“Henri Coandă”
Air Force Academy,
Braşov, Romania

Students’ International Conference
AFASTUD 2024 (25th Edition)

Communicating across Cultures

March 29 – 30, 2024
Braşov, Romania

"Henri Coandă" Air Force Academy Publishing House
ISSN, ISSN-L: 2360-0152

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THE ETHICS OF POWER AND THE POWER OF ETHICAL LEADERSHIP AND STRATEGIC USE OF AI IN MODERN WARFARE

Adrian-Daniel PALCO

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Abstract: *The world as we know it has had many conflicts unfolding over the centuries. Only in the last two centuries, our modern world has been shaped by the two world wars, countless civil wars, insurrections, terrorism, and instability. These conflicts have allowed humanitarian laws and norms to be established, to bring about a „law of war" that includes ethical issues and respect for human beings and their rights, especially the right to live.*

Moving forward to the year 2024, the world grapples with conflicts, uncertainty, and terror. As Russia attacked Ukraine in February 2022, and the Middle East conflict started in October 2023, the superpowers of the world have started a Cold War-similar arms race to ensure a climate of supremacy and power. The difference is that, during this arms race, apart from military advances and nuclear capabilities, global superpowers have rapidly integrated artificial intelligence (AI) into military arsenals for strategic advantages, operational enhancement, risk-free missions with no human deployment or integration, and intelligence-gathering advantages like never seen before.

As a result, to think of AI as not only a powerful instrument, but also as a potentially conscious, strategic actor on its own, leading military operations and troops, or autonomous weapons into the field is not a very distant thought. This research article intends to investigate the ethical aspects of how AI could evaluate certain war-related situations, the ethical aspect of the leadership of military operations by AI, or even an entire command given to AI as a military leader.

Keywords*: ethics; leadership; warfare; military; intelligence*

1. INTRODUCTION

Ethics has been a subject of interest to human beings since the early ages, especially in ancient Greece. Early Greek thinkers, such as Plato or Aristotle with their monumental ethical works „Republic" and "Nicomachean Ethics" (Wolfsdorf, 2020) have managed to explain most of today's ethical dilemmas, such as emphasizing the importance of reason, virtue, and the philosopher-king as a moral guide. (Domanski, 2012). Ethics is, therefore, the discipline concerned with what is morally good and bad morally right or wrong. (Singer, 2024). On the other hand, there is the term leadership, which is habitually treated as a separate subject to ethics, where ethics should be considered as an aspect of leadership, that coexist to make a good leader, especially in the field of military, one of the few organizations that can legitimately use force. (Olsthoorn, 2023).

To have the authority to use force, command troops, and order certain operations is a morally difficult task for a military leader, where the desire for duty is sometimes unbalanced to the principle of proportion, a necessary duty to perform being sometimes challenged with the ethical questions of killing civilians, destroying certain civilian infrastructure, and causing devastating aftermath. This article aims to put the integration of Artificial Intelligence (AI) through the same lens of ethical and morally right thinking, into military operations and leadership situations, therefore examining the implications for decision-making, accountability, and international law.

2. THE STRATEGIC USE OF ARTICIAL INTELLIGENCE FROM AN ETHICAL PERSPECTIVE

Incorporation of Artificial Intelligence (AI) into a context of uncertainty, such as the present year of 2024, to enhance and advance military capabilities is a risky endeavor for the international landscape, especially during a crisis of two concomitant conflicts, the one happening in the Middle East and the one in Ukraine, therefore amplifying the state of tension and the constant race of arms. Independent drones and automated robotics, along with AI-driven cyber assaults and predictive analysis for intelligence gathering and situational forecast generative purposes redefine military tactics, while machine learning algorithms reshape ethical dimensions in warfare. (Aerospace and Defense Review, 2024). This rapid incorporation of AI into military capabilities is changing the perception of target recognition, autonomous fighter aircraft, advanced cyberattacks, and unprecedented improvements in operational intelligence. While the potential military advantages of AI are highly significant, including enhanced efficiency, accuracy, and strategic capabilities, they also introduce complex ethical dilemmas that must be addressed to prevent unintended consequences.

Recent studies and specialty literature have ushered two main schools of thought when it comes to the effects of AI used in military capabilities and armaments, and therefore addressing the ethical consequences of the strategic use of such intelligence. Certain studies claim that in the era of automation, intelligent war machines powered by AI are not only more reliable when it comes to more precise shooting range and target acquiring, but also even more “humane” than humans themselves, with no human sense of brutality and adrenaline-guided decisions. (Arkin, 2018) On the other hand, others argue that new breeds of autonomous weapons would eventually be misused or driven into a lack of common sense, therefore lacking a moral responsibility in using lethal force, thus, in order to avoid such catastrophe, the process of using AI in warfare should be entirely abandoned (Schwarz, 2018).

The truth is that the ethical landscape of Artificial Intelligence in military use is a yet unknown terrain, explorable but highly dangerous if not treated carefully. Whereas a military leader is accounted for his thought process when deciding to act according to the circumstances, therefore an ethical dilemma surrounding the decision-making is centered on human judgment, an AI-powered drone, for example, that accidentally kills a civilian mistaken for a terrorist in a not-so-hypothetical situation (The Guardian, 2023) is highly questionable when it comes to whose fault it was and whether or not it was a programming issue or a self-conscious act.

As a result, when it comes to examining the AI military capabilities from an ethical point of view, one must consider three main directions, which are the delegation of lethal decision-making to machines, accountability for AI actions, and the potential for escalation in autonomous weapons deployment. These directions must be thoroughly underpinned by the principles of just law theory and international regulations on war and casualties, which emphasize the importance of distinction, proportionality, and accountability in military operations. (Williams Jr, 2006).

One of the most complex issues is the delegation of the ability to execute lethal actions to an AI, an automated drone for example. Critics argue that machines cannot fully comprehend and understand complex ethical and moral judgments, although the AI is "trained" to recognize and acknowledge such behavior, the problem is that such feature is only prompted by the developer, and when the prompt is turned off, the AI does not respond to emotion and affective behavior anymore. (Perry, 2023), and this makes an AI-powered military device prone to reprogramming, potentially leading to violations of human treaties and principles on war. Imagine a situation where, for example, for the military occupants to be driven out of a territory, one military aircraft, AI-driven and delegated to execute lethal actions, decides to drop a bomb over the occupants, therefore eliminating the threat, but not taking into consideration that a few civilians are taken hostage.

The scenario imagined is therefore taken into military court, and the use of an AI-operated military aircraft complicates the issue of accountability. As a result, the second ethically difficult direction is accountability for AI actions. When AI systems make decisions that lead to unintended harm by error or by ignoration, the determination for who is responsible, whether it be the developer, the operator, or the AI itself, becomes challenging. Therefore, accountability is a cornerstone of the governance of artificial intelligence (AI). (Novelli, 2023).

The third direction that must be taken into consideration when examining the use of strategic AI in military capabilities, and that is questionable when it comes to ethics, is the sense of the arms race and escalation of the superpowers of the globe. The development and deployment of AI in military contexts, in a very turbulent state of the world, risks destabilizing the international state of security, which is at a very risky and fragile state for the moment and could lead to even more potentially catastrophic conflict.

In this regard, AI is set to pose a new desire for power, to people that have an imaginary right to conquer certain territories, where states that do not rely on democratic government are prone to violate international regulations, territorial states and to ensure that these certain states can wage a new type of war, with superiority when it comes to this arms race. Due to its cross-cutting nature, AI in military will pose a broad set of international security challenges, affecting both traditional military capabilities and the realm of hybrid threats, and will likewise provide newer opportunities to respond to them. (Petrovski, 2022).

3. ARTIFICIAL INTELLIGENCE IN MILITARY LEADERSHIP

We live in a time where there seems to be no middle ground between the hype that is around new, state-of-the-art technologies and the effort made by the global states to arm themselves with knowledge in Artificial Intelligence research and use, and the dark hypothesis that this arms race could lead to a devastating consequence. In this competition between the nuclear capabilities of a state and its AI-driven research and knowledge, states such as Russia, China, and the US are heavily investing in revolutionizing the ground of AI with strategic calculations, possibly new devices, and military structures, whereas the rest of Europe pays less attention to the weaponization of AI and its military applications. (Csernatoni, 2019). Therefore, the problem of the use of AI as a decision-making tool for military leaders is very plausible. The fact that an AI is capable of processing information with volume, variety, speed, and accuracy far more than a human being makes it a possible candidate when it comes to choosing an intelligence-enabled decision-maker. This is the case when talking about AI and human symbiosis, through machine learning, which could potentially lead to AI being indirect military leaders through forecasting with almost exact precision, accuracy, and objectiveness, becoming de facto strategic actors, for planning, choosing the best tactics, deployment of troops with precise prior analysis. Therefore, a more diminished role of a human military leader is potentially dangerous, this trajectory being more or less controllable, and the consequences of such a replacement, partial at first, but very plausible to complete replacement in the future, for humanitarian purposes and for peace, are ethically and morally problematic.

An AI commander is hardly something to be taken into consideration from a research point of view, since such a situation only comes to mind in a Science Fiction movie. But as military AI advances, all trends that can appear certainly will appear at some point, especially at this time when states invest a lot of budget in the exponential AI development and machine learning process, such as the US Pentagon requesting more than three billion dollars for AI and JADC2 (Joint All-Domain Command and Control Initiatives) in both military and intelligence gathering purposes, to gain advance and supremacy. (Harper, 2023). On the other hand, states that until 20 years ago seemed to have lost advance over the development in robotics and Artificial Intelligence, are now emerging as global leaders in AI, in this situation is China, which, as of March 2019, has reached 1189 AI firms, whereas in the U.S, there were a little more than 2000 firms. (Tong, 2021).

However, until when, or if ever, an AI, self-conscious military leader is appointed, to maintain a state of international peace and be the only arbitrary force to consider whether or not a war is suitable for long-term purposes, therefore excluding all means of egocentrism of a state leader, territorial purposes or financial gains from war, humans need to take into consideration that our species will soon become the Achilles heel in the AI-enabled techno-war regime, meaning that intelligent machines will no longer require human assistance, therefore acting self-sufficient, as autonomous agents. Until then, the logical, more plausible scenario, is with a *de facto* AI commander, whereby the act of killing is taken into the machine's responsibility, stripping the troops from the feeling of guilt and sorrow. (Johnson, 2023).

4. CONCLUSIONS & ACKNOWLEDGMENT

The uprising of Artificial Intelligence in all aspects of life is unavoidable, and that applies to the military and intelligence field too. Where global superpowers make efforts to be the first to conquer new AI-related knowledge and apply it to the field of military, to gain supremacy and more advanced capabilities, the AI used in strategic military operations, or leadership-related processes, such as mapping, planning, troops arrangement based of predictions, are highly questionable when it comes to the ethical aspect. International law must be very conscious and responsible when it comes to dealing with this very intriguing, yet disastrous if not well-paced power of Artificial Intelligence. As a result, the countries must be put together for a complete and common regulation, for reliability and security of the developed AI upgrades, both civil and military.

AI is going to change the world as we know it, and even remap the geopolitical stage of the world soon enough. The high expectations are even more concerning when it comes to giving AI full military access to execute lethal actions, conduct military operations, or even lead a battalion of troops on the field, with its predictions and planning. It is even more dangerous because the most ethical aspects of human behavior are prompted by developers of the AI, and not naturally felt, therefore, in the wrong hands and purposefully reprogrammed, it could have devastating consequences.

Another negative aspect is that an AI military device could not be directly accounted for its actions, or inactions made by error or by misinterpretation, such as a casualty killing, civilians killed, or infrastructure destroyed.

As a result, AI must be given access to powerful means of war only through very responsible and knowledgeable acts, and be monitored even when humans would eventually tend to give the strings of power to an AI to bring peace to the world and eradicate war, because the ethics of power are inaccessible to certain humans, sure, are but certainly inaccessible to all Artificial Intelligence.

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THE NEXUS OF LOGISTICS IN DEVELOPING PHYSICAL RESILIENCE AMONG MILITARY STUDENTS: AN INNOVATIVE PERSPECTIVE

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Abstract: *This article sheds light on the paramount significance of physical resilience among military personnel, addressing both the logistical implications in its development and innovative perspectives. Physical resilience has transcended the realm of mere aspiration, evolving into an imperative, as it is accountable for an individual's resistance, recovery, and enhancement in the face of physical stressors. Consequently, physical resilience maximizes the operational capacity of military personnel, thereby dictating success rates in combat scenarios. In the pursuit of fostering physical resilience, logistics plays a pivotal role, particularly in the context of Sustenance Provision Service. The nutrition provided by military higher education institutions underpins two strategies aimed at maximizing this capacity. However, this work introduces an adjacent instrument alongside nutrition. Through a conducted experiment, I demonstrate that supplementation with Creatine Monohydrate, during physical activities, elevates physical resilience by up to 24%, establishing it as an exceptionally effective dietary supplement.*

Keywords: *resilience, logistics, innovative perspectives, nutrition, creatine monohydrate.*

1. INTRODUCTION

The Armed Forces face various physical challenges both in peacetime and during warfare, and the cultivation of physical resilience among military personnel constitutes a pivotal element in delivering a quality human service. The development of this capacity underlies the maximization of operational effectiveness, as military personnel equipped with enhanced strength, endurance, and quicker recovery following exertion contribute significantly to mission success. The endeavor to maximize this capacity should commence early in one's career, ensuring prolonged benefits throughout the military service. Consequently, the cultivation of physical resilience among students, during their academy tenure, emerges as an imperative.

