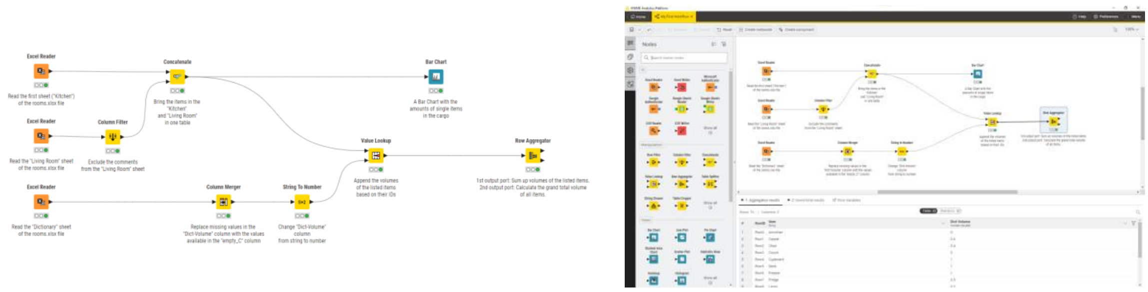


FIG.7. ArcGIS software interface

e. KNIME, is an open-source data analysis platform that provides both a visual interface for aerosol workflows and other relevant data sources, as well as integration with other popular analysis tools such as R and Python, see Fig. 8 [54].



a b

FIG.8. KNIME software a. workflow, b.interface [54]

f. SAS, is a commercial software tool for statistical analysis and data extraction, offers aerosol-specific procedures (spatial analysis, time series analysis), it can be integrated with other SAS products such as Entreprise Guide and Visual Analytics, see Fig. 9 [55].

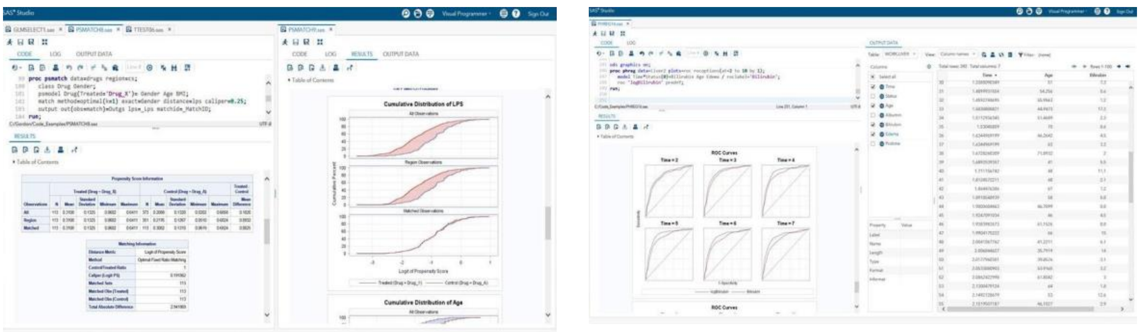


FIG. 9. SAS software interface [55]

g. Statistica, a commercial software tool based on a series of analysis tools (descriptive statistics, hypothesis testing, regression analyses), it can be integrated with other Statistica tools (Miner and Entreprise), see Fig. 10. [56].

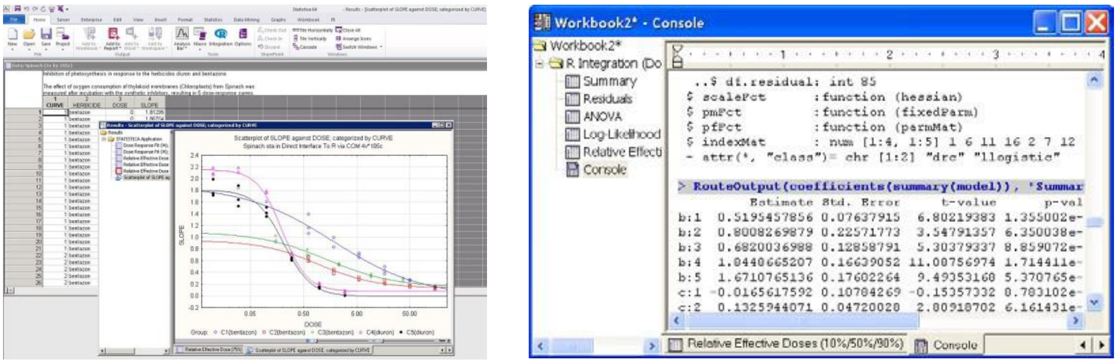
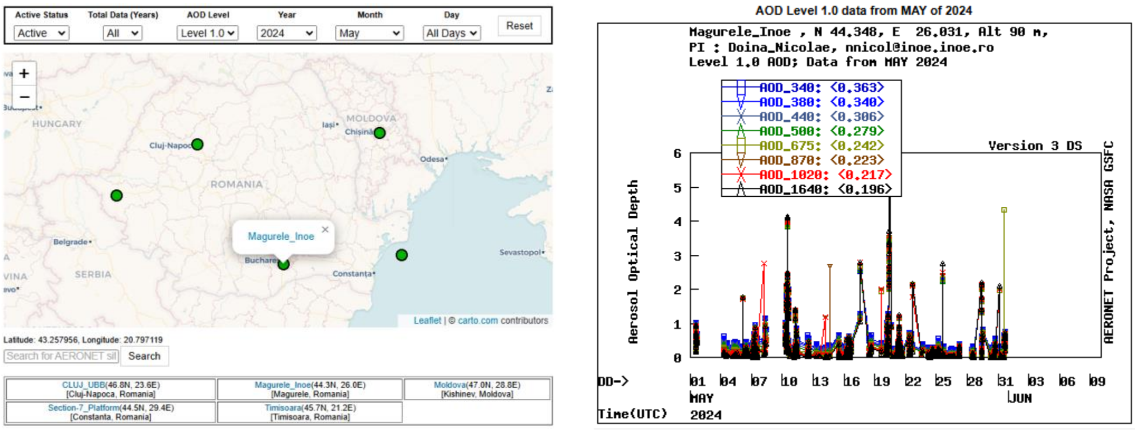


FIG. 10. Statistica software interface [56]

h. SPSS, a commercial software tool for popular or special statistical analysis (aerosol analysis), can be integrated with other IBM products such as Watson Studio or Modeler [57].

4. DATA ACQUISITION FOR AEROSOLS IN ROMANIA

AERONET is a federation of aerosol remote sensing networks (spectral optical depth) owned by NASA and PHOTRONS extended by collaborating entities such as RIMA, AEROCAN, AEROSPAIN, NEON and national agencies, institutes or universities. The data displayed are acquired from the INOE-Măgurele location, using AERONET [39] valid for May 2024, see Fig. 11.



a b

FIG. 11. AERONET network, a.Romanian location, b. aerosol optical depth AOD [39]

ACTRISS is a pan-European research infrastructure for clouds, gases and aerosols providing freely accessible numerical data on atmospheric constituents and related processes. In Fig. 12a, for May 2024, the aerosol particle backscatter profiles (354 nm LIDAR) are highlighted and in Fig. 12b the vertical resolution profile, [41].

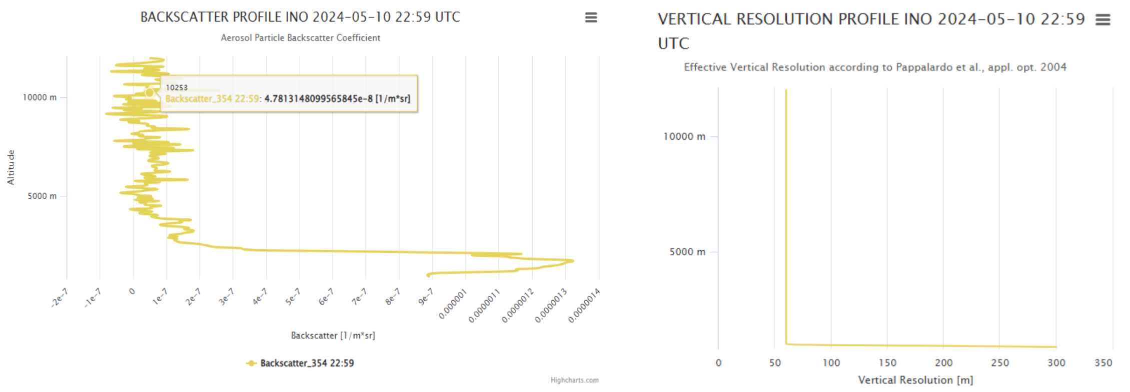


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FIG. 12. ACTRISS network, a.Romanian location, b. aerosol optical depth -AOD [41]

CONCLUSIONS

The present paper provides a panoramic view of the logical approach to aerosol-cloud interaction. The study of aerosol-cloud interaction requires multidisciplinary approaches with an integrated approach, combining both ground and atmospheric data acquisition and data analysis based on numerical models with high degrees of confidence. Understanding these interaction processes can increase the quality of climate predictions and for assessing the impact of human activities on the environment.

Aerosol-cloud interaction requires both the application of atmospheric numerical models through parameterizations of specific processes and data analysis techniques applied to the collected data to identify patterns, correlations and trends associated with field measurements.

Future specific theoretical studies will focus on multicriteria analyses of the methods and tools used in aerosol-cloud interaction to highlight their performance elements

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FROM IDEOLOGY TO IDENTITY: THE COMPLEX REALITIES OF INTERNATIONAL MILITARY VOLUNTEERS IN UKRAINE

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Abstract: *The ongoing conflict in Ukraine has drawn international military volunteers motivated by ideals far removed from financial gain. Unlike mercenaries, who fight primarily for monetary reward, these volunteers are driven by ideological convictions, humanitarian empathy, and a quest for identity and purpose, often risking their lives to support Ukraine's sovereignty. This study investigates the complex motivations, psychological impacts, and battlefield challenges faced by these volunteers. Through available literature review, this article synthesize findings from diverse studies to present a analysis of the motivations and mental health impacts that define this group. The analysis reveals three primary motivational themes: a commitment to defending democratic values, a strong sense of humanitarian duty, and a desire for personal transformation. Volunteers report significant psychological challenges, with the stress of modern technological warfare, exacerbated by surveillance and cyber operations, intensifying the need for resilience and tactical adaptability. The findings underscore the high psychological cost of volunteerism and highlight the critical difference between ideologically driven volunteers and mercenaries. This study contributes to conflict and military psychology by offering nuanced insights into modern military volunteerism. The findings underscore the need for legal protections, comprehensive mental health support, and post-conflict reintegration programs, aiming to support these volunteers who fight not for profit but for principle and solidarity.*

Keywords: *international military volunteering, ideological motivation, Ukraine conflict, volunteer psychology, modern warfare adaptation, combat motivation*

1. INTRODUCTION

The onset of Russia's military engagement in Ukraine in 2022 catalyzed a significant international response, manifesting in the mobilization of volunteers worldwide. This surge in volunteerism is not an isolated event but reflects a recurring theme in the annals of history, where ideological convictions have drawn individuals to participate in conflicts far from their homelands. Notably, mobilization echoes the spirit of international solidarity seen during the Afghan-Soviet conflict, where ideological motivations spurred thousands to join the fray. In the contemporary context, the Ukrainian crisis has galvanized a diverse cohort encompassing military veterans, humanitarian workers, and ordinary citizens, all united in their support for Ukraine's sovereignty. The plurality of motivations underpinning this engagement ranges from commitment to ideological principles to deeply personal convictions, with a significant number identifying the defense of democratic ideals against authoritarian encroachment as a pivotal concern. The precedence of such mobilizations is evident in historical instances such as the Afghan – Soviet war, where ideological and religious motivations were paramount among volunteers from predominantly Muslim countries supporting the mujahedeen against

Soviet forces. Similarly, the Bosnian conflict (1992-1995) attracted international volunteers motivated by solidarity and a desire to counter ethnic atrocities, paralleling the current influx of volunteers in Ukraine who moved by reports of aggression and human rights violations. The fight against ISIS in Syria further exemplifies this pattern, where international volunteers allied with Kurdish forces oppose extremist ideologies, driven by a commitment to defend fundamental rights and democratic values, akin to the motivations observed in Ukraine. This study seeks to delve into the multifaceted motivations of foreign volunteers in the Ukrainian conflict, exploring the unique challenges posed by a highly mediatized and technologically advanced warfare landscape. By examining both traditional and innovative combat tactics, including the use of cutting edge technology, this research aims to shed light on the adaptability and resilience required by volunteers to navigate the complexities of modern battlefields. This exploration contributes to the corpus of literature on international military volunteering, offering nuanced insights into the interplay between ideological fervor, psychological resilience, and tactical adaptability within the context of contemporary global conflicts.

2. BACKGROUND AND LITERATURE REVIEW

International military volunteering is a recurrent phenomenon in global conflicts, involving ideological stakes and universal values. According to international norms and the law of conflict, military volunteering refers to a person's free commitment to provide military support to a combatant party in an armed conflict, without external coercion. In international humanitarian law, military volunteers differ from mercenaries in their motivation - based on ideological or humanitarian convictions, not financial gain [19].

This legal framework is essential for the clear delineation between volunteers and mercenaries, legitimizing volunteer participation as an expression of solidarity and ideological commitment, especially in the context of major political and humanitarian crises. Military volunteering is legally acceptable as long as participants abide by international rules and do not carry out aggressive or illegal actions [5].

Against the backdrop of Russia's invasion of Ukraine in February 2022, the Ukrainian government established the International Legion of Territorial Defense of Ukraine, which has become a center of attraction for international volunteers committed to supporting Ukrainian sovereignty. This unit, also known as the International Legion of Ukraine, has attracted thousands of fighters from various countries, including the US, Canada, France, Germany, the UK, as well as Latin America and Asia [20].