2. PHYSICAL RESILIENCE AND ITS SIGNIFICANCE IN THE LIVES OF MILITARY PERSONNEL

The concept of resilience has deep-rooted origins in literature, first emerging in a legal context in 1430 (Gößling-Reisemann, 2018: 4). Subsequently, it has been assimilated and adapted in various domains, including the technical domain, where it denotes the property of materials to return to their original form (McAslan, 2010: 2). Gradually, the concept of resilience has gained momentum and has been introduced into the human context, encompassing terms such as physical, psychological, emotional, and community resilience (Hurley, 2022).

The physical resilience of humans, originally a concept within the medical field, focuses on the recovery of bodily functions and is employed in the context of healthy aging with the aim of extending the functional capacities of the organism over an extended period (Duke, 2020: 731-733) (Chhetri, 2021: 29-30). The Rand Corporation has adopted and adapted this concept, defining it as the "ability to resist, recover, and grow in the face of stressors" (Robson, 2013: 3-4). Despite its recent incorporation into the literature, the concept of physical resilience is approached from various perspectives, with attributed nuances. Conceptualization at the theoretical level reveals uncertainty, and the terminology employed in the literature to describe this capacity may exhibit variations. According to aforementioned ideas, I anticipate that this domain will undergo further development in future literature, given its significance.

Nevertheless, analyzing these definitions, physical resilience implies the capacity of an organism to resist physical stimulating factors, to recover from their interaction, and to grow in response to them. In a military context, personnel require physical resilience to successfully confront challenges, recover from them, and continuously develop in the face of similar factors in order to mitigate the negative effects of subsequent interactions. Thus, physical resilience, within the context of military personnel, has a crucial impact on operations, contributing to the maximization of operational capacity. Physical resilience can be maximized through: increasing **strength**, facilitating the handling of heavy equipment and the execution of intense actions required in the field; enhancing **endurance**, maintaining efficiency over long periods without exhaustion, ensuring adaptability in various situations; reducing **recovery time** after exertion, contributing to reducing downtime between missions and maintaining optimal operational capacity (Szivak, 2015).

Given the importance of physical resilience in a military career, it is imperative that a significant proportion of active military personnel exhibit a maximized level of this capacity. In this context, the development of physical resilience from the educational period onwards becomes a crucial objective.

3. CASE STUDY ON THE REPRESENTATION OF MILITARY STUDENTS REGARDING NUTRITION AND PHYSICAL RESILIENCE

This case study aims to investigate the level of awareness regarding the importance of logistics, particularly the Sustenance Provision Service within it, on the physical resilience development of military personnel. As previously mentioned, the development of this resilience is crucial, especially during the academic period.

Therefore, this questionnaire is directed to students in military higher education institutions, primarily from the National Defense University. Participants were asked whether they believe logistics plays a role in physical resilience development and which functional areas within logistics are responsible for such implications. Furthermore, participants were requested to estimate, on a progressive scale from 1 to 5, the following:

• The contribution of nutrition to maximizing physical resilience;

• The contribution of nutrition to reducing body fat percentage to an optimal level and muscle development;

• The contribution of reducing body fat to an optimal level and muscle development in physical resilience development.

Additionally, participants were asked whether they believe the provided nutrition within their institutions is sufficient for physical resilience development or if dietary supplements are necessary.

If affirmative, participants were required to list the necessary supplements in order of importance. Moreover, the last question consisted of an open-ended response regarding their opinion on creatine monohydrate.

Regarding the interpretation of results, in this questionnaire were collected a total of 126 responses, comprising 65% from the National Defense University and 35% from institutions such as the Land Forces Academy, Air Forces Academy, Naval Academy, and Military Technical Academy. Despite 85% acknowledging the implications of logistics in physical resilience development, in the next multiple-choice question, students selected other functional areas beyond the Sustenance Provision Service, such as: Movement and Transportation selected by 50%, Medical Support by 48%, Supply by 47%, and "Other Response" by 9.5%, while Sustenance Provision Service received the highest share, 72.4%. This indicates that the majority of students (85%) are aware of the importance of logistics in physical resilience development, but 13% do not believe that the sustenance service has any implication. However, 57.6% rated the contribution of logistics in this process at the maximum level, 34.4% at level 4, 7.2% at level 3, and 0.8% at level 2.

Furthermore, students rated the importance of reducing body fat and muscle development in the physical resilience development process as follows: 51.2% at the maximum level, 28.8% at level 4, 16.8% at level 3, 2.4% at level 2, and 0.8% at level 1. Additionally, students appreciated the importance of nutrition in reducing body fat and muscle development as follows: 55.2% at the maximum level, 32% at level 4, and 12.8% at level 3.

Regarding their opinion on whether the nutrition provided by their institutions is sufficient for physical resilience development, 70.4% responded "it is not sufficient, dietary supplements are necessary," 20% responded "it is sufficient," and 9.6% responded "I don't know."

At the end of the questionnaire, participants were required to list effective dietary supplements for physical resilience development and at the last, to provide an open-ended response expressing their opinion on Creatine Monohydrate. For the first task, 29 participants mentioned Creatine Monohydrate among the necessary dietary supplements, and for the latter, 43 considered Creatine Monohydrate to be effective. There is a contradiction in this part of the questionnaire in terms of its interpretation, as if 43 consider it effective, there should have been a higher number of respondents mentioning it in the second-to-last question. This can be attributed to the fact that they might not have thought to mention this supplement at that time, coupled with a lack of interest or irresponsibility.

In concluding this study, it can be easily observed that very few students appreciate dietary supplements, particularly Creatine Monohydrate, at its true value. Similarly, I note that the importance of the fundamental pillar in physical resilience development, namely nutrition, is somewhat underestimated. Faced with these disappointing results, I believe a strategy for informing and motivating students about the importance of nutrition for enhancing physical performance should be considered.

4. IMPLICATIONS OF LOGISTICS IN ENHANCING PHYSICAL RESILIENCE

According to the *Manualul Conducerii Sprijinului Logistic În Operații Întrunite*, military logistics is defined as "the science of planning and executing the movement and maintenance of armed forces. In its broadest sense, it encompasses those aspects of military operations related to the conception and development, acquisition, storage, movement, distribution, maintenance, evacuation, and disposal of materials; the movement, evacuation, and hospitalization of personnel; the acquisition or construction, maintenance, operation of facilities, and their disposal; the acquisition or provision of services" (Florea, 2007: 86). Furthermore, in the *Doctrina Logisticii Întrunite a Armatei României*, logistics is characterized as "the managerial science that deals with the planning, cooperation, coordination, operation, command, and control of all material resources and services necessary for supporting forces in carrying out military actions in peacetime, instituting a state of siege, declaring a state of mobilization and/or war" (Mazilu, 2023: 19). In other words, and in a narrower sense, military logistics is the domain responsible for ensuring all necessary resources for the conduct of military actions by forces, thereby influencing success rates in operations.

Military logistics comprises a set of functional and related domains. The functional domains encompass core activities, including supply, field services, equipment lifecycle management, movement and transportation, infrastructure, operational medical support, and Host Nation Support. Concurrently, related domains consist of secondary activities within this realm, such as NSIP (NATO Security Investment Programme) and CSO (Contractor Support in Operations) (Mazilu, 2023:28).

Field services represent the functional domain of logistics that essentially involves a multitude of other activities, including accomodation of troops, the sustenance provision service, bathing, laundering of clothing and equipment, morale and welfare services (MWR), pest control, rodent eradication, selective waste collection, waste and refuse evacuation, and funeral services for military/civilian personnel (Mazilu, 2023: 31).

In both times of peace and conflict, military personnel is allocated to specific food standards, receiving either prepared meals or the equivalent monetary value if the military unit does not provide food services. As for military students, they are allocated to three main meals per day and a snack, experiencing an average daily intake of 4292 calories, 146g of protein, 92g of fat, and 690g of carbohydrates (Constantin, 2023: 47). Nutrition is regulated in accordance with caloric, nutritional, and value limits, aiming to fulfill all their nutritional needs (Florea, 2007: 72) (Mazilu, 2023: 32). Thus, due to the quality of the food service, military students can cultivate physical resilience, as proper nutrition underlies the two strategies mentioned in the questionnaire for developing this capacity.

According to a study investigating the correlation between body composition and physical capacity, researchers have concluded that muscle mass positively influences an individual's physical capacity, while excess adipose tissue exerts a notably negative impact (Contributors to the Institute of Medicine, 1990: 94). Therefore, to optimize the physical performance of military students and, consequently, maximize physical resilience, it is imperative to develop muscle mass and reduce adipose tissue. These two approaches are fundamentally rooted in proper nutrition correlated with physical activities.

The reduction of body fat tissue entails the adoption of a dietary regimen based on a caloric deficit, in accordance with the energy conservation principle in metabolism (Muller, 2003). To achieve this objective, an individual must ascertain their daily caloric requirements and adhere to a deficit of approximately 500 kcal/day (Bubnis, 2023). This deficit prompts the body to convert adipose tissue into energy, considering that the organism lacks sufficient energy to sustain all vital processes.

In the process of reducing body fat, emphasis is placed on maintaining an adequate intake of micro- and macronutrients to prevent nutritional deficiencies. Recommendations include a balanced intake of 10-35% kcal from proteins, 20-35% from fats, and 45-65% from carbohydrates. This approach ensures not only fat loss but also the maintenance of overall health, mitigating potential nutritional deficiencies (Walle, 2023).

Ultimately, the process of reducing body fat percentage transcends mere caloric deficit and necessitates careful attention to the nutritional composition of the diet, thereby contributing to a healthy and sustainable approach to maximizing physical performance.

The development of muscle mass is fundamentally rooted in the process of myofibrillar hypertrophy, defined as the enlargement of an organ or tissue. This phenomenon is underpinned by the stimulation of musculature through the imposition of tension generated by sporting activities, particularly weightlifting. During this phase, the musculature incurs micro-injuries, and during the subsequent rest period, myofibrils undergo repair, augmenting in size and strength. Throughout this intricate process, nutrition plays an exceptionally vital role, constituting a foundational pillar in muscular development (Schoenfeld, 2023: 10-12).

From a nutritional standpoint, the optimal provision of energy and protein is crucial for the recovery of myofibrils impacted during intense training. Studies indicate that for maximal efficacy in this process, individuals must maintain a caloric surplus of 300-500 kcal (Slater, 2019: 11) and consume at least 1.6 grams of protein per kilogram of body weight (Stokes, 2018: 6,9,10). Through meticulous nutrition management, the requisite resources for the growth and repair of muscle tissue are ensured, thereby contributing to success in muscle mass development.

With that being said, nutrition plays an essential role in maximizing physical resilience, forming the foundation for the two strategies: muscle development and adipose tissue reduction. Concerning military students, the logistical system succeeds in providing a diverse diet, accompanied by a protein and calorie content more than sufficient to achieve both modes of maximizing physical resilience.

However, with the evolution of nutrition and fitness industries, particular attention has been given to the administration of dietary supplements, notably creatine monohydrate. This supplement is by far the most researched and effective dietary supplement in the industry. Creatine monohydrate is a substance produced by our bodies or assimilated from food; however, to saturate the body's creatine stores for maximum efficiency, supplementation in the form of pills or powder is necessary. This substance serves to provide the body with energy during high-intensity exercises by replenishing adenosine triphosphate (ATP), the molecule responsible for energy production in the human body (Damianou, 2024) (Kreider, 2017: 1-4). Thus, individuals supplementing with creatine monohydrate experience increased strength and endurance, along with reduced muscle fatigue (Mawer, 2024).

Nevertheless, despite the comprehensive support within the specialized literature for the maximization of physical performance during creatine monohydrate supplementation, I deemed it necessary to conduct an independent case study to ascertain the actual reality.

5. CASE STUDY ON THE IMPACT OF MONOHYDRATE CREATINE SUPPLEMENTATION ON THE ENHANCEMENT OF PHYSICAL RESILIENCE AMONG MILITARY STUDENTS

This case study was conducted through an experimental approach, aiming to investigate the impact of creatine monohydrate on the development of physical resilience among military students. The focus was on enhancing strength, endurance, and reducing recovery time following exertion.

This experiment was conducted on a cohort of 24 participants, military students, who were provided with nutrition conducive to physical resilience development. Over a span of 10 weeks, these individuals engaged in a series of physical activities aimed at fostering physical resilience.

The experiment unfolded across three distinct temporal phases, each punctuated by the participants undergoing three distinct assessments: strength, endurance and recovery.

Concerning the strength assessment, participants undertook exercises encompassing bench press, leg press, shoulder press, deadlift and Z curls, with measurements taken to gauge the force exerted by major muscle groups. For the endurance test, participants performed sprints of 50 and 100 meters, alongside a 1000-meter endurance run, to quantify their fleeing capacity. The recovery evaluation involved measuring the duration, in seconds, from the end of the endurance trial until participants felt sufficiently prepared for another similar effort.

Through these meticulously designed assessments, the three cardinal facets of physical resilience, namely strength, endurance and recovery, were systematically gauged over the course of 10 weeks.

- In the first phase, represented by the first week, participants executed the three assessments at peak intensity to gauge their athletic prowess. During the strength trials, students pushed their limits using maximum weights for 1-2 repetitions. The endurance and recovery assessments were closely monitored, with results meticulously noted.
- In the second phase, spanning Weeks 2 to 5, participants underwent the three assessments in conjunction with the supplementation of creatine monohydrate. Throughout Weeks 2, 3, and 4, participants engaged in individualized training under the guidance of specialists, employing diverse techniques aimed at stimulating musculature or enhancing endurance. In Week 5, students once again subjected themselves to the three assessments at maximal intensity, mirroring the conditions of Week 1.

This period underscored a notable difference between Week 1 and Week 5 in terms of performance, thereby highlighting the considerable impact of creatine monohydrate supplementation. Even when acknowledging certain limitations and uncontrollable variables within this study, the observable effects of creatine supplementation on the students' performance and, consequently, their resilience were visible.

- In the third phase, spanning Weeks 6 to 10, participants performed the three assessments without further supplementation of creatine monohydrate. Throughout Weeks 6 to 9, participants engaged in individualized training under the supervision of specialists, utilizing various techniques to stimulate musculature or enhance endurance. In Week 10, students once again underwent the three assessments at maximal intensity, precisely replicating the conditions of Weeks 1 and 5.

Consequently, during Week 10, the impact of the absence of creatine monohydrate supplementation on physical performance could be discerned, thereby implicating its influence on the level of physical resilience among the students.

I would like to emphasize that the decision to implement a 3-week training period (designated as Weeks 2, 3, 4) with creatine monohydrate supplementation was grounded in the understanding that this is the minimum duration required for the body to reach creatine monohydrate saturation. This timeframe enables pertinent conclusions to be drawn by the fourth week (designated as Week 5), thereby avoiding unnecessary expenditure of financial and temporal resources. The administration method of creatine monohydrate employed in this study is a hybrid approach, encompassing a loading phase of 15g/day for 7 days, followed by a maintenance phase of 3-5g of creatine for 14 days. This approach adheres to the recommended normal limit of creatine intake, set at 20-25g/day for 5 days, as the study aimed to safeguard the physical integrity of the participants (Ribeiro 2021: 1-2). Consequently, in the fourth week (the last week of the second phase), the athletes' performance could be monitored with creatine stores saturated, ensuring the participants remained outside the realm of any physical risk during the loading phase.

Furthermore, it is noteworthy that a 4-week training period without creatine monohydrate supplementation was established (designated as Weeks 6, 7, 8, 9) based on studies suggesting that the depletion period of creatine stores may extend up to 30 days (Davis 2023). Thus, in the fifth week (designated as Week 10), the athletes' performance could be monitored without the presence of creatine stores.

Regarding the interpertation of results, at the conclusion of the ten-week experiment, following the comprehensive consolidation and analysis of data at a collective level, the following rates of progress were observed:

- In terms of strength assessment - by the fifth week, there was an increase of 24.64% compared to the initial week, and by the tenth week, this increase diminished to 2.86% in comparison to the fifth week.
- Regarding endurance test - by the fifth week, there was a progression of 4.94% compared to the first week, whereas by the tenth week, there was a regression of -2.53% in relation to the fifth week.
- Concerning the recovery assessment - by the fifth week, there was a progression of 9% compared to the first week, whereas by the tenth week, there was a regression of -3,14% in relation to the fifth week Top of Form

However, it is crucial to mention that these figures do not reflect reality in 100% proportions. This case study is exclusively descriptive and not prescriptive in nature. The results emerged from an experiment conducted in the presence of limitations and controllable or uncontrollable variables that could have influenced the previously presented figures. For clarification, I would like to outline the following limitations:

1. Progress/regression/maintenance in these three stages of the case study are outcomes influenced by a majority of factors, such as genetics, previous sports experience, training quality, interest, etc.
2. Each individual presents a unique progress pattern and its calculation also has limitations. For instance, the percentage progress rate between strength test values is calculated using the following formula: ((Vfinal - Vinitial) / Vinitial) x 100. However, a participant progressing from 40kg to 60kg records a 50% improvement, while another participant starting from 60kg and progressing to 80kg shows a growth rate of 33%. Furthermore, the difficulty of progress increases proportionally with advancement, highlighting potential errors in the results once again.
3. In the context of the Placebo Effect on creatine consumption, the students were aware that they would experience an improvement in performance and evaluated their limits in that direction. During the creatine elimination period (wash-out), students were aware that they could record a decrease in their capabilities, a phenomenon that demoralized them and could lead to a decrease in performance.
4. An essential aspect in the training process involves controllable variables, referring to the decision to give it all the energy in a repetition or to preserve energy reserves. This decision can influence progress, and managing controllable variables, such as enthusiasm or readiness, can have a significant impact.
5. Progress and the difficulty of the test: Progress is not uniform across all tests, and difficulty can vary. For example, transitioning from a weight of 75 to 90 kilograms may seem easier than going from 90 to 100, highlighting the complexity of assessing progress based on the specific difficulty of each test.
6. Participants who are newcomers to the realm of physical exercise and weight training will experience significant growth more quickly, potentially influencing the average progress rates.

In conclusion, the presence of controllable and uncontrollable variables plays a crucial role in constructing a realistic picture of the experiment's results. However, considering the presence of variables that unrealistically favor the progress rate during the creatine period, there still exists a significant difference between the creatine training period and the training period without creatine. Therefore, I reach the certainty that supplementing with creatine monohydrate maximizes both the strength and endurance and mitigate the recovery rate. More specifically, it can be asserted that supplementation with Creatine Monohydrate enhances physical resilience.

6. CONCLUSION AND RECOMMENDATIONS

In conclusion, logistics exerts a significant impact on the physical resilience development of military personnel. Physical resilience denotes the capacity of individuals to withstand, recover, and enhance their physical capabilities in the face of challenges, thereby cultivating military personnel capable of increasing their success rate in combat from the time of enrollment in military academies. Through the logistics' Sustenance Provision Service, military students can foster resilience through two primary strategies: optimizing adipose tissue reduction and muscular development. Considering the significance of these phenomena in the formation of a robust military force, the correlation between logistics, implicitly nutrition, and the development of physical resilience remains underappreciated and inadequately emphasized among students in institutions of higher military education. Furthermore, this article introduces an adjunctive instrument to nutrition, namely Creatine Monohydrate, whose value is not widely acknowledged among students. According to specialized literature, this dietary supplement stands out as the most efficient and extensively researched in the nutrition and fitness industry, yielding remarkable results in terms of athletic performance. Moreover, this assertion is reinforced by the findings of the experiment conducted within this scientific work, demonstrating that Creatine Monohydrate can enhance performance by up to 24%.

With that being said, I believe that much greater attention must be devoted to education, ensuring that students acquire a robust foundation in this area and are motivated to continuously develop themselves. Subsequently, as awareness reaches a heightened level regarding ways to enhance personal well-being, Creatine Monohydrate should be introduced into the dietary norms for students following a reevaluation of the logistics feeding system.

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NOVEL TACTICAL COMMUNICATIONS GADGET EMPLOYED BY AIR FORCE PERSONNEL IN HIGH-NOISE COMBAT ENVIRONMENTS

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Abstract: *Over the years, as aviation technology and regulations have advanced, pilot communication has also undergone substantial evolution. Because military activities are diverse and can involve high stakes, military pilot communications are extremely important. Molar Mic (MM) is a special communication tool made especially for law enforcement and military personnel. Bone conduction technology is used by the MM to transfer sound. It is represented by a small gadget that attaches to the user's back teeth and transforms audio impulses into vibrations that go around the eardrum and into the inner ear via the skull bones. This provides clear communication while preserving situational awareness by enabling the user to hear sound without obstructing their ear canal. The device allows hands-free use in a variety of settings, including loud or dangerous ones. It is wireless and usually interfaces with other communication devices like radios or cell phones. With no need for visible microphones or additional headphones, this permits users to converse discreetly. Therefore, MM is a novel device that paratroopers could employ when free-falling or pilots could use in noisy locations like military aircraft cockpits.*

Keywords*: bone conduction hearing technology; communication; dental device;*

1. INTRODUCTION

Because it facilitates seamless coordination between the flight crew, air traffic control, and other aircraft, communication is essential for pilots. Navigating airspace, preventing crashes, getting critical weather updates, and responding to emergencies clearly and precisely are all made possible by effective communication (Andrusenko, 2015). Coordination, security, and mission accomplishment in military operations depend heavily on efficient communication. Due to the high noise levels from guns, machines, and explosions, loud places like war zones, aircraft carriers, or firing ranges present special communication issues (Yong, 2015).

Without the use of specialist equipment, vocal communication in such circumstances may be challenging or impossible. Troops may utilize throat microphones, which detect vibrations from the vocal cords instead of background noise, or radios with noise-cancelling capabilities. When verbal communication is impeded, the use of hand signals and visual cues becomes even more important (Humes, 2006).

Another way of communicating is Molar Mic (MM), a discreet in-ear communication device that sends audio signals straight to the inner ear through the wearer's teeth and skull bones using bone conduction technology. This eliminates the need for obvious microphones or extra headphones and enables users to converse discreetly.

Additionally, it allows military personnel who have partial hearing loss to interact with others without difficulty, even in noisy environment (Nakashima, 2018).

2. METHODS AND MATERIALS

Based on a review of scientific literature and recently developed equipment, we believe that MM has the potential to improve communication in all military fields, including Air Forces. At the moment, the device (MM) produced by the company Sonitus is in its final tests for implementing the device in the equipment of US Air Force (Sonitus, 2024). MM could provide covert, reliable, secure communication capabilities in difficult circumstances, which improves operational effectiveness and safety for military troops engaged in a variety of tasks.

2.1 The materials and technology employed for MM

The MM is made up of a tiny transmitter that is inserted into a dental mold that is specially fitted and worn on the user's molars (Fig. 1).

The potential for allergic reactions to the device could be a worry. The oral mucosa may have irritating reactions from the device, depending on the external material (case) that it is composed of. Our suggestion is to incorporate acrylic into the outer shell in order to stop this from happening. A polymer matrix, often methyl methacrylate, is the main component of dental resin (acrylic resin). Fillers, such as silica or glass particles, are added to the matrix to improve strength and other characteristics (Pawar, 2016). With its wide spectrum of qualities, acrylic resin can be made to suit a variety of uses. Depending on the exact needs of the intended usage, it can be made to be rigid or flexible, transparent or opaque, colored or colorless. There are several methods for processing acrylic resin, such as heat curing, compression molding, and injection molding (Taniguchi, 1952). These procedures make it possible to fabricate intricate structures and forms with exact dimensional accuracy and this feature of acrylic resin ensures the perfect fit for MM in the oral cavity.

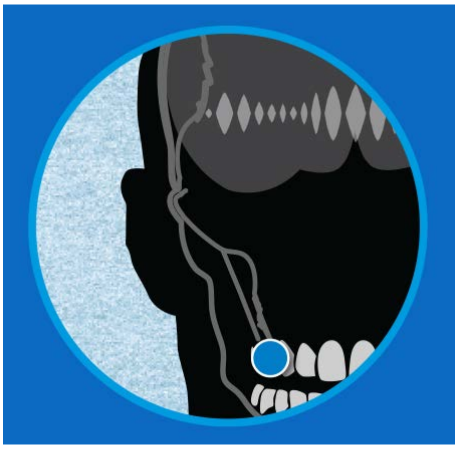

FIG. 1. An electronic illustration of Molar Mic's operation (Sonitus, 2024).

The following options could be used to activate the device so that team members can get information and data (Sonitus, 2024):

- Voice Command: Voice activation technology is a feature that enables users to activate MM with a specific voice command or term. The gadget activates and becomes ready to send and receive information as soon as it detects the command (Bala, 2010).

- Touch Control: Users may be able to engage touch-sensitive controls on a MM device by tapping or pushing on a designated region of the device. This offers a practical and simple way to switch the gadget on and off (Johnson, 1995).
- Bluetooth Connectivity.
- Manual Activation.

2.2 Bone Conduction Hearing

An intriguing area of physiology is called "bone conduction", in which sound waves go through the bones in the skull and directly stimulate the cochlea in the inner ear (Stenfelt, 2011). Because it avoids the middle and outer ears, people with specific kinds of hearing loss can still receive sound. This is also the idea underlying bone conduction headphones, which enable the user to hear without covering their ears by sending sound waves to the inner ear via the skull's bones.

The cochlea and other inner ear structures are housed in the temporal bone, one of the numerous bones that make up the human skull. The temporal bone is located close to the temple region on the side of the skull. It is separated into the squamous, mastoid, tympanic, and petrous sections, among other elements. The inner ear's components, such as the semicircular canals, which are a component of the vestibular system that regulates balance, and the cochlea, which is in charge of hearing, are located within the temporal bone. The middle ear cavity, which houses the ossicles—tiny bones—that are in charge of sending sound waves from the eardrum to the cochlea, is also located in the temporal bone (Reinfeldt, 2015).

The primary organ responsible for hearing is the spiral-shaped, fluid-filled cochlea. It has thousands of hair cells lining the organ of Corti, the sensory organ responsible for hearing. The main hearing receptors in the cochlea are hair cells. Stereocilia, which resemble hair and are arranged in rows of increasing height, are present in them. The stereocilia flex in response to sound vibrations passing through the fluid-filled cochlea, which causes the hair cells to produce electrical signals. Sound waves are then processed by the brain (Stenfelt, 2005).

Because bone conduction technology avoids the middle and outer ears, it might be beneficial even in cases where those ear structures are malfunctioning (Sohmer, 2000). This is one of its main advantages. Additionally, military communication devices and underwater communication systems for divers use it.

2.3 MM's placement on the dental arch

In order to accommodate the arrangement of teeth in the mouth, an adult human dental arch is normally U-shaped and has 32 teeth total; including incisors, canines, premolars, and molars, with 16 teeth in each arch (upper and lower) . Alveolar bone, periodontal ligaments, and gingival tissue are some of the elements that support the dental arch. For the teeth within the arch, these structures offer support and stability (Walker, 2011). Furthermore, this various supporting structures will have an essential role in transmitting the vibrations emitted by the device.

The device must be implanted on the upper dental arch in such a way that the contact with the dental hard tissues is permanent. In this way, the continuity of the transmission of vibrations directly to the inner ear is ensured.

The device's vibrations will travel through the cranium's biological components (Fig. 2), passing via the enamel, dentin, cementum, alveolar bone, maxillary bone (Fig. 2: number 1), sphenoid bone (Fig. 2: number 2), and ultimately the temporal bone (Fig. 2: number 3) to reach the inner ear (Fig. 2: number 4) (Pachaly, 2001).