The International Legion of Ukraine was created as a component of national defense, thus allowing the participation of foreign fighters under the direct authority of the Ukrainian armed forces. Members of this legion are paid a stipend to cover basic needs and support the continuity of combat, similar to Ukrainian soldiers. Thus, these volunteers are not considered mercenaries according to Article 47 of Protocol I of the Geneva Conventions, which defines mercenarism as an activity motivated primarily by substantial financial gain.

The majority of Legion members have previous military experience, either as veterans of their home countries' militaries or as former soldiers with theater of war experience [2]. This experience contributes to their professionalism and adaptability on the battlefield, although there are variations in training and skill level among unit members.

Although the international community does not perceive these volunteers as mercenaries, Russian propaganda often mischaracterizes them as "paid soldiers", however, the volunteers are motivated by a desire to defend Ukrainian democracy and sovereignty, viewing their involvement as an act of moral duty.

International volunteers in the Ukrainian Legion are motivated by a mixture of ideological and humanitarian factors. An analysis of ideological motivations, shows that many volunteers perceive the conflict in Ukraine as a defense against global authoritarianism, thus contributing to the strengthening of democratic values internationally [14].

A report [11] by the International Center for Counter-Terrorism (ICCT) indicates that about 60% of foreign volunteers in Ukraine are motivated by a desire to defend freedom and democracy, seeing Russia as a direct threat to these values, another study reveals that many of these volunteers identify with an international resistance group against oppression, seeing themselves as a barrier against the spread of authoritarianism [22]. A study [7] suggests that some volunteers are deeply influenced by reports of war crimes and attacks on civilians, perceiving their participation as a moral duty to protect the Ukrainian population from violence and abuse. This humanitarian motivation is similar to that found in other conflicts, such as the Bosnian war, where international volunteers have been driven by concerns for human rights and the protection of civilians. Another study [10] adds that the majority of the volunteers interviewed see the aggression against Ukraine as a threat not only to a nation, but also to the fundamental principles of international humanitarian. Some volunteers join conflict out of a desire for identity transformation and the regaining of personal purpose, perceiving their involvement in conflict as an opportunity to give new meaning to life and find camaraderie in a global context of solidarity [2], this study found that 45% of the volunteers surveyed see the experience as a way to overcome feelings of isolation or disillusionment in civilian life.

The literature provides numerous historical examples of military volunteering, many of which have significant parallels with the International Legion in Ukraine. For example, in the Afghan-Soviet war (1979-1989), thousands of volunteers from predominantly Muslim countries joined the mujahedeen to resist the Soviet invasion, motivated by religious beliefs and opposition to communism. Similarly, the Bosnian war (1992-1995) attracted international volunteers who, out of religious solidarity, supported the Bosnian Muslim community, seeing their involvement as a defense of humanitarian values and a response to ethnic atrocities. Similarly, in the conflict in Syria (2014-2019), many international volunteers joined Kurdish forces to fight against ISIS extremism, motivated by solidarity with Kurdish values and a desire to defend fundamental rights and democracy.

3. METHODOLOGY

This study utilizes a documentary analysis methodology based on reviewing and synthesizing interviews conducted by other researchers in the field of international military volunteering. This approach allows for an in-depth assessment of the experiences and motivations of international volunteers involved in the conflict in Ukraine through secondary analysis of qualitative data. In this study, the documentation was conducted by analyzing recent studies and interviews published in academic and reputable media sources in order to provide a comprehensive perspective on the phenomenon of international military volunteering in Ukraine, exploring the ideological and psychological aspects underlying volunteer participation. This approach allows triangulating information from a variety of sources, thus improving the reliability and accuracy of the findings.

For the analysis, interviews and qualitative studies published by researchers were selected using strict criteria of validity and relevance. The selection process focused on materials from recognized academic sources, reputable publications and international media reports published after 2022, thus ensuring the timeliness of the data and their correspondence with the context of the conflict in Ukraine. Studies were selected based on the following criteria:

- Thematic relevance, the chosen materials contain details about the motivations, experiences and psychological challenges of international volunteers.
- Methodological rigor, only studies that used recognized methodologies and provided detailed descriptions of the methodological framework were included.
- Compliance with ethical standards, only interviews that were conducted in accordance with ethical regulations and which ensured anonymity of the participants were included in the analysis.

To comply with ethical standards of secondary research, the analysis was conducted with caution to avoid interpretations that could compromise the confidentiality of the original participants. As this study is based on previously validated and published data, the results obtained are strengthened by triangulating information from multiple sources.

4. FINDINGS

This section summarizes the results of the literature review on the motivations, battlefield experiences and psychological impact on international volunteers in Ukraine. Recent studies provide detailed insights into the profile of volunteers, their motivations and the unique challenges they face in the context of a highly publicized and technologically advanced war.

The motivations to get involved in the conflict in Ukraine are complex and fall into three main categories: ideological commitment, humanitarian solidarity and the desire for personal development.

A central motivation for volunteers is the perception of the conflict as an essential struggle to protect democratic values against authoritarianism. In an analysis of 50 interviews with volunteers, Käihkö notes that the majority of participants perceive their mission in Ukraine as part of a global effort to counter authoritarian expansion [13]. The report by the International Centre for Counter-Terrorism shows that about 60% of foreign volunteers in Ukraine are motivated by a desire to defend freedom and democracy, perceiving Russia as a direct threat to these values [11]. Studies also analyzes motivations through the lens of psychological factors, emphasizing that volunteers identify with an international resistance group against oppression and perceive themselves as a barrier against authoritarianism.

Many volunteers are deeply influenced by reports of war crimes and attacks on civilians [7], from the 40 interviews analyzed, the researchers found that 70% of volunteers perceive their participation as a moral duty to protect the Ukrainian population from violence and abuse. This humanitarian motivation is similar to that observed in other conflicts, such as the Bosnian war, where international volunteers were mobilized by human rights and civilian protection concerns. The majority of volunteers interviewed perceive the aggression against Ukraine as a threat not only to a nation, but also to fundamental principles of international humanitarian law [10].

Some volunteers are motivated by a deep desire for identity transformation and personal development [2], they perceive participation in conflict as an opportunity to give new meaning to their lives and find camaraderie in a context of global solidarity. In a sample of 30 volunteers surveyed, 45% mentioned that involvement in the conflict in

Ukraine gave them the chance to experience a strong existential meaning, in contrast to the alienation and disillusionment they had experienced previously.

International volunteers in Ukraine face a unique set of tactical challenges, imposed by combining modern technologies with traditional combat strategies.

Adapting to drone warfare and advanced technology: volunteers in Ukraine need to adapt quickly to a battlefield where drones and advanced surveillance systems are widely used, nearly 70% of the international combatants surveyed feel considerable psychological pressure due to the constant risk of detection, which requires rapid adaptation to defensive strategies against aerial attacks and digital surveillance, they also note the psychological impact of surveillance technologies and the constant pressure to adapt to new combat conditions [6].

Trench warfare and defensive strategies: an analysis [23] based on the experiences of foreign combatants highlights the challenges of trench warfare, which requires significant physical and psychological endurance. Volunteers are exposed to intense artillery barrage and are forced to use modern defensive structures and adapted methods to protect themselves from continuous attacks. The study shows that 80% of the volunteers experience a significant psychological impact due to prolonged exposure to the harsh trench conditions and the constant need to remain vigilant in the face of attack.

The conflict in Ukraine generates profound psychological effects on volunteers, who are subjected to constant exposure to trauma and high stress [9], volunteers experience a variety of psychological effects, including anxiety and emotional exhaustion. In a sample of 25 volunteers, 68% reported symptoms of chronic stress and insomnia, noting that ideological motivations help them cope better with stress. Studies [21] confirm high rates of PTSD and depression among volunteers with prolonged exposure to violence, both among international combatants and civilians. The study provides insight into the emotional strain and need for structured post-conflict psychological support.

The important role of social support and camaraderie in the International Legion in the psychological adjustment of volunteers who benefit from close bonds with peers exhibit greater psychological resilience despite the physical and emotional difficulties of conflict [24]. Solidarity among volunteers helps to maintain morale and a sense of belonging, thus compensating for isolation and psychological exhaustion, social relationships may function as a psychological shield against long-term PTSD.

5. FINAL ANALYSIS AND IMPLICATIONS FOR INTERNATIONAL MILITARY VOLUNTEERING

The conflict in Ukraine marks a significant moment in the evolution of international military volunteering, bringing together fighters from different cultures and backgrounds, motivated by a combination of democratic ideals, humanitarian solidarity and a desire for personal development. This trans-national mobilization, facilitated by modern technology and media communication networks, demonstrates how ideological conflicts in the digital age continue to attract global voluntary participation, even in a context characterized by high risks and complexity.

The International Legion of Ukraine is a unique example of the integration of international volunteers into the formal military structure of a sovereign state. It has created a diversified defense force that reflects an international commitment against authoritarian aggression. The volunteers contribute not only to the territorial defense of Ukraine, but also to building international support for a cause that transcends national borders, and are perceived as representatives of a global movement in defense of democracy.

The diverse profiles of volunteers in the International Legion - including experienced veterans and civilians with no prior experience - have produced an adaptable unit capable of meeting the tactical challenges of modern warfare[2]. This structure enables rapid adaptation to changing battlefield conditions and ensures a high degree of resilience and tactical innovation in the face of threats from Russian forces. In addition, the integration of international structures into national defense, is a potential model for other states facing existential threats, contributing to an increased sense of global solidarity and social cohesion [24].

Although ideological and humanitarian motivations give international volunteers a strong sense of purpose, the psychological impact of participating in a protracted conflict cannot be underestimated. According to a research [16], constant exposure to violence, risks to life, and casualties among comrades generate high levels of stress and emotional exhaustion, while combat trauma remains a significant factor in the volunteer experience. Without adequate psychological support, many are at risk of developing long-term psychological conditions such as post-traumatic stress disorder (PTSD) and severe anxiety, thus highlighting the acute need for post-conflict support and structured psychological interventions.

Another study [7] emphasizes the critical role of social and digital support networks in maintaining morale and resilience of volunteers, the camaraderie and interpersonal bonds developed during conflict prove to be crucial for stress management, providing a base of mutual support in the absence of other resources. These social and solidarity networks help to mitigate the negative effects of trauma, but also suggest the need for structured support, both in the short term and post-conflict.

Technology plays a central role in the war in Ukraine, presenting international volunteers with both unique challenges and opportunities. The use of drones, surveillance systems and digital communications is redefining the experience of volunteers on the battlefield, adding unprecedented tactical complexity. The studies [15] document the psychological pressure generated by the constant requirement to adapt to a digitized battlefield, noting that volunteers are forced to combine traditional combat skills with advanced technological knowledge to survive and accomplish complex missions.

Beyond the direct impact on combat tactics, the digital exposure of volunteers on social media has introduced an additional psychological dimension. Volunteers face pressure to manage both their work on the battlefield and their public image, which amplifies psychological stress and creates a dual role, both physical and symbolic, this media exposure increases the commitment to the mission, but it also intensifies the emotional coping demands in a conflict where both the public and the battlefield are deeply interconnected [8].

The conflict in Ukraine demonstrates an emerging trend in international military volunteerism, showing how transnational mobilization can become a crucial component of a state's defense effort. This global engagement in support of a democratic and humanitarian cause offers valuable lessons for future ideological conflicts, suggesting that such collaboration can strengthen both the military capability and the social cohesion of a nation under pressure.

The implications of this phenomenon highlight the need for a robust psychological support system for international military volunteers, especially in post-conflict transition phases. Research suggests that psychological resources and social support networks need to be systematically integrated to sustain the motivation and mental health of volunteers in the long term. At the same time, as technology continues to advance, conflict coping strategies will require specific training in order for volunteers to operate effectively and safely in intensely mediatized and digitized combat environments [16].

5. CONCLUSION

This study unravels the intricate tapestry of international military volunteering amidst the conflict in Ukraine, offering a nuanced understanding of the motivations fueling this global mobilization. These findings underscore the potent mix of ideological commitment, humanitarian solidarity, and the quest for personal development that propels individuals from diverse backgrounds to join forces in this pivotal struggle. This study contributes to the discourse on contemporary conflict studies by shedding light on the complexities of volunteer participation in a technologically advanced and highly mediatized war environment. The analysis reveals that the motivations of international volunteers are multifaceted and deeply interconnected. Ideologically, volunteers are driven by a profound commitment to defend democratic principles against the tide of authoritarianism, seeing their involvement as a crucial front in the global fight for freedom and democracy. This ideological drive is complemented by a strong sense of humanitarian solidarity, with many volunteers drawn to the conflict through reports of human rights abuses and a moral imperative to protect the vulnerable. Additionally, conflict offers a unique context for personal development, allowing volunteers to find a sense of purpose and community in the midst of chaos. Tactically, the study highlights volunteers' adaptation to a new warfare paradigm, characterized by the integration of advanced technologies such as drones and digital surveillance. This adaptation is not merely technical, but also psychological, as volunteers navigate the dual pressures of combat effectiveness and media visibility. The resilience and innovation demonstrated by these volunteers redefine the operational landscape of military volunteering, suggesting a blueprint for future engagement in similar conflicts. Psychologically, this research emphasizes the critical role of social bonds and camaraderie in sustaining volunteer morale and mental health. These internal support networks are vital for mitigating the traumatic impact of prolonged conflict exposure, underscoring the necessity of comprehensive psychological support systems for volunteers during and after their service. Conclusively, this study not only enriches our understanding of the dynamics of international military volunteering in the modern age, but also charts a path for future research in this critical area. This calls for a deeper exploration of the psychological ramifications of volunteering, the impact of technological advancements on combat tactics and volunteer experiences, and the development of support mechanisms to aid volunteers' reintegration post-conflict. Furthermore, it highlights the importance of international solidarity and the collective defense of democratic values, urging a re-evaluation of global responses to authoritarian threats. In sum, the contributions of international military volunteers in the Ukraine conflict illuminate the evolving nature of contemporary warfare and the indomitable spirit of the global citizenry united by shared ideals. As we look to the future, this study serves as a foundational reference for policymakers, military strategists, and humanitarian organizations, guiding the formulation of strategies that harness the power of volunteerism in the service of peace, democracy, and human dignity.