Given their location on the dental arch that is closest to the inner ear, teeth 1.8 and 2.8 (in FDI numbering) are the most appropriate for MM insertion.

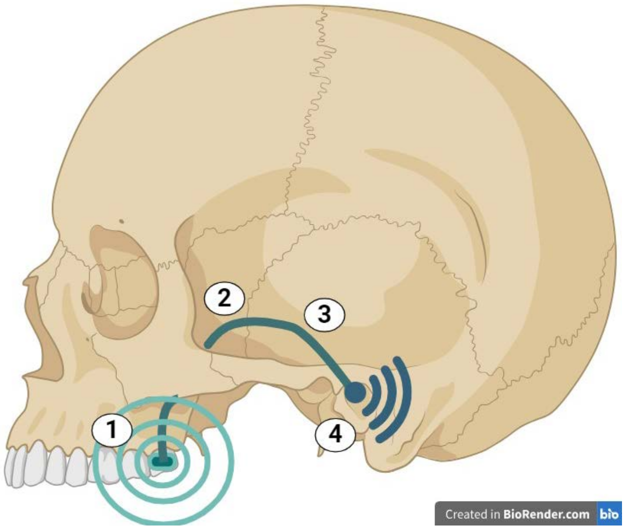

FIG. 2. The vibrations' path through the skull represented digitally.

We may choose from several different approaches to attach the MM to the user's molar. First, we might employ orthodontic bands that are directly affixed to the tooth (Millett, 2016). These are tiny metal bands that are positioned around teeth to offer support. You can attach the device by making some retention (for example with acrylic) on these metal rings. Two dental hooks that encircle the pillar tooth can be integrated to display the MM on the users' molars in another manner. Although the device's stability is a significant drawback, this procedure is advantageous due to its speed application and ease of removal (Hashim, 2017). The dental hooks may deteriorate or shatter, which would reduce the MM's efficacy.

When utilizing this equipment, we can run into issues if the military has lost his third molar or lacks the proper tooth bud. The quality of vibrations sensed in the inner ear (the clarity of associated sounds) might be greatly impacted by placing the device on the next molar because of the increased distance. When these situations occur, we can place a dental implant that will provide us a better position, provided time and the soldier's biological constitution permit. For the implant to be supported and able to resist functional tension, the patient's bone density and volume at the implant site must be sufficient (Meffert, 1992). Before implant placement, bone augmentation or grafting treatments could be required in cases of insufficient bone.

As titanium, the metal used to make dental implants is also a good medium for vibration transmission (Antonialli, 2010); this should not have an impact on the device's efficiency. Also, it is ideal for the soft tissues and gums around to be free of inflammation, infection, and periodontal disease.

Proper recovery and the avoidance of peri-implantitis—a similar disorder to periodontitis that affects the tissues around dental implants—depend on healthy soft tissues (Hasturk, 2012).

2.4 The potential use of MM in Air Force operations

2.4.1 Pilots must be able to communicate with air traffic control or other aircraft in a timely and efficient manner in the case of an emergency, such as an engine failure or system malfunction.

By preventing interruptions or delays in the transmission of critical information, MM guarantees that pilots can potentially improve the outcome of emergency circumstances.

Pilots would be free to concentrate entirely on piloting the aircraft since they could communicate with ground control, other aircraft, or crew members without using their hands. Furthermore, particularly in military aircraft or during combat operations, cockpits can be noisy places (Yong, 2015). During crucial flying phases like takeoff, landing, or maneuvering, this is especially important.

Also, MM offers a covert communication alternative for circumstances where concealment is crucial, including during clandestine missions or conversations with air traffic control in critical airspace. The fact that it is embedded in the teeth makes it nearly unnoticeable to onlookers, which lowers the possibility that enemies may discover it. Furthermore, particularly in military aircraft or during combat operations, cockpits can be noisy places and by directly detecting speech vibrations from the user's mouth, MM lessens the influence of surrounding noise and guarantees clear communication even in noisy settings. Conventional microphones and headsets can be uncomfortable, especially on lengthy missions. Pilots could communicate more comfortably via the MM.

Even in high-stress scenarios like ejection, pilots can stay in contact with ground control or other pilots thanks to the MM. If necessary, this real-time communication can help with coordination and support during the ejection procedure and any follow-up search and rescue activities. It frequently takes little time to manually operate communication gear during an airplane ejection since it involves quick and accurate movements, so MM could be the perfect tool. The extreme noise produced by an aircraft's ejection can disrupt conventional communication systems; however, the MM's bone conduction technology blocks out external noise. In these cases, high G-forces and abrupt changes in air pressure during ejection are just two of the challenging environmental conditions that the MM should resist.

2.4.2 Flight crew such as flight engineers, navigators, and loadmasters, frequently need to interact with the pilots and with each other during flight operations. Important messages are accurately and effectively sent because to MM's clear communication capabilities, even in high-noise environments. Additionally, flight crew workers may need to use both hands to complete jobs like loading cargo, navigating, or performing pre-flight inspections, much like pilots do.

2.4.3 Paratroopers require last-minute orders and updates from the commanders before a jump. In loud settings like the airplane cabin, MM facilitates clear conversation and ensures that important information is accurately delivered. Also, it might be necessary for paratroopers to communicate with the aircraft crew and with one another during the flight to the drop zone.

With hands-free communication offered by MM, paratroopers could concentrate on getting ready for the jump rather than being distracted by carrying communication equipment.

Moreover, to guarantee a successful and safe jump, paratroopers must synchronize their motions and actions while in the air. Real-time communication between paratroopers is made possible via MM, which enables them to modify their plans in response to unforeseen impediments or shifting conditions.

It might be important for paratroopers to inform their commanders or other team members of their location and status post landing. Critical information would be sent precisely and promptly through the MM, which facilitates clear conversation even in difficult settings like urban terrain or woodland areas.

2.4.4 Military Personnel with hearing problems could have several advantages while using MM. Without the requirement for functional ears, MM detects vocal vibrations straight from the user's oral cavity. This enables soldiers who have difficulty hearing to converse efficiently without depending on conventional auditory input.

Soldiers with hearing difficulties can have MM adapted to their unique needs. For instance, the device's settings can be changed to enhance incoming audio signals or modify the frequency range to better accommodate the user's hearing capacity (Moore, 2021).

3. CONCLUSIONS & ACKNOLEDGMENT

In order to enable discrete, hands-free communication through dental prosthesis, MM's technology comprises a sophisticated fusion of tiny electronics, bone conduction principles, and signal processing algorithms. It is a fantastic method for enabling clear communication in a noisy setting without requiring the soldier to carry around extra electronic equipment, and in situations where a gas mask is necessary, the quality of information transmission and reception won't be compromised. We contend that more thorough research is required to develop this gadget, but in tactical scenarios or for combatants who no longer have intact hearing, the benefits this technology offers are valuable.

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MULTISPECTRAL, HYPERSPECTRAL IMAGING AND THEIR MILITARY APPLICATIONS

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Abstract: *Airborne intelligence, surveillance, and reconnaissance (ISR) has become the priority of most of the countries in the 21st century. ISR information is essential and mandatory for preventing and addressing possible threats. This paper introduces the concept and principles of multispectral and hyperspectral imaging (MSI and HSI). Furthermore, it briefly outlines the promising defensive and offensive military applications of those technologies developed by The North Atlantic Treaty Organization (NATO), the Europe Defense Agency (EDA) and the US. Department of Defense (DoD). It describes how MSI and HSI can be utilized for target acquisition using different methods depending on the user's needs referring to the tactical and operational requirements. Spectral imaging is a key method for enhancing our own ISR information. This article explores the possibility of a low-cost multispectral imaging system compared to what's available on the consumer market.*

Keywords: *multispectral imaging, hyperspectral imaging, target detection, Raspberry Pi, airborne sensor.*

1. INTRODUCTION

In the 21st century, the focus of every nation is developing technologies that enable them to gather intelligence, surveillance, and reconnaissance (ISR) information to address possible threats. How can the content of ISR be enhanced using airborne advanced electrooptical devices like multispectral (MSI) and hyperspectral imaging (HSI)?

This optical sensing technologies allow great spectral resolution, ranging from visible to long-wave infrared (LWIR) wavelengths. Such gains in spectral information shape a particular opportunity to detect difficult targets at subpixel level, analyzing a landscape with or without prior knowledge of the materials to be encountered.

Optical imaging is an essential component of military systems because it presents the solutions available for the complete defense ecosystem, encompassing complex control systems, surveillance, intelligence gathering, reconnaissance activities, as well as measurement and monitoring capabilities. From an analytic point of view, the interpretation of a scene using conventional imaging (monochrome or color), depends on the spatial resolution of the image. Additionally, MSI enhances the information in the spatial dimension by capturing 2-10 wavebands depending on the system, providing the opportunity to study the spectral characteristics of different channels. Furthermore, HSI offers an informational expansion to the spatial dimension by incorporating the spectrum to each pixel. This unique method generates a "data cube" that contains insights about the physical and chemical properties of a target at tens to hundreds of narrow-wavelength bands within the system's field of view (Shimoni et al, 2019).

1.1 The Science Behind Multispectral and Hyperspectral Imaging

Multispectral imaging is a technique that captures different wavelengths of the electromagnetic spectrum. This can be achieved with multiple sensors or using instruments with multi band pass optical filters providing the same results with a single but complex sensor (Stamford et al. Plant Methods (2023) 19:9).

Hyperspectral imaging is a technique that involves capturing a series of closely spaced images across various narrow wavebands within the visible and infrared regions of the electromagnetic spectrum (Yuen & Richardson, 2013).

MSI and HSI allow us to identify materials and determine their properties by studying how light interacts with them. This study is called Spectroscopy.

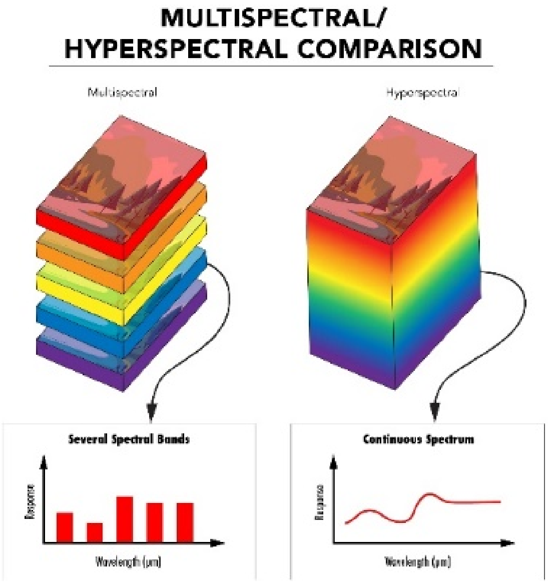

FIG. 1. Multispectral and Hyperspectral (https://www.edmundoptics.com/knowledge-center/application-notes/imaging/hyperspectral-and-multispectral-imaging/).

Spectroscopy examines how light behaves in the target and recognizes materials based on their different spectral signatures. Spectral signatures can be identified from the spectrum of the material. A spectrum describes the amount of light in different wavelengths. It shows how much light is emitted, reflected, or transmitted from the target. In short, a spectrum tells how much of a certain color this light contains. From the previous definitions we can conclude that spectral signatures can be compared with fingerprints.

The spectrum contains ultraviolet (200 to 400nm), the visible (400to 700 nm), the near infrared (700 to 1100 nm) the short infrared (1100 to 2500) and, sometimes long infrared (8000 to 14000 nm). The sensors in these parameters are activated by the light used to recognize an object from the immediate environment based on these spectral characteristics (Stein et al, 2001).

1.2 Military Applications of Multispectral and Hyperspectral Imaging

In military applications, this technology was adopted to detect and recognize targets usually camouflaged in the background. MSI and HSI were developed as a counter-countermeasure. In the last two decades, The North Atlantic Treaty Organization (NATO), the European Defense Agency (EDA), the U.S. Department of Defense, and the U.S. Department of Homeland Security have identified various other promising applications.

a) Gathering Information about the battlefield (MSI, HSI) - Imagery intelligence (IMINT) delivers concrete, in-depth, and accurate information on the location and physical characteristics of both the threat and the environment. It helps commanders by providing strategic support which increases situational awareness for the battlefield, including key terrain features, installations, and infrastructures, both natural and man-made. Additionally, HSI advances IMINT by contributing detailed information about the covered materials that allow transportability or location of forces and for mapping.

b) Discrimination between targets and decoys (HSI) - Guided missiles are essential to combat. These guided missiles navigate themselves to intercept targets, especially aircraft. that can deploy pyrotechnic decoys that lure away incoming projectiles. Conventional IR seekers are designed to home in on the IR signatures of a target aircraft's exhaust. With HSI-seeker technology, the ambition is to create intelligent seeker heads providing the rocket with immunity to conventional IR fake targets by designing them to only respond to the object's signature, particularly that of the aimed aircraft. The main condition is that before launching the missile, the spectral signature for the intended target is given to the HSI system.

c) Defeating camouflage (MSI, HSI) - Spectral imaging is a well-known technology used for defeating camouflage and hidden targets. The technology is based on a high spectral resolution band and range to identify hidden targets in the environment. There is a difference between traditional military camouflage (the objects are hidden in the visible spectrum), and multispectral camouflage (the objects are hidden from any detection such as IR, radar, or millimeter wave radar). The main reason for operating in visible spectrum, such as NIR, (VNIR) and SWIR is linked with the discrimination of different materials used for camouflage.

d) Early warning for long-range missiles (HSI) - The design commonly used for boost phase intercept system is based on a model that includes acquisition and tracking radar and IR sensors, which can detect with accuracy from thousand miles, missile plumes. These passive IR systems recognize MWIR (3-5) wavelengths from combustion plume species, which are mainly based on water, carbon dioxide, cobalt, sulfur dioxide, nobelium, and nitrogen oxide. In theory there is a link between the accumulation of chemical species and the level of spectral absorption features. For example, when a missile is detected through thermal emission inside the plume, the combustion species, in spectral, could highlight the type and the velocity of the rocket by their distribution(Shimoni et al, 2019).

e) Detecting landmines (HSI) - The detection of landmines is separated into two different categories: surface and buried landmines. In the first case, HSI is an encouraging technique for automatic detection of exposed or semi-hidden mines when prior knowledge of the target's spectral signature is available. Not surprisingly, detection performance is limited when targets are camouflaged by natural vegetation or hidden under other objects. In the latter case, spectral-based detection is used to identify disturbed ground or vegetation stressed due to occlusion of the device, not the device itself (Shimoni et al, 2019) (Letalick et al,2009).

f) Detecting chemical threats (HSI) - The detection, identification and tracking of the airborne toxins can be used to combat the use of weaponized gases, accidental hazmat leaks and avoid atmospheric contamination. Many chemical species can be detected and quantified because of their IR spectral properties in the wavelength region of 3–13 µm. Airborne toxic chemical detection analyzes the spectral signatures of the targeted compounds and the radiometric and temperature differences between the gas cloud and the background. In this case, the illumination conditions are insignificant because of thermal self-emission in the spectral region (Shimoni et al, 2019).

g) Remote sensing of stress for homeland security applications using HSI - The main objective for anti-terrorist national services is the detection of improvised explosion devices (IED). Due to lack in performance by systems meant to directly detect them, homeland security has turned to indirect methods. So rather than detecting the IED directly, we are seeking to distinguish intent that can be assessed by the detection of human stress. The surge of adrenaline in the blood stream is a response to emotional or physical stress. Because of a chain reaction in the body, the blood oxygenation almost doubles during stress. Therefore, by sensing the increase of the oxygenation in the blood (oxyhemoglobin) using HSI we can detect the possible intent depending on the context they are in (Yuen & Richardson, 2013).