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THE PORTRAIT OF A LEADER - THE ROLE OF THE LEADER IN THE ROMANIAN AIR FORCE DURING PROFESSIONAL DEVELOPMENT

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Abstract: *The history of the Romanian Air Force is full of examples regarding the quality of the leaders who worked within this category of forces, and one of the aspects that made this possible was the interest shown by this organization in attracting and training them. In today's context, where the evolution of technology and the dynamics of global security require a new approach to what is desired to be a framework for training and improving leaders, the Air Force is forced to adopt a new approach to the process, one that can keep up with the imposed needs.*

Human resource development is both an individual and organizational function and responsibility. All air force personnel thus have the duty to take advantage of the facilities offered by the military organization to improve their training and thus develop their knowledge and leadership skills.

Keywords: *leadership, professional development, military profession, traits, characteristics, skills and attitudes of a leader, Romanian Air Force.*

1. INTRODUCTION

When we approach a profession, the first aspects we refer to are those related to the work performed, the years of study and training, the diplomas to be obtained, the code of ethics and the status acquired in society. If we refer to a nurse, a policeman, an accountant, an architect, a priest or a soldier, there is only one thing, common to all of them, that will make us truly understand what a profession is, namely that it is a calling, a vocation.[1]

The basic task of the military profession is the armed defense of the society, the territory, the population and the vital interests of the nation. In this sense, the defining mission of the armed forces is the preparation and conduct of war, which includes securing military victory until the political restoration of peace. The combat mission is therefore what determines how forces are organized, equipped and trained. Regardless of its special forms, this unique and specialized service to the nation gives the military profession its own distinctive nature and status.

The military profession is seen as a lifestyle, which goes beyond the framework expressed by the notion of simple occupation, or what you have to do to occupy your time and earn a daily living. The military profession is a way of being, a way of thinking, a way of behaving and a way of growing. In short, it is a way of life, more than a job or lifestyle.

The military also requires an exceptional level of commitment from its members.[2]

Military service, as we stated earlier, is synonymous with sacrifice, involving long periods of separation from family members, frequent movements and displacements, the rigors of intense training and the horrors of combat. A military life is rewarding, but it is also hard, taking both a physical and emotional toll.

There are certainly professionals, from various fields of activity, who would say that they do what they do for various reasons, including the love of what they do, the fact that they can't do anything else, or that they would do it regardless. whether or not it would be remunerated in any way. The military profession must not be limited to the frameworks created by these stereotypes, and that is why it is important to distinguish between being military, from an occupational point of view, as a profession, and military as a profession.

The job of a military officer represents the highest embodiment of the military profession. The moment an individual chooses the military career, to serve in the officer corps, represents the moment he chooses to join a body of leaders who have proudly chosen to serve the nation and dedicate themselves to achieving uplifting ideals.

A leader's maturity develops progressively throughout their career. Lessons learned at the tactical level are applied at the operational level, those learned at the operational level are applied at the strategic level, and the process continues. The accumulation of knowledge, skills and abilities, acquired at each level, represent constructive, basic elements of leadership competence. Competency components have different attributes at each level of leadership manifestation.

As for the roles and responsibilities of leaders, they are positioned throughout the three levels, in such a way that the depth and breadth of vision become personal attributes, which are acquired through experience, training and education. In this sense, the degree of use of competences in conjunction with the level of expertise can be related to the level of manifestation of leadership (Fig. 1).

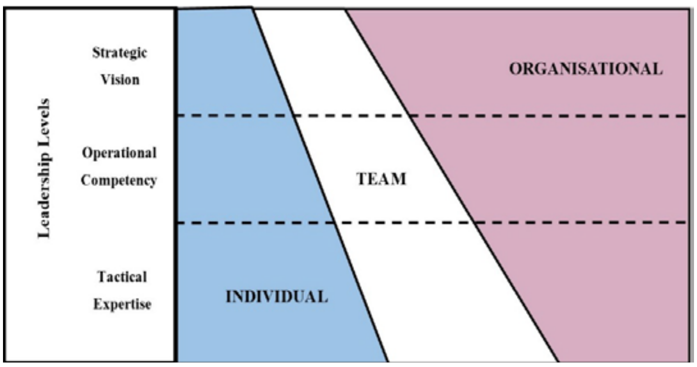

FIG. 1 Correlation of competencies with leadership levels
(adapted from Department of the Army Pamphlet (DAP) 600-80, Executive Leadership, HQ, Department of the Army, 9 June 1987, p. 4)

It is important to state that these levels can overlap and interact for organizations to achieve their results.[3] At the same time, two aspects must be mentioned: these attributes can be manifested at any level, depending on the position occupied by the leader, and that leadership it is situational and there is no recipe or formula for success.

2. THE ROLE OF THE LEADER DURING THE MILITARY PROFESSION

Roles, in essence, are the natural result of sustained human interaction and the hallmarks associated with such interactions suggest the expected behavioral pattern (eg client, parent, commander, etc.).

Roles are important because they communicate behavioral expectations: the actions necessary to execute an order as they are perceived by the executor but also by the others involved.

In his book, "*Organizational Psychology*", Edgar H. Schein states the following: "*From the point of view of an organization, the most appropriate way to think about leadership is that in which it is considered as a function exercised within it. The membership of an organization but also the management position, associated with it, must merge with each other to have an efficient organization. It is as much a member's job to help the group achieve its goal as it is the formal leader's job to do so*."[4]

In the spirit of this statement and, corroborated with the ideas supported by the theory of stratified systems,[5] I can conclude that the tasks of leaders are more and more complex as their career tends towards the upper echelons of an organization.

From the point of view of the degree of complexity of the tasks, it increases in relation to the extent to which the level of responsibility entrusted by the occupied function also increases (Fig 2). It is obvious that there is a difference, I say clear, between the type of activities carried out by leaders at the tactical level and those conducted by leaders at the operative or strategic level.

The factors that describe this differentiation are multiple and varied and are related to the complexity, the scope, the level of the commanded unit, the area of control, the vertical and horizontal relationship, the higher hierarchical level, the number of subordinates and the missions received.

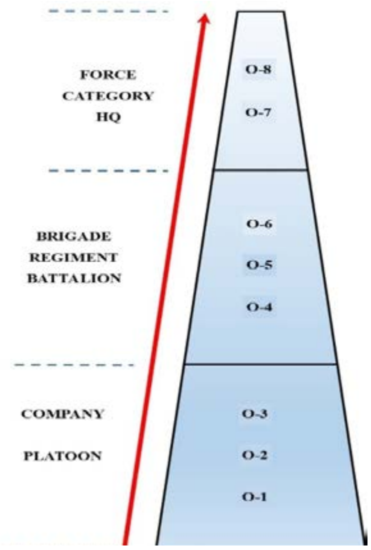

FIG 1 The pyramid of officers' career development [6]

At the lower levels of the military organization, the primary activity of officers is to conduct tasks related to real-time problems and execute missions with a limited time horizon.

Their activity can be described as leading small military structures, at platoon level, with a small number of subordinates, which requires them to make more use of their individual qualities and skills, formed and developed in the initial stage of their career. Along with entering the career and occupying positions at higher levels, the number of subordinates increases, but the degree of direct relationship with them begins to decrease. The command of the battery, battalion, regiment, brigade requires that, due to the large volume of tasks that must be solved and the planning of daily activities, to reduce the time in which direct contact with subordinates can be made.

This aspect does not imply the fact that the use of relational skills with group members is absent, only that this is done in a narrower framework, at the level of the commander's work group. The leadership exercised at this level is limited, in this way, to the subordinates in the headquarters and the members of the general staff, and at the same time an expansion of the network of colleagues/collaborators can be noted.

In other words, military leaders, in relation to the hierarchical level at which they are, lead people or institutions.[6] Leading people means developing individual, team and unit-level capacities and using them to execute the assigned tasks and missions, and leading the institution means developing and maintaining the strategic and professional capabilities of the armed forces and creating the necessary conditions for their operational success.

3. PORTRAIT OF A LEADER – AN IMAGE FOR THE PROFESSIONAL DEVELOPMENT

Taking into account the previously presented aspects, I tried to define my own, regarding the role played by the air force leader during his career, and for a better perception of the meaning, I described, in the form of an enumeration of traits, characteristics, skills and attitudes, the significance and I emphasized the importance of the role of the leader in the positions held. The leader profiles that I propose are specific and fall within a well-defined time horizon, as can be seen from the graph of the development of leaders during the military career, presented in Fig 3.

A secondary goal of creating this *so called guidance* would be to reinforce the conviction of Air Force leaders that, to be successful, they will need to identify and behave in accordance with the requirements of these roles at all times. This must also be the main reason for understanding the role he plays in the function he holds, when exactly he must act, in accordance with the status of the role, and what are its characteristic elements.

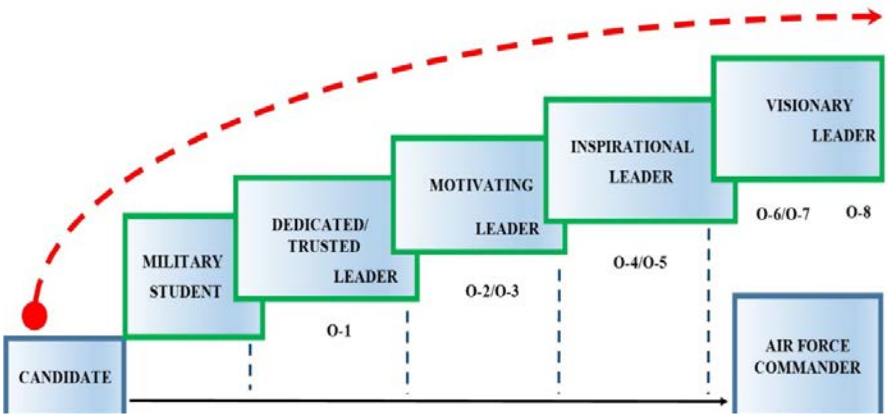

FIG 3 Development of Air Force leaders, throughout the military career [5]

The first steps in the military career can be classified under the title of *Dedicated/Trusted Leader*. The young second lieutenant is the newly formed leader within the academy who understands the relationship he must have with his chosen profession and who lives in accordance with the values of the Air Force, and in the spirit of the oath taken.

Personal values are included in the fundamental values of the Romanian Air Force. He/she is a positive example for all those around him, behavior manifested through truth, ethics, principles but also through impeccable military attire.

He/she has an enthusiastic approach to leadership, with a developed sense of time management and the ability to make plans. Shows a strong sense of duty towards subordinates, understanding the value of taking care of people, investing time to achieve their well-being but also to gain their trust and respect.

He/she is a results-oriented team leader and appreciated for the good decisions he makes, thanks to his abilities to manage risks and hazardous situations. Shows courage and calm in stressful situations, putting the needs of the team above personal needs. Exercises sound, imaginative judgment and demonstrates developed analytical ability in the management of the subunit, using clear rules and procedures in the activity of managing the resources at his disposal. In this sense, he/she quickly develops his professional skills, directly associated with his tasks, specializing, progressively, both from the point of view of knowledge of tactics and from the point of view of knowledge and exploitation of the equipment provided, thus requiring more and more little supervision.

He/she has developed writing and oral communication skills, which he/she constantly improves, improving the chain of command, by practicing two-way communication, being at the same time a good transmitter of orders and a good listener.

From the point of view of the operative art, he/she is able to understand both the nature and purpose of war.

The end of the minimum internship period in the rank and advancement to the rank of lieutenant already implies intense employment and the assumption of new responsibilities. The number of subordinates increases, simultaneously with the level of the echelon, battery/company (similar), representing the subunit at which it will carry out its activity.

As can be seen in the graph presented in Fig 3, there is a period which is common to the two classes of leaders. The transition from one level to another is not sudden, but coincides with the period in which the leader is empowered by his superiors to perform the duties of the functions targeted for recruitment.

Now is the time for the *Motivating Leader* to step into his full rights and put the commander's vision into action, preparing and completing the mission. It is the lieutenant/captain who demonstrates an innovative approach to unit administration and resource management.

Has problem-solving, decision-making and risk-management skills, anticipating demands to some extent and working independently. From a technical-tactical point of view, the level of skill improvement is high, being, in this sense, a model for high standards of performance through personal example, self-discipline and commitment to self-development.

He/she behaves ethically, demonstrating moral responsibility, and is a credible leader, acting in accordance with the requirements imposed by the Air Force's core values. He/she has influence on communication, is a good team trainer and contributes to a large extent to achieving group cohesion.

In this sense, he drives the maximum professional development of subordinates, by effectively delegating tasks, in accordance with the level of training of subordinates, and is an effective instructor, good advisor and mentor for them. He/she understands the science and art of war on a tactical level.

Advancing to the rank of major and simultaneously moving into the category of officers with a higher rank represents, for the vast majority of them, approaching the middle of their military career. It is time for every leader to start thinking about what they are leaving behind.

The experience accumulated in all these years, corroborated with the training and education received, will represent the foundations of the inspirational framework in which the majors and lieutenant colonels will have to fit.

It is time for the *Inspirational Leader* to emerge, the one who instills in all his/hers subordinates the fighting spirit and the will to win. Thus, he/she is a gifted orator, who inspires a vision, shared with that of the commander, having a strong purpose, direction and motivation. Receives the authority and responsibility of commands with enthusiasm, devotion and total commitment to mission preparation and accomplishment. In this sense, he is discerning and acts boldly and prudently, when he makes a decision, being very attentive to the risks. It includes the fundamental values of the Romanian Air Force in its command culture and becomes a moral arbiter for subordinates.

It develops a positive climate of cooperation, based on mutual trust, loyalty and respect, which leads, in unity, to the achievement of the goal and to the strengthening of the feeling of pride of belonging to the group. He/she is an innovative, critical and self-aware thinker, a skilled fighter, effective in leading with tact and confidence.

Completing the military career, from the position of senior colonel or general, is a very important stage, because it is precisely the one that sets the expectations in terms of leadership development. And these must be very large ones, commensurate with the positions occupied. *Visionary Leaders* are now seen as symbols, role models who embody the core values of the organization and set the example that is worthy of following.

At this level, the strategic leader not only serves as a role model for all members of the organization but is also responsible for creating the vision of the organization. The visionary leader shapes the future, keeping the organization's culture intact and maintaining credibility in all endeavors.

He/she is the protector of the values of the military profession and the air forces, whose behavior, actions, decisions and communication are exemplary for all members of this category of forces. He/she is the one who takes his/hers service to the highest standards, showing strength, determination and dignity.

He/she has boldness and brilliance in conceptualizing, articulating and executing an action plan. It has created a suitable command and control architecture and develops communication procedures to facilitate the decision-making process, as well as their implementation in military operations.

Shows adaptability and flexibility in the application of operational doctrine to adjust to the aggressive pace of combat in a dynamic operational environment and understands mission requirements, motivating subordinates to act with authority by giving concise and clear orders to facilitate them the actions.

Demonstrates a strategic and anticipatory perspective in terms of surprise, necessary in making certain decisions. It provides information to the entire chain of command to increase the speed of decision-making by superiors or subordinate commanders.

From the point of view of resources, it proves a high capacity to use them, effectively, to ensure the completion of the mission with minimal losses of equipment and personnel.

CONCLUSIONS

These should, in my view, be the outcomes of officer development within the Air Force, which will form the building blocks for shaping character, improving behavior, and honing the skills required of a leader as responsibilities increase throughout a military career. The results, built over time, are both inspirational and aspirational, along with the advancement in the air force hierarchy.

I believe that this *guide* can be used by leaders at all levels, as a tool for designing their own development, but also as inspiration for the development of those they lead. In this direction, it will be possible to establish personal and professional goals, which will help in obtaining such desired ones.

All of this will only be possible if one makes the most of the opportunities that air force education, courses, thematic experiences and personal development activities include.

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EMPOWERING LEADERS THROUGH INTENT – BASED LEADERSHIP: A TRANSFORMATIVE APPROACH IN MILITARY EDUCATION

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Abstract: *This article examines the application and potential impact of intent-based leadership (IBL) in military education, focusing on its ability to enhance decision-making, autonomy, and responsibility among military cadets and officers. IBL, a leadership model popularized by the former U.S.. Navy Captain David Marquet shifted authority from a centralized, top-down approach to a decentralized system that empowers subordinates to make decisions aligned with the commander’s intent. This study aims to document the existing research on IBL and analyze its effectiveness in military settings, drawing insights from both case studies and leadership programs in high-stakes environments. This article reviews documented evidence from various military academies and allied organizations, focusing on the alignment between IBL principles and the desired leadership competencies of military personnel. The findings suggest that IBL can address key gaps in traditional military leadership training by enhancing critical thinking, adaptability, and accountability among trainees. However, implementing IBL in military institutions presents challenges, including resistance from entrenched hierarchical structures, and the need for extensive cultural adaptation. This study provides a foundation for understanding the potential of IBL in military education, highlighting both the opportunities for leadership development and the structural considerations necessary for effective implementation.*

Keywords: *Intent-Based Leadership (IBL), military leadership development, decentralized decision-making, leadership models in military, adaptive leadership, command and control limitations*

1. INTRODUCTION

Intent-based leadership (IBL) has emerged as an influential model for fostering initiative, accountability, and decision-making autonomy within hierarchical organizations. Unlike traditional leadership approaches that emphasize a rigid command structure and centralized decision-making, IBL promotes a culture in which authority is distributed across team members, enabling leaders at all levels to act with a purpose and alignment to the broader mission. Developed by former U.S. Navy Captain David Marquet, IBL shifts the role of a leader from giving orders to creating an environment where subordinates are empowered to make decisions in line with the commander’s intent. This model has gained traction in various high-stakes industries, including aviation, healthcare, and emergency services, but its potential application in military education remains underexplored.

In contrast to traditional leadership models, such as transformational and servant leadership, Intent-Based Leadership (IBL) fundamentally redefines the distribution of authority and decision-making within a military context.

While transformational leadership seeks to inspire and motivate followers toward a shared vision through charisma and encouragement, and servant leadership emphasizes prioritizing the needs and development of subordinates, both models maintain a top-down approach where strategic direction and control predominantly remain centralized. IBL, pioneered by former U.S. Navy Captain David Marquet instead promoted a decentralized model, shifting authority to empower team members at all levels to make mission-aligned decisions independently, guided by the overarching intent of their leaders. This approach not only encourages autonomy and accountability but also enables quicker, more adaptive responses, which are crucial in high-stakes military environments. By fostering a culture where subordinates are actively engaged in the decision-making process, IBL aims to cultivate a more resilient and adaptable military leadership structure better suited to the complexities of modern operational contexts.

2. CONTEXTUAL BACKGROUND

Traditional military leadership models, particularly the "command and control" structure, face challenges in addressing modern military demands that require rapid adaptability and independent decision making in high-stakes environments. This top-down approach, while effective in ensuring cohesion and discipline, often inhibits junior leaders' autonomy and critical thinking. For example, studies on U.S. military training programs indicate that strict adherence to command limits subordinates' ability to develop situational awareness and adaptability, which are increasingly critical in complex, unpredictable combat scenarios.

Case studies have shown that while this structure produces disciplined forces, it can hinder effective responses under dynamically changing conditions. For instance, research within the Australian Defense Force suggests that reliance on hierarchical directives can delay timely decision making and limit proactive engagement, which are essential qualities in contemporary warfare. In contrast, models such as IBL, which encourages autonomy aligned with mission intent, foster greater resilience and operational flexibility. Studies in military academies reveal that IBL enhances initiative and problem solving among cadets, addressing gaps left by traditional methods by empowering leaders to interpret and act on commands independently.

By highlighting the limitations of command-and-control structures, these findings underscore the need for decentralized models, such as IBL, which offer a more adaptable framework for military training and leadership development in complex, fast-evolving environments.

While Intent-Based Leadership (IBL) offers promising benefits for fostering autonomy and adaptability, several limitations and criticisms of the model merit consideration, especially within structured environments like the military. First, IBL’s emphasis on decentralizing authority and encouraging individual decision-making may conflict with the strict discipline and adherence to hierarchy central to military culture. Critics argue that this shift can create ambiguity regarding authority boundaries, potentially leading to inconsistencies in decision-making, especially among less-experienced leaders who may lack the situational judgment required for high-stake decisions. This can present risks in environments where a unified response is critical, and deviations from command can compromise mission coherence.

Additionally, IBL requires a high level of trust and mutual understanding between leaders and their subordinates, which is not always feasible in high-turnover or high-stress military environments, where building such rapport may be challenging.

A lack of trust or misunderstanding about the leader's intent could result in actions misaligned with the overall mission objectives, reducing the effectiveness of the leadership approach. Research on military applications has suggested that without proper guidance and support, implementing IBL may foster uncertainty among subordinates who are accustomed to more directive forms of leadership, thus requiring a careful balancing act to avoid undermining established discipline.

Furthermore, the adaptability encouraged by IBL can sometimes lead to delays in decision-making, as leaders at various levels assess the intent behind commands rather than following pre-established procedures. In time-sensitive operations, such deliberation might hinder response speed and unity of action, particularly when decisions require immediate execution under conditions of limited information. Moreover, critics of IBL in high-stakes contexts suggest that the cognitive load imposed by making autonomous decisions may overwhelm some team members, leading to stress or indecision, especially among those not well versed in the IBL philosophy or in the operational nuances of their roles.

Finally, implementing IBL within traditional military structures often requires extensive cultural adaptation, training, and institutional support, which may not always be available or feasible in every military context. Such implementation costs, combined with potential friction between traditional military culture and IBL principles, highlight significant barriers to its full-scale adoption.

This critical perspective suggests that while IBL can address certain limitations of traditional leadership models, its effectiveness may be contingent upon carefully managed integration processes, sustained support, and adaptive modifications tailored to the unique demands of military settings.

A. Purpose of the Study

This study aims to bridge the existing knowledge gap on Intent-Based Leadership (IBL) within military education by evaluating both the potential strengths and limitations of IBL as a leadership model. However, it is essential to critically assess the quality of the reviewed studies, as some of the existing research on IBL lacks robust empirical validation. Many studies supporting IBL in military and high-stakes contexts rely heavily on case studies and observational data, which, while valuable for generating insights, often lack the rigor associated with experimental or longitudinal research designs. Consequently, findings may reflect context-specific outcomes rather than universally applicable principles, limiting their generalizability to other military settings or units.

Additionally, there is a need for more rigorous quantitative studies that assess IBL's impact on leadership qualities such as adaptability, autonomy, and decision-making efficiency within controlled military training environments. Current literature, often based on anecdotal evidence or qualitative assessments, may overstate the effectiveness of IBL without adequately addressing potential limitations. For instance, studies demonstrating improvements in decision making through IBL frequently come from civilian sectors or smaller military programs that differ significantly from the hierarchical and structured environments typical of military academies. Without more stringent research designs, including larger samples, control groups, or cross-institutional analyses, it remains challenging to determine whether the observed benefits of IBL can be effectively scaled across military institutions.

Furthermore, while the literature emphasizes IBL's principles of autonomy, mission alignment, and empowerment, it is less explicit in identifying how these principles address specific deficiencies in traditional military education models.

For example, traditional military training often emphasizes obedience and standardized responses, which may inhibit critical thinking and adaptability under rapidly changing operational conditions. Linking these gaps explicitly to IBL's principles—such as how empowering decision-making at lower levels could mitigate rigid adherence to orders—would strengthen the argument for IBL's integration. This critical lens also highlights the need for adaptive training curricula that blend IBL with established military values to create a hybrid model that respects both discipline and autonomy.

Therefore, this study seeks not only to examine the potential of IBL, but also to underscore the importance of adopting a balanced view that recognizes both the advantages and possible limitations of this model in military education

B. Significance of Intent-Based Leadership in Modern Military Training

The evolving nature of global conflict and the increasing complexity of military operations demand leaders who are not only technically skilled but also highly adaptive and resilient under pressure. Military academies worldwide face the task of producing officers who can lead in volatile environments, often with limited information and in unfamiliar contexts. The IBL model aligns with these demands, emphasizing that leadership is proactive rather than reactive, mission-driven rather than task-oriented, and based on initiative rather than rote execution. By embedding IBL principles within military training programs, academies have the opportunity to cultivate leaders who are not only capable of following orders but also skilled at interpreting and acting upon their commander's intent in ways that advance the mission.

C. Research Questions

This study addresses the following research questions to guide the exploration of IBL's applicability in military education:

1. What are the documented effects of IBL on leadership development and decision-making autonomy in a hierarchical setting?
2. How can IBL principles be integrated into existing military educational frameworks to support leadership development?
3. What challenges arise in implementing IBL within the rigid structure of military academies, and how can these be addressed?
4. What empirical evidence exists on the benefits and limitations of IBL in military or similarly high-stake fields?

In answering these questions, this study aims to build a comprehensive understanding of IBL's potential of the IBL to transform military education. By examining research findings, case studies, and theoretical frameworks, this article contributes to the ongoing discourse on military leadership development, proposing IBL as a model that aligns with the needs of a modernized, adaptable force structure.

3. LITERATURE REVIEW

The literature review explores the historical context of leadership models in military education, the foundational principles of intent-based leadership (IBL), and documented applications of IBL in both military and civilian high-stake environments. This section synthesizes existing research to provide an understanding of how IBL can align with and enhance military training objectives, addressing both the potential benefits and challenges of its implementation.

Military leadership models have traditionally emphasized a strict hierarchy with top-down command structures, a method designed to ensure unity of action and disciplined execution under high-pressure conditions.

This "command and control" approach has proven effective in maintaining order and cohesiveness, yet it can limit individual agency and hinder adaptive decision-making at lower levels. Research indicates that while this model instills discipline, it often restricts subordinates' ability to take initiative or think independently under dynamic operational conditions [5].

As warfare has evolved to require rapid adaptation and decentralized decision making, alternative models have been considered in military education. Servant leadership, transformational leadership, and decentralized models, such as Auftragstaktik (mission command) from the German military doctrine, have gained attention. These approaches prioritize the development of individual leadership capacities and autonomy, which are essential in complex, modern conflict scenarios. The shift toward these models aligns with the goals of IBL, which emphasizes empowering subordinates while maintaining a clear mission focus [7].

Moreover, as empirical evidence directly assessing IBL in military contexts remains scarce, this methodology relies on extrapolations from case studies and experience from sectors with fundamentally different operational structures. The lack of direct, longitudinal studies within military settings makes it challenging to validate IBL's long-term impact on leadership development and operational effectiveness, underscoring the need for future research that rigorously tests IBL in military academies.

4. FINDINGS AND ANALYSIS

In this section, we present key findings from the collected studies and case analyses, examining the potential benefits and challenges of adopting intent-based leadership (IBL) in military education. The findings were organized according to four thematic areas identified during the analysis phase: leadership autonomy and initiative, decision-making and adaptability, trust and accountability, and challenges of integration.

A. Leadership Autonomy and Initiative

Research demonstrates that IBL enhances leadership autonomy by empowering individuals to make mission-aligned decisions without relying on constant directives from superiors. In military training environments, fostering autonomy could prepare cadets and junior officers to act decisively in high-pressure situations. Studies on decentralized leadership models, such as mission command, show that encouraging autonomy strengthens leadership skills by requiring trainees to understand the broader mission and act accordingly, rather than simply following orders [6].