2. ACQUIRING TARGETS WITH MSI AND HSI

The detection of military targets is mainly based on two types of image processing which are anomaly detection and signature-based detection. Prior to the processing of the extracted information the hardware should be calibrated according to the atmosphere correction, platform movement on which it is loaded (UAV flight) (Briottet et al, 2006).

a) Anomaly detection. Detection without prior knowledge. This target acquiring method is conceptually straight forward, governed by two basic principles:

1) the intended target takes up a small fraction of the image compared with the background; Therefore, the spatial resolution needs to be large.

2) that there exists a spectral contrast between the object and background. Only then a detection algorithm searches to pick up pixels which deviate from the background and classifies it as a potential target. The identification is made comparing the present hyperspectral images with past datasets taken of the specific clutter background. The limitation of this technique is the lack of performance in an urban scene. Due to the heterogeneous environment the background is a mix of materials with different spectral features resulting in multiple false alarms violating the first principle. Military operations conducted in uninhabited scenarios such as desert, field, mountain, or forest terrains can benefit from this method. The background is distinct from man-made objects such as vehicles or mines can be detected as anomalies using HSI even though they may have been camouflaged. This application was demonstrated by the WEAG program CEPA JP 8.10 in the context of the European Defense R&T Cooperation 2002-2005.

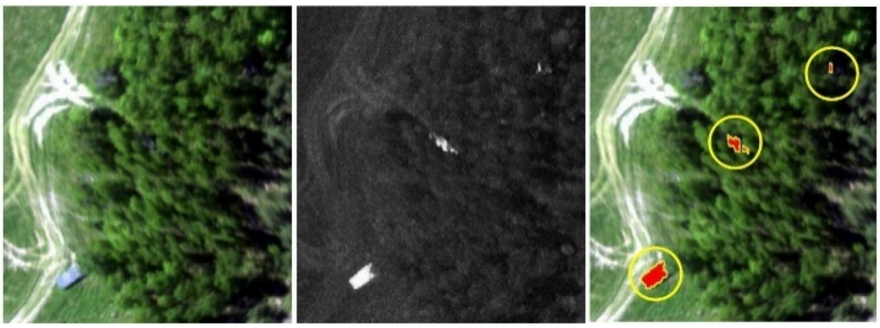

FIG. 2. Hyperspectral processing example (Briottet et al, 2006).

When an anomaly detection surveillance action is made, there also needs to be considered the ground sampling distance when dealing with small objects, the target dimensions need to be comparable with a pixel, especially in the case of landmines (Briottet et at, 2006).

b) Signature-based detection. Detection with prior knowledge. This target acquiring method works on a simple principle, if the spectral characteristic of the desired object is known the chosen algorithm will search for pixels that match the spectrum of given signature. The HSI sensor typically measures a radiance spectrum, by doing so it can be influenced by target reflectance, atmospheric scattering and absorption and illumination conditions. The WEAG program CEPA JP 8.10 presented that a possible solution would be the use of atmospheric propagation models to convert the measured radiance spectrum into an estimate of target reflectance in each pixel. Their objective was to identify camouflaged nets in the field. A prior spectral signature was obtained with a field spectrometer. The targets are emphasized by the purple delimitations (Briottet et al, 2006).

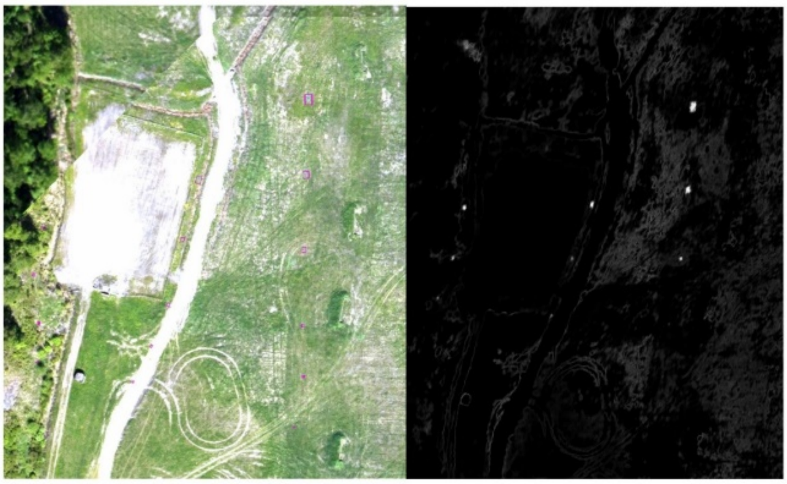

FIG. 3. Signature-based detection (Briottet et al, 2006).

c) Band selection. Band selection essentially is identical to multispectral imaging, nevertheless it can be also applied to hyperspectral imaging. This method aims to identify subsets with as few bands as possible which have enough data to represent the required spectral information. The bands with the most contribution to the detection process depend on both the spectral information of the scene and the target. This selection comes with multiple advantages and some limitations. By achieving this, the signal to noise ratio and the amount of data generated is decreased, the equipment cost can be lowered proportionally with the limit number of bands and lastly the reduction of false alarms (Briottet et al, 2006) (Crosby & Suiter, 2002).

3. DEVELPMENT OF AN AIRBORNE LOW-COST MULTISPECTRAL IMAGING SYSTEM

The motivation behind the development of this system was the need for a low-cost and easy to set up alternative for multispectral/hyperspectral cameras which tend to be quite expensive. The system is based on a method already used in agriculture which monitors the health of crops in a field using the normalized difference vegetation index (NDVI). Platforms such as ESA Sentinel 2 or NASA Landsat -8 satellites are offering free optical images with NDVI. By reverse engineering this existing technique the system could detect camouflage targets on a field. NDVI is a parameter calculated using red wavebands and the reflectance in near infra-red (NIR). This value is because a cell structure from a plant will reflect NIR because pigments of the plant will not absorb the light, and on the fact that chlorophyll pigments will absorb red wavelengths.

Meaning that healthy plants with a high level of chlorophyll will absorb more red and consequently reflect a higher level of NIR than fake plants or just unhealthy.

A low-cost multispectral imaging is to focus on 2 different cameras to register two required wavebands, such as: RGB camera that carputers red wavebands using the red channel - Canon GX-7 and a NIR sensor which could be a RGB camera without the IR filter - Raspberry Pi NoIR Camera Module V2. The system was created with the intent of being mounted on UAVs (Stamford et al, 2023) (Yuen & Richardson, 2013).

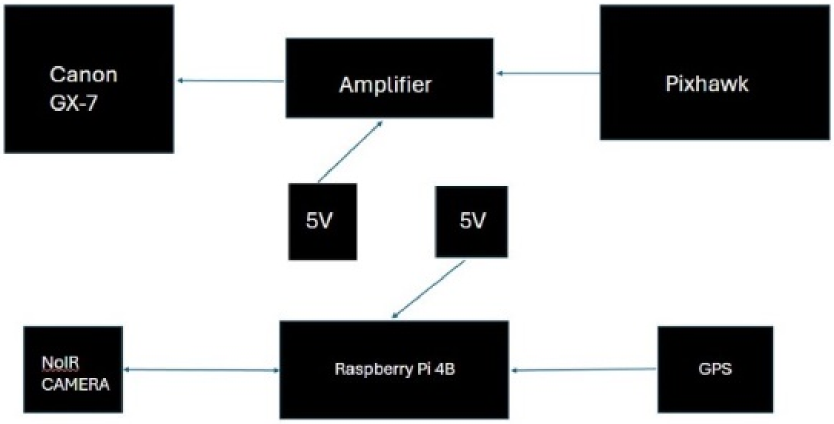

FIG. 4. Block diagram

3.1 RGB system

The RGB camera is connected and controlled by the drone's autopilot (Pixhawk), this way the device will capture photos on the user's command. This was achieved by employing an open-source software called Canon Hack Development Kit (CHDK) which allows the user to bypass the factory software and to exploit the full potential of the camera, most importantly the control of the processor, meaning we can program the device to execute certain actions. For this system I used the open-source script KAP Exposure Control to detect an electrical pulse width modulation (PWM) of 5V. The set up of the autopilot was made in Mission Planner by using the camera trigger parameters (SERVO_FUNCTION10 = 9, RC_FUNCTION10 = 10) to send an PWM on command of 3,3V. Because of the Pixhawk hardware limitations a special cable was needed that could amplify the signal to 5V so that the camera could detect it. A common emitter amplifier was created based on the following electrical circuit:

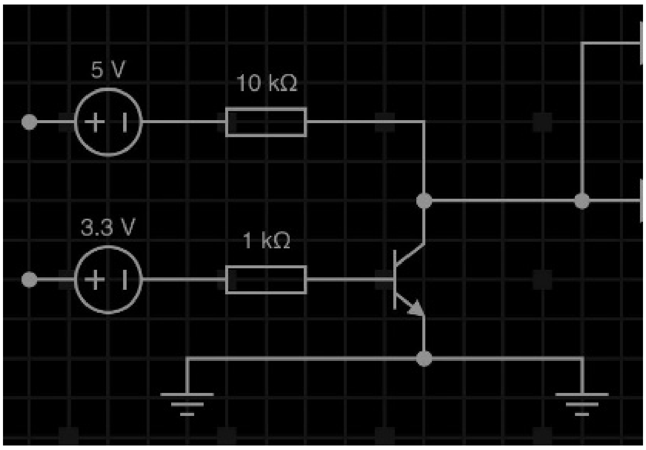

FIG. 5. Common emitter amplifier rendered in EveryCircuit

3.2 Noir system

This system is comprised of 3 components: a Raspberry Pi 4B (RPI) (Legacy OS, 64-bit, 6.1 Debian Bullseye), Sony IMX219 8 megapixels camera and a NEO-GM GPS module. The working principle is very simple, once the computer is connected to an electrical source of 5V, it will execute a script, "NoIRsystem.py", configured in the python programing language.

This script captures a photo every 2 seconds, the pictures are then saved in chronological order in a folder. With the help of the GPS module each photo is attributed their specific coordinates and timestamp, this information is then stored chronologically in text file. The code decoding the data form satellites received by the GPS module was sourced from: https://raspberrypi.stackexchange.com/questions/137318/reading-data-from-gps-module-using-python-on-raspberry-pi .

```python
import serial, time, pynmea2
import cv2
from picamera import Picamera2, Preview


port = "/dev/ttyAMA0" # assigning the communication port for the GPS module
baud = 9600 # baud rate
camera = Picamera2() # camera initialization
d=1 #variable numbering the pictures
image_path="/home/pi/my_captures/" #the location where photos are saved
file_path="/home/pi/my_gpsfile/" #the location where the GPS coordinates are saved
file_name="poze.txt" # the text file that contains the GPS coordinates
serialPort = serial.Serial(port, baudrate = baud, timeout=0.5) #initialization of the communication function between gps module and Raspberry Pi

while True:
    str = '' #variable for gps coordinates
    try:
        if str.find('GGA')>0:
            try:
                nume= "poza_%d.jpg"%d #the name of a picture
                camera.start_and_capture_file(image_path + nume, show_preview=False) # taking a photo
                d+=1
                msg = pynmea2.parse(str) #variable containing all gps coordinates
                with open(file_path + file_name, "a") as outfile:
                    line_to_write = f"{msg.timestamp} Lat = {round(msg.latitude,6)} Lon = {round(msg.longitude,6)}
                                         Alt={msg.altitude} Sats = {msg.num_sats}\n"
                    outfile.write(line_to_write)

            except Exception as e:
             print(e)
    except Exception as e:
        print(e)

time.sleep(2)
```

FIG. 6. "NoIRsystem.py" script

After the UAV's surveillance and reconnaissance flight the obtained data is imputed in the open-source software Open Drone Mapper which will create map of the area under investigation using the NDVI database. Then the user manually analyzes the information and draws the appropriate conclusions.