The For example, in the U.S. army uses mission-oriented training exercises, and cadets are instructed to execute commands based on mission intent, allowing them to adapt tactics and make decisions independently. This approach aligns closely with IBL principles, as it encourages trainees to think critically about their actions within the scope of the commander's goals rather than rigidly following predetermined steps [5]. Such methods have been shown to build resilience, situational awareness, and initiative—qualities that are vital in complex combat scenarios.

B. Decision-Making and Adaptability

One of the most significant advantages of IBL is its potential to improve decision-making efficiency and adaptability in volatile environments. Studies in civilian high-stakes settings, such as healthcare and emergency services, have shown that IBL enhances responsiveness by allowing team members to make real-time decisions without waiting for orders from superiors. This adaptability is crucial in military operations, where changing conditions often require immediate action [2].

In military training, adaptability is often developed through simulations and live exercises that challenge trainees to respond to unexpected scenarios. Research on the U.S. Air Force's exploration of servant leadership as a means of promoting flexibility and initiative among cadets underscores the benefits of leadership models that prioritize mission intent over rigid control [1]. Adopting IBL could enhance these training exercises by requiring cadets to interpret and act on mission goals, thereby honing their ability to adapt their strategies and tactics in response to evolving circumstances.

C. Trust and Accountability

IBL places a high emphasis on trust between leaders and subordinates, which fosters accountability across all levels of an organization. By giving subordinates the freedom to make decisions, IBL requires a culture in which leaders trust their team members to act in the best interests of the mission. Studies on trust-building in military and civilian settings have highlighted the positive effects of such leadership approaches on organizational cohesion and individual responsibility [7].

For example, research from the Australian Defense Force has shown that trust is a critical component of effective leadership development. In environments where autonomy is supported, officers tend to exhibit greater accountability and are more engaged in their roles, as they feel responsible for both their actions and the outcomes of the mission [7]. This aligns with IBL's objective of cultivating responsible, mission-focused leaders who are prepared to take initiative when required.

D. Challenges and Limitations of IBL in Military Education

Although IBL offers numerous potential benefits, its implementation in military education faces considerable challenges. Military institutions are typically built around hierarchical structures that emphasize discipline, uniformity, and adherence to a chain of command. Introducing a decentralized leadership model, such as the IBL, can overcome resistance due to cultural and structural factors inherent to military institutions. The emphasis on hierarchy and control may conflict with IBL's principles of autonomy and distributed decision-making, making it difficult for leaders and trainees to shift from traditional models [4].

Additional research indicates that successful implementation of IBL would require significant adjustments in military training and education curricula. This includes rethinking the role of instructors, shifting evaluation criteria from task execution to decision-making quality, and providing institutional support for experimentation with decentralized leadership models. Furthermore, some studies suggest that not all trainees are equally prepared for the demands of autonomous decision-making, and additional support may be required to transition them from a follower mindset to one that is initiative-driven [5].

E. Comparative Case Studies

In reviewing military and civilian case studies, we found consistent support for the idea that decentralized models such as IBL enhance leadership qualities by empowering individuals to think critically and act independently. For instance, case studies of medical education programs utilizing IBL have demonstrated improvements in situational awareness and trainee engagement. These outcomes suggest that military academies could achieve similar results if they incorporate IBL principles into their curricula [2].

In summary, the findings indicate that while IBL offers a valuable framework for military education, its successful implementation requires a nuanced approach. The model's emphasis on autonomy and mission-aligned decision making aligns well with the evolving needs of modern military operations.

However, adapting IBL to military institutions will require overcoming cultural resistance, modifying training approaches, and ensuring that trainees are equipped to handle increased responsibility and initiatives.

The insights from this analysis will inform subsequent discussions on the feasibility of adopting IBL in military education and the strategies necessary to address potential challenges.

5. EVALUATION OF FINDINGS

The findings highlight both the potential advantages and challenges of implementing intent-based leadership (IBL) in military education. In this section, we discuss how IBL can enhance leadership qualities in military personnel by fostering autonomy, decision-making skills, and accountability, while also addressing the structural and cultural barriers that may complicate its integration.

A. Benefits of IBL in Military Training

The documented benefits of IBL closely align with the goals of modern military education. By empowering individuals to interpret and act on the commander's intent, the IBL encourages initiative and promotes mission-focused decision making. This approach cultivates several qualities that are essential to military leaders.

Enhanced Autonomy and Initiative: Traditional military training often focuses on adherence to protocols. Although discipline is critical, it can sometimes limit the development of independent judgments. IBL encourages trainees to take ownership of their roles and make mission-aligned decisions, which research shows can build resilience and adaptability, particularly under pressure. In an operational setting, leaders trained under IBL would likely exhibit stronger decision-making abilities in complex or rapidly changing environments [6].

Improved Decision-Making Speed and Adaptability: IBL's decentralized approach allows for faster responses to emergent situations, as leaders on the ground have the authority to make decisions based on their understanding of the mission's goals. This adaptability is essential in military contexts where conditions can change unpredictably. Civilian case studies, such as those in healthcare and emergency services, provide evidence that decentralized leadership models like IBL can improve situational awareness and responsiveness, outcomes that are critical for military operations [2].

Building Trust and Accountability: By empowering subordinates to make mission-critical decisions, IBL fosters a culture of trust and accountability. Leaders in IBL environments learn to trust their teams, which in turn builds stronger cohesion and dedication to the mission. Studies show that such trust-based environments lead to higher levels of accountability as team members invest more in the success of their decisions. This is particularly relevant in military training, where developing trust within a hierarchical framework is essential [7].

B. Challenges to Implementation in Military Academies

Despite its potential, IBL faces structural and cultural barriers in military settings, where traditional hierarchies and command structures are deeply ingrained. Transitioning to a model that emphasizes decentralized decision making may require significant adjustments at both institutional and cultural levels.

Cultural Resistance to Decentralization: Military institutions often prioritize order, discipline, and a clear chain of command. These principles can conflict with IBL's decentralized approach, which emphasizes individual autonomy.

Shifting from a directive-based model to one that encourages initiative and independent decision-making may encounter resistance from both instructors and trainees accustomed to a more structured environment [4].

Training Adaptations and Curriculum Changes: Implementing IBL in military academies would likely require modifications to training curricula, focusing on developing critical thinking and decision-making skills alongside traditional military competencies. Case-based teaching methods, which encourage scenario-based problem-solving, align well with IBL's objectives. However, integrating such methods into the existing military education framework may necessitate changes in instructor training and curriculum design [3].

Assessment and Evaluation of Leadership Skills: Evaluating the effectiveness of IBL may require a shift from traditional performance metrics, which often emphasize task completion and adherence to orders, to metrics that assess decision-making quality, adaptability, and mission alignment. Implementing such evaluation methods requires clear frameworks to assess initiative and accountability in a way that reflects the values of IBL.

C. Comparative Lessons from Other High-Stakes Fields

Insights from high-stake environments outside the military provide valuable perspectives on how IBL can be adapted within hierarchical structures. For instance, the successful application of IBL principles in graduate medical education and emergency response contexts suggests that decentralized decision making is feasible within structured organizations. These fields, like the military, require a balance between individual autonomy and adherence to overarching goals, demonstrating that IBL can be effectively tailored to structured environments without undermining discipline or unity of purpose [2].

Additionally, studies on servant leadership in the Air Force indicate that trust and empowerment-based models can thrive within military settings. These models foster a culture in which individuals feel valued and accountable, and outcomes that align with IBL's principles. Such examples provide a roadmap for adapting IBL to fit within the military's cultural and structural frameworks while preserving the model's core values of autonomy and initiative [1].

D. Implications for Military Education Reform

The potential benefits of IBL in developing adaptive, accountable leaders suggest that military education systems could benefit from incorporating elements of this model. To do so successfully, military academies might consider the following strategies:

- Gradual Implementation, introducing IBL incrementally allows trainees and instructors to adapt to this new approach without overwhelming the traditional structures. Starting with scenario-based training exercises that emphasize mission intent may be a practical initial step.
- Instructor Training, equipping instructors with the skills to facilitate IBL-aligned exercises is essential. This could involve training instructors to guide rather than direct them, helping them foster critical thinking and autonomy among cadets.
- Evaluation Reforms, adjusting assessment methods to value initiative and mission-aligned decision making over strict adherence to orders can help reinforce the principles of IBL, ensuring that trainees are rewarded for exercising autonomy within the scope of their training.

E. Future Research Directions

Further research is needed to explore IBL's long-term impact of IBL on leadership development in the military context.

Empirical studies that assess trainee performance, leadership effectiveness, and team cohesion under IBL-aligned programs can provide valuable insights into the model's applicability. Additionally, pilot programs within military academies could offer concrete evidence on IBL's potential to enhance traditional training approaches.

The findings of this study indicate that IBL has significant potential to enrich military education by fostering autonomy, adaptability, and accountability among trainees. However, successful implementation requires a nuanced approach that respects the cultural and structural specificities of the military institutions. By gradually integrating IBL principles through scenario-based training, instructor education, and evaluation reforms, military academies can cultivate leaders who are both disciplined and capable of making independent, mission-focused decisions. These leaders will be better prepared to navigate the complexities of modern warfare, where adaptability and initiatives are essential for success.

Through this examination, we see that IBL aligns well with the evolving demands of military operations, suggesting a promising pathway for military education reform that balances traditional values with innovative, empowering leadership approaches.

5. CONCLUSION

The application of intent-based leadership (IBL) in military education offers a transformative potential for developing adaptive, accountable, and autonomous leaders who can respond to the complexities of modern warfare. As warfare increasingly requires flexible and rapid decision-making, the traditional, hierarchical "command and control" model of military leadership is evolving. IBL aligns with this evolution by promoting a decentralized approach to leadership that empowers individuals to act with initiative and purpose, even within structured military environments.

The findings of this study suggest that IBL could bridge critical gaps in military leadership training by enhancing decision-making, fostering autonomy, and building accountability. These qualities are essential in high-stake settings, where leaders must be prepared to make rapid, mission-aligned decisions. Evidence from studies in other high-stakes fields, such as healthcare and emergency response, supports the adaptability of IBL principles in hierarchical organizations, providing a promising framework for the military's structured environment.

However, implementing IBL in military academies is challenging, particularly in terms of cultural resistance and structural adaptation. The hierarchical nature of military institutions, along with deeply ingrained traditions of discipline and command, may complicate the shift towards a more decentralized leadership model. To address these challenges, military academies could consider a gradual approach to integrating IBL, beginning with scenario-based training exercises, instructor development, and adjustments in evaluation metrics to reward initiative and mission focused decision-making.

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CHARACTERISTICS THAT A MILITARY LEADER SHOULD POSSESS - AN INTERNATIONAL AIR FORCE SEMESTER CADET OFFICERS PERSPECTIVE

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Abstract: *This study aims to present the perception of young officers, present within the international air force semester program, on what they consider a European-level military leader should be. The general perception of what they consider a military leader to be can be a starting point for designing an individual training/instruction path, which will help them in achieving the desired goal proposed by the international military educational community.*

Keywords: *leadership, International Air Force Semester, cadet officers, initial military education, profesional development, leader characteristics and traits.*

1. INTRODUCTION

The history of the Romanian Air Force is full of examples regarding the quality of leaders who have worked within this category of forces, and one of the aspects that made this possible was the interest shown by this organization in attracting and training them. In the current context, in which the evolution of technology and the dynamics of global security require a new approach to what is intended to be a framework for training and improving leaders, the air forces are forced to adapt and adopt a new approach to the process, one that can keep up with the imposed needs.

The success of the operations carried out by the Romanian Air Force depends on the effective integration of human capabilities with the tools, tactics, techniques and procedures that combine to produce the entire spectrum of air power. The first steps in integrating leaders in such operations are defined by obtaining the necessary capabilities, and then by organizing the skill sets necessary to produce these capabilities.

Human resource development is both an individual and organizational function and responsibility. All air force personnel have the duty to take advantage of the facilities offered by the military organization to improve their training and thus develop their knowledge and leadership skills.

2. EMILYO’s INTERNATIONAL AIR FORCE SEMESTER

EMILYO (European MILitary Young Officers) represents the European Security and Defence College (ESDC) (Fig.1) initiative for the exchange of young officers. ESDC is an EU body embedded in the External Action Service of the European Union thet provides training and education at EU level in the field of the Common Security and Defence Policy, which is part of the EU’s Common Foreign and Security Policy[1].

This educational approach was inspired by ERASMUS (European Region Action Scheme for the Mobility of University Students), the EU programme for education, training, youth and sport.

FIG. 1 ESDC logo

The aim of the project is to create a common study programme that will be part of the basic education for military officers (a common semester), in order to facilitate and promote long-term student exchanges between different institutions of the European Armed Forces.

The basic idea that was taken into account in the initial start-up process of this project lies in the need to have a common educational path, of initial training and subsequent improvement/development, for officers within the European armed forces. Eligibility for participation in such a programme is given by admission to the academies of different categories of force within all participating countries.

In this way, it was desired to facilitate and promote exchanges of military students, for an initial period of one semester, with the aim of developing in them skills and competences specially designed to be able to be demonstrated, in the future, within the framework of operations carried out in the international environment. Among such skills and competencies, selected as appropriate to be developed in future young officers, are leadership skills, language skills, self-development, and cultural awareness.

The program is running under the direct suppervision of an Implementation Grup consisting of specialists and which, currently, is developed under several Lines of Development (LoD) - 21, and International Air Force Semester is identified as LoD 12.

This year, a total of 33 cadet officers from 6 EMILYO member countries are participating in the international semester. Their numerical distribution can be seen in fig. 2. As additional information, it should be noted that this is a single military specialization, namely pilots.

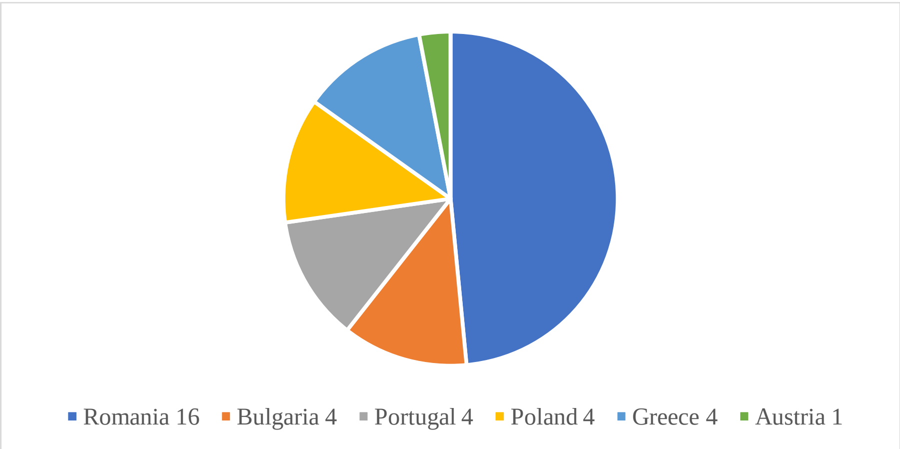

FIG. 2 Origin countries of IAFS cadet officers

3. ATTRIBUTES AND CHARACTERISTICS OF A GOOD LEADER

The challenge for the Armed Forces in developing leaders will remain to determine precisely what attributes and characteristics they will need to be able to face the modern conflict environment.

In the first volume of the book *The Military Leader in the Romanian Air Force - Theories, Vision, Desire (Liderul militar din Forțele Aeriene Române – Teorii, Viziune, Deziderat),* I presented how the senior leadership of the US Army proceeded to identify those characteristic elements necessary to identify a human resource development solution[2]. The US Air Force Research Institute (AFRI) based its approach in this regard on a study previously conducted by another corporation, RAND, with research interests in the same field.

Using in this regard the discoveries previously made by the RAND corporation and augmenting them with their own conclusions, the AFRI researchers managed to create a portrait of the leader, based on three sets of characteristics, considered essential by them, as follows: cognitive, interpersonal and personal style. One of the premises taken into account in the development of these three sets of characteristics was the level of leadership manifestation within the military organization.

1. Cognitive characteristics:

a.Visionary Thinker. This is the leader who thinks critically, strategically, and creatively in equal measure, in order to be able to respond to current and future challenges in equal measure. Visionary leadership is transformative and relies on the power of inspiration.[3]

b. Polymath. According to the definition in the Miriam-Webster dictionary, polymath[4] refers to a person who possesses vast knowledge in various fields. The erudite leader has a strong desire for self-improvement that leads to lifelong learning deeply rooted in his psychological profile.

2. Interpersonal characteristics:

a. Team-building and networking. The essence of leadership is represented by the strong relationship that is created between a leader and his followers. However, it is not enough to focus on what we create at the micro level of our own organization, but it is also necessary to think at the macro level, to expand and diversify our connections with other organizations, whether they are from the same category of forces or from other categories of army forces or from similar services in specialization, with which we interact.

b. Political acumen. The political-military relationship must be one of subordination. This does not mean that a military leader must not understand the political phenomenon. On the contrary, a military leader will need to perfect his ability to understand and apply the art of politics within organizations or leadership structures at higher levels.

c. Cultural competence. Going hand in hand with political skill, this ability must be the result of a deep understanding of both one's own organization, its culture, and that of others, so that this can be useful when holding effective discussions about various issues of common interest.

d. Skilled negotiator and facilitator. The modern conflict environment proves to be a continuous challenge to the act of leadership and therefore, from the position of commander in one of the theaters of operations of the future, leaders will be faced with the situation of having to exert their influence on people who are not under their direct authority. Persuasion and the art of influencing others can be considered essential elements of the functioning of negotiation skills.

e. Emotional resilience. The conflict environment of the future will be one characterized by vulnerability, uncertainty, complexity and ambiguity that will manifest themselves at a higher level, never seen before. In order to face such challenges, from an emotional point of view, leaders will have to train, develop and perfect their adaptive skills at the same time as the pace at which actions are carried out in the operational environment.

3. Characteristics of personal style:

a. Ethical. Two things can be best associated with ethical behavior: altruism and self-humility. These are best found in the manifestation of the leader's serviceability, they are cultivated and rooted, by their own will, in their character. As an example of this characteristic, I will also use the words of General Montgomery Meigs: "Good generals are not worried about themselves when making the hard decisions."[5]

b. Strategic communication. Speaking and writing, although temporally separated by a short period, can be said to develop simultaneously over time. Perfecting these two skills is done with dedication to reading, motivation for listening, and practical exercise in the art of communication.

c. Mentor. A dedicated leader is one who is worried and concerned about the future of the organization. A mentor is one who is skilled enough to help and advise his team members to develop and perform collaboratively to increase efficiency in fulfilling the organization's mission.

d. Resource manager. In order to effectively support the operational strategy, an efficient or productive leader is characterized by a good capacity for managing resources.

Thus, from the combination of these 11 characteristics, one can imagine a leader developed in the three directions of action suggested by the aforementioned study, who, from a cognitive point of view, is concerned with a constant and permanent improvement of the knowledge base in order to be able to make the most of creative and critical thinking skills in formulating the strategic vision. From the teamwork point of view, the presented leader demonstrates a strong desire for relationships, both within the core group and outside it, a fine understanding of the political phenomenon with applicability in the process of organizational understanding through the art of influencing others.

The last aspect of team involvement is proven by the strength with which he can stabilize himself emotionally in conditions of constant challenges. From the character point of view, this leader is one of high morality and modesty and with a strong manifestation of helpfulness. The altruism he demonstrates is expressed in the desire to prepare those he works with in making the transition to a new future for the organization, an aspect instrumented through sophisticated communication and active listening. The resources he uses are varied and prove effective in the actions taken.

The image described above is the one that I considered to be the most appropriate for relating the results obtained from the study mentioned in the title of the article.

4. CHARACTERISTICS THAT A MILITARY LEADER SHOULD POSSESS

Research purpose. The study started from the assumption that young cadet officers have formulated an idealized mental image of what it means to be a good leader. I chose, as a participant group, the cadet officers participating at the international semester, with the intention of seeing whether a coherent portrait of a leader can be identified at the level of a group of future officers coming from different countries and cultures.

Following what was stated previously, I was able to formulate the question that was the basis for starting the research effort.

Objectives and preliminary hypotheses. The objectives proposed, for the proper conduct of the study, were the following:

O_1. *Identifying the characteristics that a leader within the armed forces should display, from the perspective of future officers, currently attending, as cadet officers, the international semester courses at the "Henri Coandă" Air Force Academy*;

O_2. *Comparison of the results obtained with the elements described in the theoretical framework, previously presented*.

Hypotheses are constructs that reflect the generality, specificity, determinability, falsifiability, testability, predictability, communicability, reproducibility and utility of plausible explanations that are to be verified through observational facts.

There can be two approaches to deducing working hypotheses: deduction from theory and direct experience. Since the theoretical basis regarding leaders in the Romanian Army is limited, I have resorted to personal experience in developing the following working hypothesis:

H_1. *At the group level, regardless of nationality, the number of characteristics identified will be very large and will be expressed by the impossibility of identifying an eloquent portrait of a leader*.

H_2. *The theoretical elements described above will be found among those obtained from data collection.*

The research universe. For the study *Characteristics that a military leader should possess - an International Air Force Semester cadet officers perspective*, it was limited, as I mentioned earlier, to a number of 33 cadet officer, participants in the IAFS.

Research method. The investigation method used to carry out this study is that of selective survey research. For this purpose, we used as a research instrument the questionnaire, built on the basis of a single question, common to all participants, regardless of nationality:

Q_1 *What are the characteristics that a military leader should possess from the point of view of the cadet officer participating in IAFS?*

The open-ended request was formulated in such a way as to provide the respondents with the opportunity, based on the training practiced up to that point, their own preparation and the education received up to that point, to be able to formulate opinions, make judgments and express points of view, supported by arguments, regarding the formulated request. I directly administered the questionnaire/opinion poll to the cadet officers, in an organized manner, in the classroom. The instruction regarding the response method was given prior to handing it over, while honesty in providing answers was requested. The advantages of applying this instrument reflected the acceptance and desire for communication (openness towards it) of the young military personnel, as well as the quality and quantity of information provided (some exposing complex issues, others having a greater emotional charge). In this sense, the answers provided by the officer trainees constituted, both in terms of quantity and diversification, an appropriate basis for drawing conclusions.

Data processing and interpretation. The data were collected and interpreted from a statistical point of view, while also tracking the degree of consensus or number of repetitions in the case of identifying the same characteristic in multiple subjects.

After studying the results obtained, based on the application of the questionnaire, I found the following:

- At first count, the characteristics extracted from the group consultation led to the enunciation of a total number of 461 elements, this being due to the number of answers given by each respondent. The number of answers collected from each individual varied from a minimum of 9 to a maximum of 20. After accounting for the number of repetitions, 135 elements remained consisting of skills, character traits and values which, in the respondents' understanding, can constitute descriptive parts of the portrait of a military leader.

- For a more precise portrayal, I continued with the identification of those elements collected that proved synonymy or expressed the same thing. This aspect was also helped by the additional justifications that the respondents brought to each element presented, this being also an initial request, formulated in the questionnaire. This resulted in a number of 66 elements. As an example of the synonymies and additional explanations encountered, I present the one of tenacity-dedication-patience-determination-perseveration-hard worker.
- At the constitutive level of the entire population of subjects, we considered as relevant for creating a portrait of the leader only those elements that are found in a weight of at least 50%. The cumulative result obtained is made up of 10 representative characteristics, with a relative frequency between 6.17 and 3.66 percent, as presented in the table below.

Table 1. Absolute and relative frequencies for identified characteristics

CHARACTERISTIC	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY
		%
COMMUNICATION	27	6.17
ADAPTABILITY/FLEXIBILITY	24	5.49
INTEGRITY/HONESTY	22	5.03
CONFIDENCE	21	4.8
DISCIPLINE	21	4.8
COURAGE	18	4.11
VISIONARY	17	3.89
EMPATHY	17	3.89
RESPONSIBILITY	16	3.66
TENACITY	16	3.66

• Regarding the second objective proposed for this study, the characteristics presented as theoretically suitable to be associated with a successful leader are found in the multitude of characteristics collected, either as they were presented or in the form of their characteristic elements. The results obtained are presented below, in tabular form:

Table 2. Cognitive characteristics

THEORETICAL CHARACTERISTICS -COGNITIVE-		IDENTIFIED CHARACTERISTICS	ABSOLUTE FREQUENCY
VISIONARY THINKER	→	VISIONARY	**17**
	→	INTELLIGENCE	**6**
	→	STRATEGIC THINKER	**9**
POLYMATH	→	CRITICAL THINKER	**9**
	→	COMMITMENT TO CONTINOUS LEARNING	**4**
	→	KNOWLEDGE	**4**

Table 2. Interpersonal style characteristics

THEORETICAL CHARACTERISTICS -INTERPERSONAL STYLE-		IDENTIFIED CHARACTERISTICS	ABSOLUTE FREQUENCY
TEAM-BUILDING AND NETWORKING	→	TEAM ORIENTED MINDSET	**6**
POLITICAL ACUMEN	→	DIPLOMATIC	**3**
CULTURAL COMPETENCE	→	CULTURAL AWARENESS	**2**
SKILLED NEGOTIATOR AND FACILITATOR	→	COLABORATIVE	**2**
EMOTIONAL RESILIENCE	→	RESILIENCE	**14**
	→	PHYSICAL AND MENTAL STAMINA	**7**

Table 3. Personal style characteristics

THEORETICAL CHARACTERISTICS -PERSONAL STYLE-		IDENTIFIED CHARACTERISTICS	ABSOLUTE FREQUENCY
STRATEGIC COMMUNICATION	→	COMMUNICATION	**27**
ETHICAL	→	ETHICALY JUDGEMENTAL/MORAL	**9**
MENTOR	→	MENTOR	**3**
RESOURCE MANAGER	→	PROFESSIONAL	**4**

Analysis of the research study results. Within this analysis, my focus was to identify those elements that describe the degree of confirmation/refutation of the working hypotheses.

As can be seen from the data presented, the portrait of a leader that can be created using the collected data is very different from the one presented in the theoretical framework. This is mainly due to a very large and varied number of characteristics collected. The only characteristics selected to create a representative image for the group level and that are found in the theoretical framework are those of visionary ability, emotional resilience and strategic communication. In fact, communication is the characteristic that was chosen by the largest number of respondents. In this way, the first research hypothesis is confirmed.

Although the portrait created was different, through the multitude of elements collected, the theoretical framework presented previously is found in the data collected, which makes me consider the second hypothesis to be confirmed.

5. CONCLUSIONS

The training of future European leaders is an approach that works and is in a process of continuous expansion. There is a constant focus on the elements that need to be improved, and leadership competence is one of these. It can thus be considered that a first step has been taken, namely that of reaching a consensus on what a successful military leader should look like, at least in terms of the qualities and personality traits that characterize such a personality.

If one knows where one needs to go and what the starting point is, then it will be very easy to design the path to follow to get there.

The only aspect that remains to be done is to identify, on the one hand, the educational means necessary for modeling, and on the other hand, to establish what young people aspiring to the status of military leader have to do.

The task and responsibility of reaching the proposed goal is a common one and will not be able to be fulfilled unless all parties involved perform at their best.