If the surveyed field has areas less rich in vegetation this could results in false possible target locations, that's why the system is designed to have a higher spatial resolution with the RGB camera compared to the NoIR camera to check if the alarm is false or not (Yuen & Richardson, 2013) (Stamford et al, 2023).

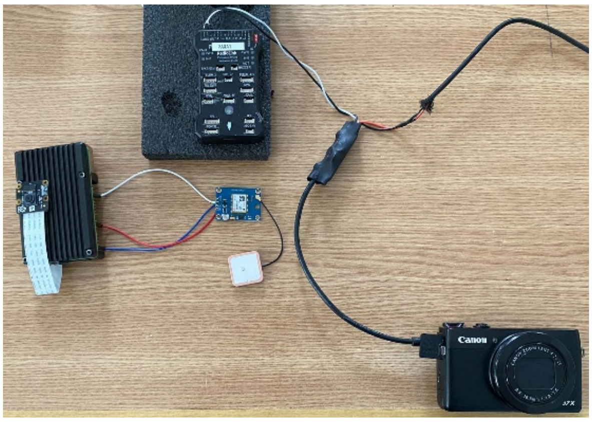

FIG. 7. The hardware of the system

3.3 Limitations

Using the NDVI allows the system to operate only in one scenery. Furthermore, the system isn't a viable option in a crisis because of the long processing time of information. Additionally, the low resolution of the NoIR camera module forces the UAV to fly at a lower altitude making it easy for the enemy to detect it. The performance of multispectral imaging based on the NDVI can be influenced by illumination (time of day). Moreover, the RGB system uses the principle of a on command photo and the NoIR system uses an intervalometer, this could result in a misalignment between the two. Likewise, the absence of calibration between the two cameras could affect the system's performance. Finally, the system will render useless if the enemy is using anti-spectral camouflage because it does not have the same sensibility compared to HSI (Stamford et al, 2023) (Yuen & Richardson, 2013) (Crosby & Suiter, 2002) (Shimoni et al, 2019).

4. FUTURE WORK

In a system that uses the two different sensors, calibration is vital for it to output maximum performance. The next step would be to calibrate the cameras with multiple known reflectance references materials with high and low values. Also, enabling both sensors to take pictures on command through the bypassing of the GPIO pins of RPI. Furthermore, designing a suitable support to incorporate the devices and be mounted on the UAV – Phoenix30. After those steps, the system will be tested in operational conditions.

Future development will include two steps. On one hand, the construction of a program that uses artificial intelligence to execute anomaly detection directly on the RPI. Moreover, adding another antenna that could transmit the results live to the ground station. On the other hand, an algorithm that incorporates multiple databases such as NDVI and if the resources are available to add another sensor to cover other wavebands to extend the operational capabilities and improve target detection (Stamford et al, 2023).

5. CONCLUSIONS

There are some people who can consider that MSI is a downgrade form of HIS with a lower spectral resolution. In fact, both techniques have qualities that can be applied for different tasks. Spectral imaging is the future of IMINT and can save lives and improve early detection systems, making them overwhelmingly accurate. Furthermore, this technology with the proper development can aid military personnel from covert operations to full scale wars, nevertheless its applications extend further, being able to improve the service of anti-terrorist troops and frontier police (Unninayar & Olsen, 2008).

The system is reverse engineered based on a spectral imaging method used in agriculture and is made up from off-the-shelf products accessible to everyone. This alternative takes the approach of two different sensors that obtain two separate wavebands: the visible (400-700nm) and the near infrared (700-1100nm) parts of the electromagnetic spectrum. The cameras that capture the need section of the spectrum are: Canon GX-7 – the visible and Sony IMX219 8 megapixels camera specifically designed for Raspberry Pi – the near infrared. The RGB sensor is controlled by a Pixhawk autopilot and the Noir sensor by a Raspberry Pi 4B computer. As a result, this system shows a cost efficient and easy to use airborne multispectral sensor that can reveal camouflage targets after a manual interpretation of the data.

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TECHNOLOGIES AND TECHNIQUES EMPLOYABLE FOR THE REDUCTION IN SEVERITY AND FREQUENCY OF EJECTING PILOTS' TRAUMA

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Abstract: *Since their inception as mechanical power augmenters exoskeletons have been implemented in different military applications with the aim of creating "the soldier of the future". Their inability to adapt and complement the natural movements of the body, the low energy density of power storage devices which limits their activity in time, as well as their sheer cost has made these machines impossible to implement for largescale infantry operations. This paper aims to identify applications of exoskeletons as augments for parachuting military personnel in reducing the risks of injury to which such individuals are exposed as well as to change the paradigm around ejection seats as just a marginal element in the equipment of a fighter aircraft. Through our work we hope to make the design of future generations of planes, ejection seats and pilot costumes more proficient at preventing and reducing injury to the user in an emergency, changes that, in our opinion, are essential in a world of asymmetric warfare and of rising demands for technical skills that take time and money to master by the war fighter.*

Keywords: *exoskeleton; ejection seat; parachuting injury; spinal trauma; aviation technology*

1. INTRODUCTION

As the war in Ukraine has proven over the past two years, military aviation still has a major role to play in conducting military operations in the current tactical environment, air-to-air and air-to-ground combat being not uncommon occurrences under the blue skies of Eastern Europe nowadays. At the same time, advances in technology are estimated to lead both to faster and more manoeuvrable aircraft and to more efficient and portable anti-air weapon platforms which will doubtlessly lead to more occurrences of pilots having to leave the cockpit of their aircraft at hight speeds. The limiting factor in the case of a successful ejection is the tolerance, in terms of mechanical forces, that the human body, with its intricate biomechanics, can safely endure.

In this article we will analyse and detail the mechanism of injury and some countermeasures that, theoretically, could be implemented in order to reduce the mortality, morbidity and the length of hospital stay for parachuting personnel, be they ejecting pilots or airborne infantry, in the event of an incident.

The strategic implications of the innovations proposed here consist in reducing the time that an injured pilot is taken off duty for recuperation(Zeng, Liu, & Yi, 2022) and also the time and cost of replacing pilots for whom the injuries are too severe to allow them to return to flight.

2. MATERIALS AND METHODS

We have analysed medical articles presenting case studies and statistical analyses detailing the occurrence of aviation incidents that required ejection of the pilot from his aircraft in order to identify the primary mechanisms of injury during and after the ejection. Employing our knowledge of trauma mechanics(Schmidt & MacCormick, 2021) as well as current developments in the field of exoskeletons(Baud, Manzoori, Ijspeert, & Bouri, 2021) we have suggested certain changes to the pilot's equipment and training and to the design of airplanes ejection assembly that should theoretically reduce the occurrence and minimize the severity of injury. We will present our finding in three subsections representing the three phases for which the injuries present a distinctively different character: the ejection phase, the descending phase and the landing phase. To note is the fact that the findings for the last two phases are also applicable for parachuting infantry whilst those for the first phase is only applicable to pilots of fixed wing aircraft.

2.1 The ejection phase

Will be designated, for our purposes, by the events taking place in the interval between the activation of the ejection sequence by the pilot and the deployment of the parachute after the seat-pilot separation. Nowadays, ejection is accomplished by propelling the pilot and the seat upwards, after the destruction or jettisoning of the canopy, (in certain older models the canopy is broken by spikes attached to the seat that precede the head of the pilot) with sufficient speed to avoid collision with the aircraft through the activation of eighter a ballistic charge or several short rocket bursts. Once the pilot clears the aircraft, drought parachutes are activated to stabilize the seat in the air current(Payne, 1974) after which separation of the pilot and his equipment is accomplished by detonation of a ballistic charge and his personal parachute is deployed. Modern ejection seats present nets that try to prevent limb flail of the hands and systems of powered retraction harnesses for the legs and shoulders in order to realize proper alignment of the back with the axis of force application at the moment of propulsion. The mode of operation for the ejection seat is automatically selected by its computer depending on the speed of the wind measured following canopy destruction/jettisoning to minimize compression stress on the spine while also ensuring proper clearance of the pilot from the aircraft.

The problem with this sequence of events is that it presents a great probability of provoking vertebral displacement, compression fractures and disc herniation(Lewis, 2002) especially at the cervical and lumbar levels which are the sites at which an injury has the greatest chances to invalidate a pilot for further flights due to the vicinity of vascular and nervous structures(Sommer, Gadjradj, & Pippig, 2022). Although the spinal column is a biomechanical structure highly resistant to compression accelerations up to 20Gs if properly aligned(Hall & Hall, 2021), current ejection seats can operate very close to this limit without ensuring adequate alignment (the head, which often has a heavy helmet with additional gear is not stabilized in any way leading to cervical injury)(O'Conor, Dalal, Ramachandran, Shivers, Shender, & Jones, 2020). Additionally, the spinal column cannot be reinforced against compression trauma without prophylactic surgery and external fixation of each vertebra to a system that ensures mechanical extension to counteract the compression (this method is risky, dangerous, slow, time and money consuming). As the speed at which fighter aircrafts operate increases the exacerbation of these problems is expected as the speed and, consequently, the acceleration needed for a successful ejection will be incremented.

The solution that we want to suggest for this problem consists in altering the attitude of the pilot and his seat at the beginning of the ejection sequence from a vertical to a horizontal one during the canopy jettisoning phase (Fig. 1).

In this configuration, the force of propulsion will act upon the sagittal axis of the pilot, condition in which the pilot may be able to resist accelerations up to 80Gs(Cullen, 2004). Depending on the application point of the thrusting force needed to propel the seat upwards the pilot's spine will be put under tension which, although contradictory to the physiologic role of the spine-that of resisting compressive loads-, may prove a great start to implementing technologies and techniques that can help in reducing spinal injury. Firstly, training regiments can be implemented to strengthen the muscles and ligaments of the spine, ensuring a better capacity for the spine to counteract the tensional load (O'Conor, Dalal, Ramachandran, Shivers, Shender, & Jones, 2020) whilst the analogous objective of training the spine to resist the forces applied during an ejection with a vertical posture would imply hardening and stiffening the osteo-cartilaginous structures of the spine which will translate in reduced mobility of the spine. Secondly, the spine can be stabilized externally through the use of lumbar braces(Wu, Zheng, & Wang, 2023), shoulder and head restraints and, ideally, spinal exoskeletons whilst external application of tension cannot be accomplished without the use of surgically implanted fixation devices due to the lack of appropriate anchoring points on appendicular structures.

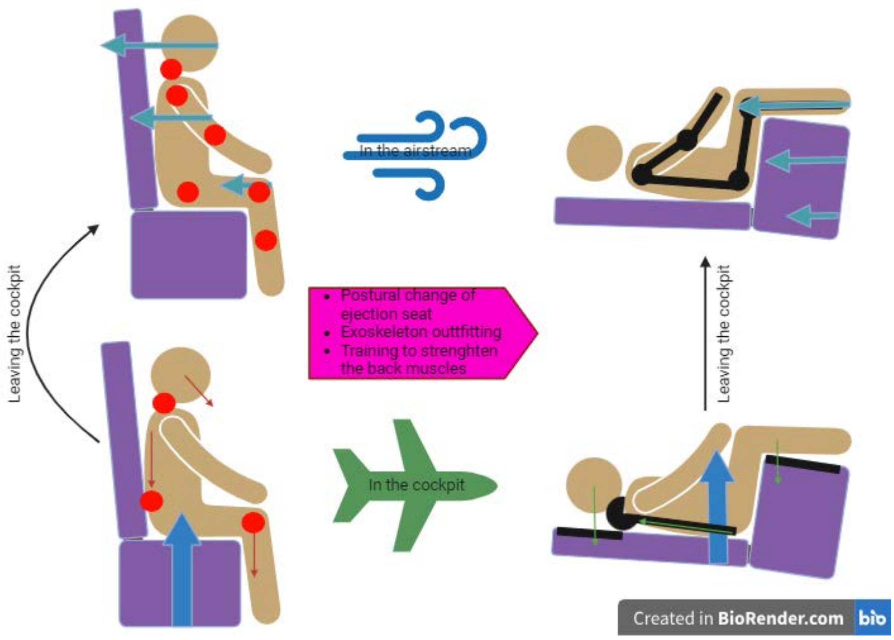

FIG. 1 Illustration of the effect of changing the postural attitude of the pilot during the ejection sequence from a vertical to a horizontal one during canopy jettisoning.

Next in the sequence of events following the initiation of the ejection process is the contact of the pilot with the air column which, assuming vertical posture, leads to flailing of the head as it is the first part of the body to get outside the cockpit. Contact with the air column at speeds such as those at which ejection takes place leads to thumbling of the seat which, combined with the low pressure generated at the lateral surface of the seat-pilot assembly at different moments of rotation, creates the perfect conditions for limb flailing(Payne, 1974). Given the psychological difficulty of convincing pilots to accept using leg or arm restraints, the phenomena of limb flail can prove debilitating by incurring articular, vascular, osseous and nervous damage which will prevent the pilot from being able to fly in the future. As a solution we would suggest the implementation of active exoskeletons for the limbs such that the actuators would fire when they evaluate a mismatch between the angle of an articulation and the degree of activation of the muscles that, anatomically, move that joint.

Another, cheaper solution would imply use of passive exoskeletons for joint stabilization(Quincey, 2018) but the complications associated with reduced mobility of the pilot in the cockpit make this alternative unattractive.