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TEACHING AVIATION WEATHER VOCABULARY TO ROMANIAN AIR FORCE CADETS – QUANTITATIVE ERROR ANALYSIS BASED ON TRADITIONAL MATCHING AND MULTIPLE-CHOICE EXERCISES

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Abstract: *The main focus of the article is on the quantitative proportion and distribution of aeronautical meteorology adult learner errors around a few main vocabulary topics in aviation weather as ESP: precipitation (liquid, freezing, frozen), the atmosphere (air, sky cover, visibility, air movement, cloud formations) and their effects (runway conditions). The purpose is to analyze errors found in undergraduate (Air Force cadet) classroom-produced materials featuring rather traditional vocabulary-focused activity types (matching and multiple choice lexical reinforcement exercises) in order to identify areas of difficulty and lay the groundwork for further quantitative and qualitative approaches on the specific challenges affecting Romanian learners studying aviation English as EPP.*

Keywords: *metacognition, ESP/EPP, aviation weather vocabulary, error analysis, error distribution*

1. INTRODUCTION: THEORETICAL BACKGROUND AND PURPOSE

It is generally thought that learning about the general grammar and vocabulary of a foreign language is sufficient for second language (L2) acquisition (SLA) – and of course, it remains a prerequisite. However, one of the many new lines of thought in SLA-related research revolves around the general concept of metacognition, which refers to a learner's induced self-awareness in understanding the processes articulating their own acquisition of knowledge. This approach to teaching and learning has opened a new and engaging territory for educational studies in both science and humanities, from mathematics to Foreign Language Teaching (FLT) and methods in English as a Second Language (ESL) teaching [1, 2, 3]. Among the main lines of attack, error analysis is seen as one of the cornerstones of student/adult learner ability enhancement [4, 5], providing such learners with the necessary vital instruments to assist them in critically assessing their own performance and successful or unsuccessful learning habits and mental processes. There are also researchers who have implied that metacognition and error analysis was to be integrated into their respective L2 learning frameworks [6].

To add to this line of thought, the present article is a first step in a series of researches meant to analyze errors: 1. from the perspective of their quantitative distribution around common topics in Aviation English as a college/university/higher education study subject, and 2. the subsequent qualitative interpretation of the typical mistakes identified under stage 1, focused on a perspective meant to highlight the bearing of L1 interference in FLA, to the ultimate aim of covering the basic difficulties that Romanian users of ESL as EPP in the aviation industry come across in their learning process. In the long run, this identification and interpretation of mistakes is to support the potential metacognitive enhancement of linguistic abilities with this specific group of learners.

Note should also be made that we consider this contribution to be a pre-research experiment done within the framework and set timeline of a research project meant to support further analyses (see Acknowledgement), to be continued and developed as new generations of cadets agree to furnish additional material.

As such, this article focuses in particular on aviation weather vocabulary and its main difficulties as they result from the quantity and topic-centered organization of errors in Romanian Air Force cadet classroom-produced worksheets and final exam simulation tests, with the objective of assisting the educational process in typical error identification.

The methodology is based on seminal contemporary literature in the field [7, 8].

2. METHODOLOGY

For this limited experiment, four mixed-ability undergraduate student groups' classroom produced materials were subjected to analysis. The learners' approval for their work to be used under the protection of anonymity was asked and received at the beginning of the respective courses. The four military cadet groups involved belonged to two successive classes counting 20, 12, and 10 undergraduates, respectively. The largest of the three was made up by two compeer air traffic management-oriented groups (from now on called A and B for privacy concerns), while the other two were two successive meteorology-oriented groups (the largest of the two will be codenamed C, while the smallest will be assigned the letter D).

For the scope of this article, specialist vocabulary proficiency was tested by means of a small variety of traditional exercise types, involving limited, standardized language contexts such as the (as-such or slightly rephrased) definitions in matching exercises (upper intermediate-level structures, used as first semester material), with the objective of noticing both the quantitative bearing of the mistakes and their proportional distribution around a few main semantic fields organized as course topics: precipitation (liquid, freezing, frozen), the atmosphere (air, sky cover, visibility, air movement, cloud formations) and their effects (runway conditions). Specifically, the activities were: two intermediate-level matching exercises (final test simulation reinforcement exercises) and a vocabulary reinforcement multiple-choice exercise.

Student work was done on paperback handout materials, collected and processed within the Academy's Foreign languages dedicated lab (supported and financed through the research project mentioned in the „Acknowledgement" section at the end of the article), along with corresponding Professor feedback sheets. The full scanned or paperback material is not included here for obvious reasons (space concerns), but all the errors in the feedback materials containing personalized feedback for each individual student's work were collected manually under tabular form with no exception whatsoever, to assure the correctness and reliability of the analytical approach.

To calculate percentages and do the statistics, rather simple in this pilot study due to the dimensions and low degree of complexity of the corpus involved, no specific software was used, except for a few researcher-supervised data syntheses (calculations) provided by Open AI's free version of Chat GPT. All mistakes were manually introduced in the specific tables mentioned above (and analyzed in the following sections) for each of the tasks. In order to analyze them from the perspective(s) we were interested in, heuristic methods were used to interpret the above-mentioned tables and synthesize conclusions.

3. CORPUS ANALYSIS

As mentioned under section „2. Methodology”, the actual corpus consists of 39 student written contributions and the corresponding 39 one-on-one Professor feedback sheets, distributed as follows:

- 29 responses/answer sheets (8 A +10 B + 11 C) to two vocabulary-centered matching exercises, out of which the first activity was separated into 3 topic-oriented tasks (I. Precipitation, II. Snow, III. Air, wind, visibility and clouds) and managed simultaneously in 3 laboratory sub-groups (via specific row seat allocation to avoid copying); the other was a mixt exercise synthesizing essential vocabulary loosely organized around the same topics, distributed simultaneously within group C; out of the 20 undergraduates in the first group (AB), 2 were absent at the time the assignment was given, while 11 of the 12 group C cadets were present;
- 10 responses/answer sheets (10 D) to an intermediate-level classic multiple-choice vocabulary exercise (10 out of 10 cadets were present in class as the task was given);

The distribution above resulted in 4 „error-collection” tables: 4 error-collection tables for the two vocabulary-centered matching exercises considered together (3+1, respectively, according to the specific row/group allotment) and 1 error-collection table for the intermediate-level multiple-choice vocabulary exercise.

Thus, 9 to 11 answer sheets coming from four different workgroups, two specializing in air traffic management (ATM), the other two specializing in aeronautical meteorology (AM) were collected for each specific exercise (9 to matching I + matching III, 9 to matching II, 11 to the matching vocabulary mix and 10 to the multiple-choice exercises), while all cadets were of perfectly similar age groups, qualifications and years of study. We also chose to specifically compare study profiles with slightly different focuses on aviation weather English as a subject for learning: while it is one of the important thematic concerns of the ATM-oriented English course, if forms the ultra-specialized core of the contents designed for the AM-oriented English course. The total amount of answers received from the cadets in all the four groups (ABCD) was 271.

The following analysis will detail the errors in the sense of error quantification, topic-related distribution and proportions, according to the criteria set in the previous sections (see *1. Introduction: Theoretical Background and Purpose*).

3.1 Two matching exercises. As a brief description of the exercises, the „I. Precipitation” task was to match 5 words and phrases and their definitions. The specific terms to be defined, displayed in a vocabulary box framing a string of concepts separated by bullets were shown as: 1. FZRA (freezing rain), 2. PL (ice pellets), 3. GS (graupel/soft hail), 4. GR (hail), 5. build-up. Correspondingly, 5 short, mildly rephrased definitions (as compared to the definitions present in course materials) were provided. The correct order of the concepts after matching the definitions was 2,1,3,4,5. The same organization (5 words and phrases and 5 mildly rephrased definitions were provided and displayed in the same manner) for the „II. Snow” and „III. Air, wind, visibility and clouds”-related tasks. Under task „II. Snow”, the concepts to be defined were: „1. snow rut, 2. snow drift, 3. compacted snow, 4. snow bank, 5. build-up”, and the key was 1,2,5,3,4, whereas under task „III. Air, wind, visibility and clouds”, the concepts were displayed as „ 1. crosswind, 2. wind shear, 3. gust, 4. BKN, 5. SCT” (with no expansion of the sky-cover descriptor acronyms, as they were considered to have been all-present during class activities throughout the semester); the key read 2,1,3,4,5. These shorter, thematic exercises were used to train the ATM groups (designated here as A and C), for whom the final exam was meant to include this type of simpler, topic-specific matching exercise to check the aviation weather jargon.

The „Vocabulary Mix” tasks in the final simulation tests applied during a final exam simulation test including 11 concepts: 1.GR, 2.wind shear, 3.(cloud) tops, 4.cloud ceiling, 5.moderate chop, 6.backing wind, 7.veering wind, 8.snow rut, 9.GS, 10.crosswind, 11.snow drift (with 6, 5, 2,7,10, 3, 4, 8, 11, 9, 1 as key). Of course, this more complicated test design was used to train the aviation weather group (designated as C) for their final exam matching exercise.

Student answers turned out as described in Tables 1-5, where each cadet was assigned a number and a group designator (A and B for the two lab groups studying air traffic management, C for the group studying aviation weather as the core of their respective curricula), to observe the privacy-related ethical concerns mentioned under section „2. Methodology”. Asterisks in the first four tables mark the fact that one wrong answer implied the other (the same confusion between terms resulted in two wrong answers at once).

Table 1. I. Precipitation

	Std. code	*No. of errors/ No. of answers*	*Details (based on answer key: 2,1,3,4,5)*
1.	A2	0/5	–
2.	A5	0/5	–
3.	A8	4/5	Answer: 4,2,1,3,*5* • *GR* identified as *PL* • *PL* identified as *FZRA* • *FZRA* identified as *GS* • *GS* identified as *GR*
4.	B10	2/5	Answer: 4,*1*,*3*,2,*5* • *GR* identified as *PL** • *PL* identified as *GR**
5.	B9	4/5	Answer: 4,2,1,3,*5* • *GR* identified as *PL* • *PL* identified as *FZRA* • *FZRA* identified as *GS* • *GS* identified as *GR*

This is an assessment of the 25 answers listed under the 5 worksheets received.

According to the 5 answer sheets under consideration, 2 cadets out of 5 were able to perform flawlessly, while the other 3 made mistakes. Among the cadets in the first group having performed the same activity (designated as group A), 2 out of 3 respondents answered perfectly (A2 and A5), while the third (A8) was only able to come up with one correct match. In the second group (designated as group B), both respondents made mistakes: B10 made 2 mistakes, while B9 made 4 out of 5. It may also be relevant that nobody mistook concept 5 (build-up) for any of the other terms or phrases, and that most mistakes involved, from the highest to the lowest number: the confusion between *4.GR* and *2.PL* (3+1), then with an equal number of occurrences, *3.GS* and *4.GR* (2), *2.PL* and *1.FZRA* (2), *1.FZRA* and *3.GS* (2). It may also be relevant to notice that A8 and B9, even though belonging to two different generations, made the exact same mistakes. We also need to note that B10’s mistakes are based on a single confusion (between *4.GR* and *2.PL*).

The proficiency level of this particular sub-group seems to be by far the lowest in AB, judging by the fact that a majority of 60% (3 out of 5) of the cadets making at least two mistakes (a reciprocal mismatch or two different wrong answers) and 40% of the entire number of answers given counted as wrong.

We must also note that out of the 10 wrong answers given, only one was a reciprocal mismatch, accounting for only 2 incorrect solutions (20%). Additionally, the number of mistakes per student is also the highest (2 learners missed out on 4 matches, and this with no reciprocals in any of the cases, against only a maximum of two per student in the other 2 workgroups, all generated by mutually implicating errors resulting in 2 wrong answers at once).

Table 2. II. Snow

	Std. code	*No. of errors/ No. of answers*	*Details (based on answer key: 1,2,5,3,4)*
1.	A1	0/5	–
2.	A3	2/5	Answer: *1*,*2*,3,5,*4* • *snow bank* identified as *compacted snow** • *compacted snow* identified as *snow bank**
3.	B2	0/5	–
4.	B3	0/5	–
5.	B4	0/5	–
6.	B5	0/5	–
7.	B6	0/5	–
8.	B7	0/5	–
9.	B8	0/5	–

This is an assessment of the 45 answers received on the 9 worksheets.

A very visible result here is the fact that all cadets in group B answered the grid perfectly, while among the two cadets in group A who received this assignment, one was just as proficient. Therefore, out of the total of 9 respondents, only one made mistakes (A3), and those mistakes involved a reciprocal confusion: as the phrase *5.snow bank* was mistaken for *3.compacted snow*, the first mistake implied the second. Extremely high proficiency seems to characterize about 88.88% of the group, with approximately 95.55% correct matches out of the total number of answers given.

Table 3. III. Air, wind and visibility and clouds

	Std. code	*No. of errors/ No. of answers*	*Details (based on answer key: 2,1,3,4,5)*
1.	A4	0/5	–
2.	A6	0/5	–
3.	A7	0/5	–
4.	B1	2/5	Answer: *2*,*1*,*3*,5,4 • *BKN* identified as *SCT** • *SCT* identified as *BKN**

This is an assessment of the 20 answers received on 4 worksheets.

In this case, 3 out of 4 respondents made all matches correctly, and all 3 were part of group A. B1's mistake also only involved a reciprocal confusion: as the phrase *4.BKN* was mistaken for *5.SCT* and the other way around. This means 75% of these cadets' performances are indicative of extremely high proficiency, with only 10% errors among all the answers given, while the cadet with the lowest ability still answered 60% of their test correctly.

Table 4. Vocabulary Mix

	Std. code	*No. of errors/ No. of answers*	*Details (based on answer key: 6,5,2,7,10,3,4,8,11, 9.1)*
1.	C1	0/5	–
2.	C2	0/5	–
3.	C3	0/5	–
4.	C4	0/5	–
5.	C5	0/5	–
6.	C6	0/5	–
7.	C7	0/5	–
8.	C8		Answer: *6,5,2,7,10,3,4,8,11*,1,9 • *GR* identified as *GS** • *GS identified as GR**
9.	C9		Answer: *6,5,2,7,10,3,4,8,11*,1,9 • *GR* identified as *GS** • *GS identified as GR**
10.	C10		Answer: *6,5,2,7,10,3,4*,11,8,*1,9* • *snow rut* identified as *snow drift** • *snow drift* identified as *snow rut**
11.	C11	0/5	–

In group C, 121 answers received via the 11 worksheets considered for assessment. 8 out of the total of 11 respondents made all matches correctly, with only 3 committing errors, which brings us to an approximate 72.72% vs. 27.27% score in favor of extremely high versus high learner proficiency and a total of 4.95% vs 95.04% proportion of erroneous vs. right answers. It must also be noted that all six errors are reciprocal (i.e., based on single confusions resulting in two simultaneous mistakes), and that both C9 and C10 made the same mistake – mistaking *1.GR* for *9.GS* – while the other mistake involved a confusion between *11.snow rut* and *8.snow drift*. Note should be made that just like with groups A and B, the vocabulary revolving around air, air movement, wind, visibility and clouds was the least problematic (as it posed virtually no challenge at all).

By comparison, groups AB scored generally higher, but with a low in the semantic field of precipitation, leading to a mean result of 20 out of 90 answers gone wrong (an error percentage of 22.22% vs. 88.88%, approximately) and 8 cadets out of 18 committing at least a reciprocal (44.44%).

The rather visible difference could be accounted for by the fact that group C studied aviation weather as one of its core subjects, while AB groups didn't.

There is also the larger number of learners and answers, but while the first is relatively relevant, let us also remember that the second is not: while in group C each cadet had to do an 11-match exercise, in groups AB each learner only needed to execute 5 matches correctly. The time management should be counted as virtually identical, as during the same test, cadets in group C had 5 other matches to do (in ATM-related vocabulary), while groups AB had other 11 ATM jargon-based terms as part of the same test. The items that were not included here were designed as a different exercise during the same test.

However, another relevant class/test management factor might have been the 3 versus one row allocation of students.

The tables visibly show, however, despite the extremely high levels of proficiency, that precipitation seems to be the most difficult to assimilate efficiently, followed at a distance by snow, while air, wind, visibility and sky-cover seem to pose no problems at all.

3.2 Classic multiple-choice vocabulary exercise based on reading. This exercise is a simple reading designed for the main purpose of reinforcing essential vocabulary for cadet group studying aviation weather as the core of their respective curriculum. The worksheet comprised 6 multiple-choice grid response items, each made out of a stem (questions or partial sentences / incomplete statements) with 4 potential alternatives (answers) each, out of which 3 were distractors and one was the correct choice. In the case of items 3 and 4, the degree of difficulty was raised by the presence of strings (enumerations) of four terms and/or phrases, the invalidity of any resulting in the dismissal of the answer as incorrect, e.g.: *Stem 3. Choose the string which includes at least one term/phrase that does not refer to air movement. Answers: a) crosswind, tailwind, head wind, windshear; (…) c) downdraft, gradient wind, glaze, drift; d) (…)*, where neither glaze nor drift are related to air movement and thus making answer c) into the right choice. Under item 5, further difficulty was added by the requirement to choose one correct match, to the purpose of reinforcing counter-intuitive abbreviations: *Stem 5. Find the wrong correspondence between the phenomenon and its METAR code. Answers: a) small hail/snow pellets/graupel = GS; b) hail = GR; c) small hail/snow pellets/graupel = GR; d) clear-sky precipitation / diamond dust = IC*, where the right answer was c).

No other linguistic context than the stems was provided in this classic multiple-choice vocabulary exercise. Previous lectures and topic-centered seminars had already preceded this reinforcement exercise. The content of the stems and grids basically remains upper intermediate-level in terms of difficulty: the stems are not basic, but are rather accessible while the specialist vocabulary in the answers is only slightly above the general military English vocabulary included in level 2 – intermediate STANAG 6001 descriptions; mention also need to be made that group D was studying aviation weather as a fundamental in its curriculum.

Learner answers turned out as described in Table 6, where each cadet was assigned a number and a group designator (in this case, D), to observe the privacy-related ethical concerns mentioned under section *2. Methodology*.

Table 6. Multiple-choice vocabulary exercise

	Std. code	*No. of errors / No. of answers*	*Details (based on answer key: 1c, 2d, 3c, 4b, 5c, 6a)*
1.	D1	1/6	• *1*, turbulence intensity*:*1b, moderate (Correct: *1c*, *severe*)
2.	D2	0/6	–
3.	D3	2/6	• *1*, turbulence intensity*:* 1b, moderate (Correct: *1c*, *severe*) • *6,* runway conditions (water, clouds & precipitation)*:* undecisive marking (all four answers marked)
4.	D4	0/6	–
5.	D5	0/6	–
6.	D6	0/6	–
7.	D7	1/6	• *1*, turbulence intensity*:* 1b, moderate (Correct: *1c*, *severe*)
8.	D8	1/6	• *6,* runway conditions (water, clouds & precipitation)*:* undecisive marking (2 answers marked: *6a*, *pool of water* and 6b, standing water)
9.	D9	1/6	• *5,* METAR codes*:* 5d, clear-sky precipitation/diamond dust = IC (Correct: *5c*, *small hail/snow pellets/graupel = GR*)
10.	D10	1/6	• *4,* precipitation*:* undecisive marking (all four answers marked)

In group D, 60 answers received via the 10 worksheets included for assessment. The table demonstrates that certain unexpected difficulty associated with item number 1, focused on degrees of turbulence intensity, dominates the chart (3 wrong answers against none under item 3, one under item 4, which would have been the most difficult for learners struggling with intermediate-level proficiency).

The stem was made out of an incomplete sentence to be filled in, reading: *1. --------- turbulence is described as disturbed air that may cause an aircraft to briefly drift in and out of control, while inside the aircraft walking becomes temporarily impossible.* This is a slightly rephrased definition of severe turbulence as compared to the two-fold general textbook definition provided in previous class materials, i.e., *Aircraft reaction: large and abrupt changes in altitude and/or attitude and, usually, large variations in indicated airspeed. The airplane may momentarily be out of control. Inside the aircraft: Occupants of the airplane will be forced violently against their seat belts. Food service and walking impossible*. The answers were made up of the modifiers in the noun phrases technically describing the classic 4-leveled turbulence intensity scale, from *light* to *extreme*.

Another improbable finding is the cadets' difficulty with item 6 (standing second just behind item 1 for having resulted in 2 wrong choices out of the total of 7). This was basically a classic, one-concept-per-answer find-the-best-synonym exercise focused on the terms describing different types and sizes of water build-ups (form standing water patches to running water and cloud build-ups) as runway conditions: *puddle, pool of water*, *standing water*, to which distractors describing cloud formations or running water descriptors had been added, namely *c) CB build-up* and *d) runoff*. Of course, the terms rely heavily on general/plain English vocabulary, but they do have rather specific, technical synonymies in the aeronautical jargon (for disambiguation, see the *Global Reporting Format (GRF) for Runway Surface Conditions* [9]) and may be rather counter-intuitive for Romanian learners (e.g., the synonymy between pool of water and puddle to describe standing water patches of similar shapes, surfaces and depths under the larger umbrella of the hypernym *standing water*). However, these details were one of the main focuses of the corresponding lecture and previous seminars. Thus, D8's hesitation is rather strongly motivated, while D3's is much less justifiable.

It is also relevant, perhaps, that just like the vocabulary around liquid and freezing precipitation, or the terms describing frozen water buildups in the case of the matching exercises, the semantic field of water (liquid runway build-ups, in this case) still holds one of the top ranking places.

Other than that, students in this group still performed very well, but with lower levels of performance than their AM peers in group C: out of the total of 60 answers, only about 11,66% were erroneous. Still, learners having made mistakes counted more than 60% of the group, while only 40% made no mistakes throughout. The lowest cadet performance was at approximately 66.66% correct answers. This may also pint out that this type of multiple-choice item grid is less learner-friendly than the classic matching exercises, even in spite of the fact that arithmetically, students are faced here with a higher chance of error since they need to manage a 4-answer, not an 11-answer choice per assignment.

4. CONCLUSIONS: SYNTHESIS AND FURTHER LINES OF INQUIRY

The quantitative error approach under section *3. Corpus analysis* readily and distinctly points out the areas of difficulty as far as the selective topics and related specialist vocabulary are concerned: with 22 out of the total number of 27 erroneous answers given by all the students tested on all the worksheets provided, i.e., a percentage of approximately 88,88% of all the mistakes made (which cand be broken into the 6 errors out of the 6 mistakes made by the 11 cadets in AM group C and 4 out of the total of 7 mistakes made by the 10 cadets in AM group D, plus the 85.71% or 12 out of the total number of 14 mistakes made by the 18 students in ATM groups A and B), the semantic field of specialist terms related to water and precipitation (in the following order from precipitation METAR codes, leading with almost half of the errors committed (10 errors), followed by snow, ice and water buildups in a relatively equal amount (11 errors considered together) heads the chart.

While sky cover and visibility poses a virtually negligible threat (7.40% / 2 mistakes per 27), wind having a literal zero impact factor on error-making, but snow buildup representing a 14.81% percentage (4 out of 27 mistakes), and air movement made into an almost equally inconsequential threat (with 3 mistakes and 11.11% of the total), standing water as a runway condition is the only water and precipitation-related sub-topic falling in the same category as sky cover and visibility, with a 7.40% rate of error.

Thus, only the 22.72% of the total number of mistakes (i.e., 5 out of 22 mistakes) were fully unrelated to water (without even considering the presence of water under the form of clouds). Another area of concern may be pertaining to the classification of turbulence according to degrees of intensity, since all the errors under air movement concern the one corresponding item.

The numeric values included in the study are synthesized in Table 6 and results are detailed in Tables 7 and 8 for a better grasp on the various data around our topic and sub-topic list. Table 6 shows the proportions of right (94, 77.68%) and wrong (27, 22.31%) answers out of 121, accounting for general student performance throughout the four groups (A, B, C, and D) considered together. More detailed insights were not calculated as our objectives do not include student group performance assessment. However, the general proficiency demonstrated by the cadets involved will be relevant for future developments, as the same groups and students will be used (and their performance, relevant) for research concerning other activity types, as well as the qualitative interpretation of all results.

Table 6. Quantitative sum-up (general values)

General information	**Values**
total no of answers	121
total no of wrong answers	27
proportional value wrong answers	22.31%
total no of right answers	94
proportional value of correct answers	77.68%
total no of items	45

The last two sum-up tables (Table 7, Table 8) were generated by manually counting an introducing data into Microsoft Word documents and Microsoft Excel dedicated sheets. OpenAI's free ChatGPT website (https://chatgpt.com/) and an online free Percentage Calculator provided by calculator.net (https://www.calculator.net/percent-calculator.html) were also used for certain calculations (percentages, final line-up) and check-ups (i.e., result double-checking). While Table 7 synthesizes the final ranking of the topic and sub-topic related errors, based on the full calculations displayed under Table 8, as previously summarized at the beginning of this section, with values truncated to two decimal places without rounding them (as the same procedure has been applied consistently, for simplification, throughout). The general topics have been highlighted for better visibility and easy calculations.

Table 7 provides insights on the synthetic final ranking of topic difficulty based on the quantitative error analysis. All major topics and sub-topics are numerically present. It is visible how sky cover and air movement are largely surpassed by precipitation, with METAR codes, buildup and snow/ice at the top of the list and wind at the absolute bottom, with zero mistakes throughout.

Table 7. Quantitative sum-up (final ranking)

	Topics (highlighted) and sub-topics (regular)	Number of Errors	Proportional Value of Errors (%)
1.	Water and precipitation	22	81.48%
2.	METAR codes	9	33.33%
3.	Buildup	6	22.22%
4.	Snow/Ice	5	18.51%
5.	Runway Conditions	2	7.40%
5.	Sky Cover and visibility	2	7.40%
6.	Air Movement	3	11.11%
6.	Turbulence & Chop	3	11.11%
7.	Wind	0	0%

Table 8 provides a visible comparative take on items and the distribution of presence of topics and sub-topics among the items in all exercises, beside the number of errors and their proportional distribution around topics and sub-topics.

Table 8. Quantitative sum-up (details)

Topics (highlighted) and sub-topics (regular)	Items / total no. of items (45)		Errors / total no. of errors (27)	
water and precipitation	24	53.33%	22	81.48%
METAR codes	10	22.22%	9	33.33%
buildup	7	15.55%	6	22.22%
snow/ice	6	13.33%	5	18.51%
runway conditions	1	2.22%	2	7.40%
air movement	12	26.66%	3	11.11%
wind	10	22.22%	0	0.00%
turbulence & chop	2	4.44%	3	11.11%
sky cover and visibility	4	8.88%	2	7.40%
other*	5	11.11%	0	0.00%

Of course, we should also take into account the fact that out of the total of 45 items, approximately 24 (53.33%) were focused on or included vocabulary around water and precipitation (phases and their METAR codes, buildups of cloud, snow, ice, and standing water/runway conditions), about 12 (26.66%) around air movement (wind, turbulence and chop), 4 (8.88%) around sky cover and visibility conditions and 5 (11.11%) around other related vocabulary, e.g. drift. water buildups (snow, ice, cloud and standing water), about 3 (9.37%) around, and finally about again 10 (31.25%) around air movement (mostly wind, turbulence, chop).

But even so, the disproportion between topic and sub-topic related mistakes persists even when the number of items is considered (22 mistakes per 24 items revolving around water and precipitation, against 3 mistakes per 12 items about air movement, 2 errors per 4 items on sky cover and visibility etc.) and cannot be fully accounted for without a complementary quantitative analysis organized around less traditional activity types such as skill-focused tasks, where specialist terminology is provided with simulations of real-life communicative abilities and contexts and a qualitative sum-up based on both quantitative researches. The findings may seem disconcerting, as water may seem to attract error in an almost occult manner. Of course, nothing of the sort is to be really suspected: rational hypotheses may be mainly assumed to gravitate around the (user) unfriendliness of truncation and etymology, cultural and educational backgrounds, the presence or absence of real or realistically simulated linguistic and communicational contexts, learning habits such as memorizing and L1 interference. To be (or not to be) confirmed.

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