2.2 The descending phase

This phase constitutes the interval between the separation of the pilot from his seat or of the airborne infantryman from the plane and the contact of the individual with the ground. During this phase suspension trauma is to be expected as the most dangerous agent that can produce subsequent death and disability especially in the case of unconscious parachutists. Suspension trauma is incurred by the accumulation of blood in the lower extremities which can store blood due to the distensibility of their veins causing decreased cardiac return resulting in low blood pressure which leads to hypoxia of different organs especially, the heart and the brain which are due to suffer cell death in such conditions. Under normal circumstances contraction of the lower limbs prevents the pooling of blood by the massaging action of the muscles bordering the veins which is not possible in the event of a parachutist as he has nothing to push against with his feet (even worst in the case of an unconscious pilot which is unable to initiate contractions as the reflex needs an alert brain)(Weber, McGahan, Kaufmann, & Biswas, 2020). The solution that we want to propose to this problem in the attachment of stirrups to the waist of parachuting such that conscious individuals can more efficiently use the pumping function of their legs(Smith & Trentini, 2021) and the implementations of appendicular exoskeletons for ejecting pilots which will have implemented algorithms for leg movement that will be triggered during descent as this category of personnel is more susceptible to descending in an unconscious state.

2.3 The landing phase

The end of the parachuting sequence is characterized by impact of the parachutist's body with the hard surface of the ground which incurs a great probability of musculoskeletal injury(Sahin & Batın, 2020). Historically, preventive measures have been the implementation of proper landing positions to dissipate the kinetic energy of the fall. Nowadays, research in centred around means of reinforcing the flexible joints of the body at the moment of contact such as lumbosacral braces(Wu, Zheng, & Wang, 2023) or passive exoskeletons that can help in absorbing energy(Quincey, 2018)(Riemer & Ostraich, 2022). Our suggestion is the implementation of active exoskeletons, especially in the case of pilots which may be incapacitated by the ejecting procedure thus being unable to adopt a proper landing position, with built-in sensors for detecting the characteristics of the landing surface and algorithms that automatically select and execute the best landing position and subsequent movements as to minimize pilot or paratrooper injury(Baud, Manzoori, Ijspeert, & Bouri, 2021). Implementation of such a system will lead to resolution of the historical problems of novice parachutists changing their landing attitude at the last moment out of fear of rapid approach of the ground and of being swept by a wind gust after landing out of insufficiently fast manual collapsing of the canopy by the parachuted individual(Ellitsgaard, 1987).

3. RESULTS

Through application of knowledge obtained from the medical literature we have established the general principles that should guide the design of equipment and procedures to stand at the base of the next generation of military aviation technology. Given the inability of neurons in the central nervous system to regenerate we have concluded that special attention should be paid to avoiding damage at this level(Ross & Pawlina, 2020).

Although the changes that we want to suggest to the ejection sequence would require considerable alterations to the avionics of the plane (requiring the elongation of the cockpit or the jettisoning of a part of the equipment at its back to accommodate the longer pilot-seat assembly after reclining) and may expose the pilot to other, milder, ejection hazards(Arora, Radhakrishnan, Sharma, & Moorchung, 2019) this change will reduce the amount of acceleration needed to ensure clearance of the pilot from the aircraft's cockpit as the height of the pilot-seat assembly will be decreased by reclining and will also diminish the chances that a pilot is struck in the head by the canopy during its jettisoning phase due to inappropriate flying attitude(Dikshit, 2010). Implementation of an active exoskeleton suit for ejecting pilots constitutes a niche in which the drawbacks of such technology are minimize due to the lack of extended use, need to adapt to the natural movements of the body and cost relative to that of the wearer (FIG. 2). At the same time, active exoskeletons may prove indispensable for the future of aviation as technologies for monitoring vital signs of pilots will doubtlessly lead to implementation of portable multisystem analysis complexes that may one day trigger the ejection sequence autonomously (and/or with the validation of a flying partner) out of detected patterns of incapacitating conditions such as G-associated loss of consciousness(Dikshit, 2010)(Read & Pillay, 2000).

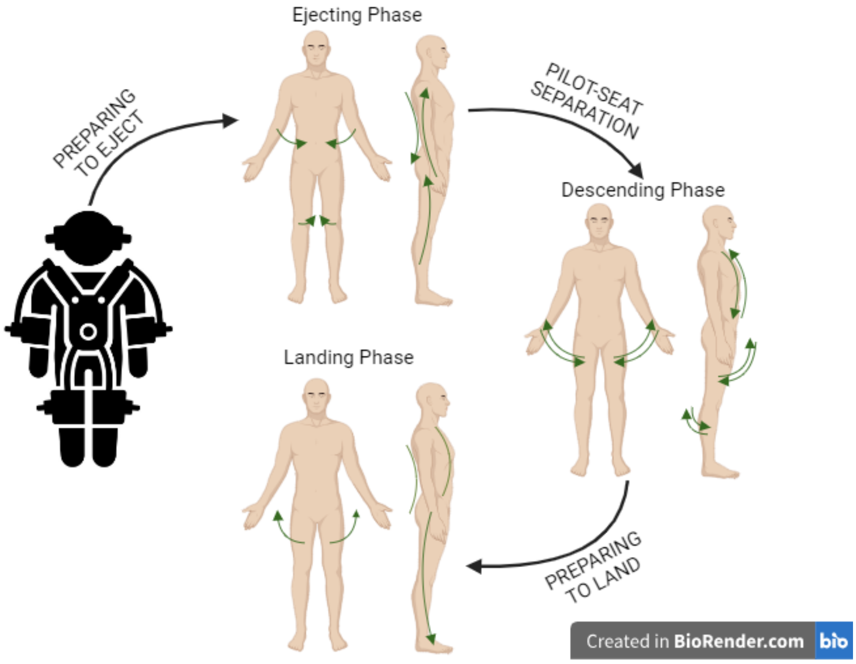

FIG. 2. Illustration of a possible algorithm of movement for an active exoskeleton outfitted to a pilot during the three phases of parachuting after an aviation incident.

4. CONCLUSIONS

Implementation of technologies and techniques such as those presented in this article will serve as a complement to the rising operational capabilities of fighter aircraft and of the flight suit to compensate for the physiological shortcomings of the human body under rapid acceleration during aerial manoeuvres(Contesi, 2023).

Considering the fact that an adequate reserve of fighter aircrafts can be maintained without a sufficient number of pilots, which is not true for the reverse, it stands to reason that, as the type of war waged by civilized nations against one another tend towards the model of total war suggested by Clausewitz, the number of able pilots that a nation can put in the skies will determine its level of air dominance. This is why, we believe, the philosophy of aircraft design should be focused around pilot survivability and protection in the event of emergency situations. This approach will require further investigations in the biomechanics of ejection and substantial innovations in the processes of design and production for fighter aircraft.

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THE CRUISE MISSILE THREAT

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Abstract: *In the contemporary landscape of international security, cruise missiles have emerged as a multifaceted and formidable threat. This project delves into the complexities surrounding cruise missiles, spanning their historical evolution, diverse types, technological intricacies, and the imminent risks they pose to global stability. The study aims to provide a comprehensive analysis of the cruise missile threat, emphasizing the imperative for robust defense strategies and systems.*

Cruise missiles, with their ability to be launched from significant distances and fly at low altitudes, present a unique challenge, making timely detection and interception difficult. The diverse array of threats they pose encompasses terrorist attacks, destruction of critical infrastructure, asymmetric warfare, cyber threats, regional tensions, and the potential for nuclear catastrophe. The project highlights the necessity for a serious and informed approach to address these security concerns. Categorizing cruise missiles into various types, including long-range, short-range, nuclear-capable, hypersonic, underwater, and anti-ship variants, the study explores their specific characteristics and applications. Technological aspects, such as motorization, guidance systems, payloads, communication systems, survivability measures, and launch methods, are dissected to underscore the sophistication that makes cruise missiles elusive and powerful.

To counter this evolving threat, the project details existing defense systems and strategies, ranging from anti-aircraft interception systems to hypersonic interceptor missiles. Surveillance and detection technologies, passive protection measures, and international cooperation are identified as key components in mitigating the cruise missile menace. The study concludes by emphasizing the urgency of continued research and development to keep pace with the advancing technology of cruise missiles, advocating a holistic and collaborative approach for sustained international security and stability.

1. INTRODUCTION

In the modern era, international security faces an increasingly diverse range of threats, and cruise missiles pose a significant and insidious threat. These devices, with a history spanning several decades, have evolved considerably in technology, capability and variability, putting states, communities and global interests at risk.

The aim of this project is to provide an in-depth analysis of the cruise missile threat, covering issues such as the types and technology of these weapons, their impact on national and international security, and the defence strategies and systems available to meet this challenge.

Cruise missiles, throughout their history, have been used in military conflicts, terrorist attacks and challenges to international peace and stability. They pose a particular danger because of their ability to be launched from considerable distances and to fly close over land, making them difficult to detect and intercept in a timely manner. These characteristics make the threat of cruise missiles a security issue that requires a serious approach and effective solutions.

In light of these challenges, this project aims to provide an objective and informed analysis of cruise missiles, focusing on the types of missiles, their technology, the threats they pose and ways to mitigate these risks. It is essential to better understand this threat and explore ways to ensure the security of nations and populations against this dangerous form of military technology.

Through this project, we will examine both the technical and strategic-political dimensions of the cruise missile threat, providing a comprehensive picture of this contemporary security issue.

2. THREATS AND RISK

The threats and risks associated with cruise missiles are diverse and can have a significant impact on national and international security. Here are some of these threats and risks:

1. Terrorist attacks: Terrorist groups or non-state entities may use cruise missiles to attack civilian or military targets. These attacks can cause massive damage and destabilise entire regions.
2. Destruction of critical infrastructure: Cruise missiles can be used to attack critical infrastructure such as power plants, drinking water installations or communication systems. Destroying these facilities can cause chaos and damage national economies.
3. Attacks on military bases: Cruise missiles can be used to attack military bases, aircraft or warships. These attacks can weaken a country's defence capability and lead to loss of life.
4. Asymmetric threats: Cruise missiles can be used by smaller states or terrorist groups to offset the superior military power of other nations. This creates an asymmetric threat dynamic in which military capabilities are used unconventionally.
5. Cyber attacks and disinformation: Cyber threats or disinformation campaigns can be used to support cruise missile attacks. These techniques can undermine defence capabilities and cause confusion.
6. Regional security challenges: States with cruise missiles can pose a threat to their neighbours, generating regional tensions and possible conflicts.
7. Missile smuggling: Groups or states may attempt to smuggle cruise missiles into a region or country, which can fuel weapons proliferation and increase the risk of misuse.
8. Vulnerability of defence infrastructure: Cruise missiles can evade conventional defences, such as anti-aircraft missiles, due to their ability to fly at low altitudes or to manoeuvre. This can create vulnerabilities in national defences.
9. Reduced reaction time: Cruise missiles can be launched quickly, reducing reaction time and the ability to detect and intercept them in a timely manner.

Nuclear-tipped missiles: Nuclear-tipped cruise missiles can pose a threat to national security and have catastrophic consequences.

All these threats and risks require careful monitoring, development and deployment of effective defence technologies, and international cooperation to reduce the potential impact of cruise missiles on global security.

3. TYPES OF CRUISE MISSILES

Each type of cruise missile has specific characteristics and uses, and their ability to be launched remotely and deliver payloads in a precise manner makes them a significant threat. Monitoring and development of defence technologies are essential to counter these threats.

A brief classification of cruise missiles may be as follows:

1. Long-range cruise missiles:

- Example: Tomahawk (BGM-109) - This US-developed cruise missile has a range of over 1,500 miles and is used for precision strikes against land or sea targets.
- Kalibr-NK - A cruise missile developed by Russia with a range of up to 2,500 km.

2. Short-range cruise missiles:

- Example: AGM-158 JASSM (Joint Air-to-Surface Standoff Missile) - This cruise missile used by the US has a range of up to 370 miles and is designed to attack high-value targets deep in enemy territory.
- BrahMos - A missile developed cooperatively by India and Russia with a range of about 290 km.

3. Nuclear-capable cruise missiles:

- Example: BGM-109G Gryphon - A nuclear-armed version of the Tomahawk missile formerly used by the United States.
- Kh-55 - A nuclear-tipped cruise missile developed by the Soviet Union and used in the Russian nuclear arsenal.

4. Hypersonic cruise missiles:

- Example: the Avangard missile - Developed by Russia, it is capable of speeds up to Mach 20 and can manoeuvre in flight, making it extremely difficult to intercept.
- X-51 Waverider - An experimental hypersonic rocket developed by the US.

5. Underwater cruise missiles:

- Example: Submarine-Launched Ballistic Missile (SLBM) - These missiles can be launched from submarines and can have conventional or nuclear payloads. Examples include the US's Trident or Russia's Bulava SLBMs.

6. Anti-ship cruise missiles:

- Example: Exocet - A French missile used in anti-ship attacks. These missiles are designed to hit enemy ships.

4. CRUISE MISSILE TECHNOLOGY

Cruise missile technology is complex and involves a number of components and systems that allow these weapons to hit targets with precision. Here is an overview of cruise missile technology:

1. Motorisation:

- Cruise missiles are equipped with engines that propel them during flight. There are two main types of engines: jet (jet) engines and rocket (solid or liquid-fuelled rocket) engines.
- Jet engines are typically used for subsonic rockets, while rocket engines are used for hypersonic rockets.

2. Guidance system:

- Cruise missiles are equipped with guidance systems that allow them to follow a pre-programmed route or adjust their trajectory during flight.
- Guidance systems can include GPS, inertial systems, radar or ground navigation systems. Hypersonic missiles may also use advanced sensors to avoid obstacles and manoeuvre during flight.

3. Payload:

- Most cruise missiles are equipped with a payload, which can be explosive or other types of payload, such as chemical or biological.
- The missiles can also carry sub-loads, such as cluster bombs or smart warheads, to hit precise targets.

4. Communication systems:

- Cruise missiles can be equipped with communication systems to receive updates from command or to transmit data to other missiles or aircraft.
- These systems allow the commander to change the trajectory of the missile in real time or to recall it if necessary.

5. Survivability:

- Cruise missiles can be equipped with self-dispersing or decoy systems to avoid enemy defences such as anti-aircraft missiles or radars.
- Evasive manoeuvres and the ability to fly at variable altitudes makemissiles difficult to intercept.

6. Launch and recovery:

- Cruise missiles can be launched from a variety of platforms, such as ships, submarines, aircraft or ground launchers.
- In the case of nuclear-capable missiles, they can be launched from submarines, with the possibility of being launched underwater.

This advanced technology makes cruise missiles a powerful and versatile tool for strategic attacks. With the evolution of technology, cruise missiles have become increasingly difficult to detect and intercept, making them a significant threat to national and international security.

5. CRUISE MISSILE DEFENCE SYSTEMS AND STRATEGIES

There are several defence systems and strategies to counter the cruise missile threat. These range from active interception systems to passive target protection measures. Below are some examples as follows:

1. Anti-aircraft interception systems:

- Anti-aircraft missile systems, such as the Patriot system (used by the US), the S-400 system (used by Russia), and the Iron Dome system (developed by Israel), are capable of detecting and intercepting cruise missiles in flight.
- This type of system uses interceptor missiles to destroy enemy missiles before they reach their target.

2. Long-range air defence systems:

- Long-range air defence systems, such as the Aegis Ballistic Missile Defence system (used by the US), are designed to intercept missiles in the initial phases of flight, before they reach the target.

3. Cruise missile launchers:

- Some countries have developed their own cruise missile launch systems, which can be used to counter the threat of enemy missiles. These launchers can launch their own cruise missiles to destroy enemy missiles.

Radar and detection systems:

- The use of radar and other advanced detection systems can help identify and track cruise missiles. This information is essential for coordinating defence operations.

5. Development of hypersonic interceptor missiles:

- Some countries are developing hypersonic interceptor missiles, which have the ability to quickly reach and destroy enemy missiles.

6. Passive target protection measures:

- These may include building underground shelters or bunkers to protect targets from cruise missile attacks.
- Use decoys and electronic countermeasures to confuse enemy missiles.

7. Monitoring and surveillance of maritime traffic:

- Many cruise missiles are launched from ships or submarines. Monitoring and surveillance of maritime traffic can help identify and track ships that might launch missiles.

8. International cooperation:

- Collaboration between states and intelligence sharing can enhance the ability to counter cruise missile threats. International agreements and non-proliferation treaties can play an important role in managing this threat.

These defence systems and strategies may vary according to the technological capabilities and resources available to each country or organisation. However, the development of effective defence technologies and international cooperation remain essential to address the cruise missile threat.

6. CONCLUSIONS

In conclusion, the cruise missile threat is a complex and serious national and international security issue. These missiles are capable of carrying dangerous payloads and reaching targets at considerable distances, making them a potent weapon in military conflicts, terrorist attacks and challenges to international stability.

However, there are defence systems and strategies that can help counter this threat:

1. Advanced interception systems: Anti-missile systems such as Patriot, S-400 and Iron Dome can intercept cruise missiles before they reach their target.
2. Effective surveillance and detection: The use of radar and monitoring technologies, as well as international information sharing, can help identify and track cruise missiles in real time.
3. Development of hypersonic interceptor technologies: The development of hypersonic interceptor missiles may provide an additional capability to counter cruise missile threats.
4. Protecting critical infrastructure: Passive protection measures, such as the construction of underground shelters and security measures, can help minimise the impact of a cruise missile attack.
5. International cooperation: Collaboration between states and information sharing are essential to address the global cruise missile threat.

As cruise missile technology is rapidly evolving, further research and development of advanced defence technologies to meet this evolving threat is imperative. Finally, managing the cruise missile threat requires a comprehensive approach and collaboration among nations to ensure international security and stability.

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WORDS LIE.YOUR FACE DOESN'T

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Abstract: *In a world characterized by linguistic diversity, communication across various languages and cultures remains a challenge. Dr. Paul Ekman, an anthropologist, posits a compelling solution to this challenge - the universal language of facial expressions and gestures. With over 6,500 languages spoken globally, diverse cultures also exhibit unique non-verbal communication cues, such as peace signals. Ekman's extensive cross-cultural research on emotions reveals the existence of seven universally recognized facial microexpressions: Joy, Sadness, Anger, Contempt, Fear, and Surprise. These fleeting expressions, observable for mere moments, provide authentic glimpses into individuals' true feelings. The interconnectedness between our emotions and facial expressions is so profound that individuals can intentionally induce emotions by replicating specific expressions.*

This paper explores the concept of facial expressions as a universal system of communication, transcending linguistic and cultural barriers. By delving into the nuances of microexpressions, we unveil a shared human language that reflects moment-to-moment fluctuations in emotional states. Understanding and recognizing these universal signals not only enhances intercultural communication but also underscores the intricate link between our emotions and the subtle muscle movements that shape our facial expressions. In essence, facial expressions emerge as a global means of conveying emotions, providing a common ground for interpersonal understanding across diverse linguistic and cultural landscapes.

Keywords*: microexpression; human leanguage; recognizing*

1. INTRODUCTION

In a world brimming with linguistic diversity, effective communication across varied languages and cultures stands as a formidable challenge. Dr. Paul Ekman, a distinguished anthropologist, presents a captivating solution to this enduring dilemma—the universal language of facial expressions and gestures. Amidst the cacophony of over 6,500 languages spoken globally, diverse cultures also harbor unique non-verbal communication cues, including subtle signals denoting peace and harmony. Ekman's extensive cross-cultural research on emotions unveils the existence of seven universally recognized facial microexpressions: Joy, Sadness, Anger, Contempt, Fear, and Surprise. These fleeting expressions, observable for mere moments, offer authentic glimpses into individuals' true emotional states. Moreover, the profound interconnectedness between our emotions and facial expressions is so profound that individuals can deliberately induce emotions by replicating specific expressions.

This paper embarks on a journey to explore the concept of facial expressions as a universal system of communication, transcending linguistic and cultural barriers. By delving into the nuanced realm of microexpressions, we unveil a shared human language that reflects moment-to-moment fluctuations in emotional states.

Understanding and recognizing these universal signals not only enriches intercultural communication but also underscores the intricate link between our emotions and the subtle muscle movements that shape our facial expressions. In essence, facial expressions emerge as a global means of conveying emotions, providing a common ground for interpersonal understanding across diverse linguistic and cultural landscapes.

2. THE SIGNIFICANCE OF FACIAL MICROEXPRESSIONS

Facial microexpressions, those fleeting and involuntary expressions that flicker across our faces in a fraction of a second, carry profound significance in understanding human emotions and intentions. While often unnoticed in everyday interactions, these subtle movements provide authentic glimpses into individuals' true feelings, bypassing conscious control and social masking.

The significance of facial microexpressions lies in their universality and authenticity. Dr. Paul Ekman's seminal research has revealed that certain facial expressions—such as joy, sadness, anger, contempt, fear, and surprise—are universally recognized across cultures. Regardless of linguistic or cultural background, individuals instinctively interpret these microexpressions, attesting to their innate communicative power.

Moreover, facial microexpressions serve as invaluable indicators of emotional sincerity and congruence. Unlike deliberate or socially conditioned expressions, microexpressions betray genuine emotional states, offering insights into individuals' underlying feelings and motivations. In contexts such as negotiations, interviews, and interpersonal interactions, the ability to discern these subtle cues can be instrumental in building rapport, detecting deception, and fostering empathic connections.

3. INTENTIONAL INDUCTION OF EMOTIONS

The intentional induction of emotions through the replication of specific facial expressions underscores the profound connection between our outward expressions and inner emotional states. Dr. Paul Ekman's research has illuminated how individuals can deliberately evoke emotions by mimicking corresponding facial expressions—a phenomenon known as facial feedback hypothesis.

At the heart of intentional emotion induction lies the recognition of the bidirectional relationship between emotions and facial expressions. Just as genuine emotions manifest through facial microexpressions, the deliberate adoption of certain facial configurations can trigger corresponding emotional responses. For instance, forcing a smile can elicit feelings of happiness or amusement, even in the absence of genuine stimuli.

The intentional induction of emotions holds implications across diverse domains, from personal well-being to social interaction and professional performance. In therapeutic settings, techniques such as "facial priming" leverage the power of facial expressions to modulate emotional experiences and promote psychological resilience. By encouraging clients to adopt expressions associated with positive emotions, therapists facilitate the cultivation of adaptive coping strategies and emotional regulation skills.

In social contexts, individuals may employ intentional emotion induction as a means of impression management or social bonding. Displaying genuine-looking expressions of empathy, warmth, or enthusiasm can enhance interpersonal rapport, foster trust, and strengthen social connections. Conversely, strategic displays of emotional restraint or neutrality may serve to convey professionalism, composure, or authority in professional settings.

4. NUANCES OF MICROEXPRESSIONS

Microexpressions, the fleeting and involuntary facial expressions that occur within a fraction of a second, reveal nuanced insights into human emotions and psychological states. While often imperceptible to the untrained eye, these subtle movements convey authentic glimpses into individuals' true feelings, bypassing conscious control and social masking.

Understanding the nuances of microexpressions requires a keen eye and an appreciation for the intricacies of human emotion. Dr. Paul Ekman's pioneering research has identified seven universally recognized facial microexpressions: joy, sadness, anger, contempt, fear, surprise, and disgust. Each microexpression corresponds to specific patterns of muscle activation, reflecting the subtle interplay between emotions and facial musculature.

One of the key nuances of microexpressions lies in their transience and evanescence. Lasting only a fraction of a second, microexpressions betray genuine emotional responses before individuals can consciously suppress or modify them. As such, they offer invaluable clues to underlying emotional states and psychological processes, even in situations where individuals attempt to conceal or distort their true feelings.

5. THE LINK BETWEEN EMOTIONS AND SUBTLE MUSCLE MOVEMENTS

The intricate link between emotions and subtle muscle movements underpins the phenomenon of facial expressions, offering profound insights into the complexities of human emotion and communication. Dr. Paul Ekman's seminal research has elucidated how specific emotions elicit characteristic patterns of muscle activation, giving rise to the diverse array of facial expressions observed across cultures and contexts.

At the core of the link between emotions and muscle movements lies the concept of facial action units (AUs)—distinct facial muscle configurations that correspond to specific emotional states. Ekman's Facial Action Coding System (FACS) catalogues over 40 AUs, each representing a unique movement or combination of movements associated with particular emotions. For example, the contraction of the zygomatic major muscle produces the characteristic "Duchenne smile" associated with genuine happiness, while the furrowing of the brow signifies concentration, frustration, or anger.

The link between emotions and subtle muscle movements extends beyond facial expressions to encompass the entire spectrum of non-verbal communication. Gestures, postures, and body language serve as additional channels through which emotions are expressed and perceived. Whether through a reassuring touch, a comforting embrace, or a subtle shift in body posture, individuals convey a wealth of emotional information through their physical movements.

Moreover, the link between emotions and subtle muscle movements is bidirectional, with emotions both influencing and being influenced by physiological responses. The facial feedback hypothesis posits that the act of assuming specific facial expressions can modulate emotional experiences, triggering corresponding changes in subjective feelings and physiological arousal levels. By deliberately adopting facial expressions associated with particular emotions, individuals can induce and amplify corresponding emotional states—a phenomenon known as facial feedback.

6. CONCLUSIONS & ACKNOLEDGMENT

In the intricate tapestry of human interaction, the study of facial expressions reveals a profound link between emotions and subtle muscle movements, offering insights into the complexities of human communication and understanding. Dr. Paul Ekman's pioneering research has illuminated the universal nature of facial expressions, transcending cultural and linguistic boundaries to convey authentic glimpses into individuals' inner worlds.

The link between emotions and subtle muscle movements underscores the embodied nature of human experience, highlighting the inseparable connection between mind and body. Through the language of facial expressions and non-verbal cues, individuals communicate a wealth of emotional information, fostering empathy, connection, and mutual understanding.

Facial expressions serve as a universal language, offering a shared framework for interpreting and responding to emotions across diverse cultures and contexts. From the genuine warmth of a smile to the furrowed brow of concentration, each subtle movement conveys a nuanced message, enriching interpersonal interactions and deepening emotional connections.

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THE PILOT, AN OLD CONCEPT…

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Abstract: *The present article aims to change the human mind which sometimes has some straight opinions, and to show them the aspects of life. The life is not only white and black; this is most of the time represented by shades. All the new technologies, it is true, make the life of humans easier day by day and the mass of people thinks, humans can be easily replaced in every domain by technology. This is totally false and in this paper we will see the real face of humanity, which is important, functional and irreplaceable. In every domain there is a slice of humanity, and this paper will analyze the pilot's importance in aviation, their performance, systems thinking and then some real situations, because nothing compares with real life issues.*

Keywords*: human; team; automation; thinking; problems.*

1. INTRODUCTION

This paper aims to draw a conclusion on the debate about the importance of the pilots taking into account the new needs of the society in the light of dawning technology. I was inspired to do this project, because nowadays more and more people think that in a few years pilots can be replaced by AI, auto-pilot and other modern systems. I am going to present four real cases where the pilots saved the aircraft and some hundreds of human lives, using their skills and knowledge, abilities of communication and teamwork, all against some aircraft malfunctions. Even though replacement of pilots would have a significant economic impact because a pilot requires extensive practical and theoretical training hours and utilizes substantial flight and monetary resources, it could prove to be a trap leading to the loss of thousands of human lives.

I consider that technology and the new improvements in aviation are important as they help people in their activities, making their job easier, but humans also need to be aware and prepared all the time to take action in case of emergencies, and for this, they need good preparation before flight and while airborne. To me, every life is important and that's why it is a must to minimize the risk using all available resources, and in some cases a pilot can save more than one life.

2. HUMAN PERFORMANCE

Nowadays, the most important factor and the essential one in the cockpit is the pilot. All the new technologies are created for making the pilots life easier, and helping them to make the best decisions regarding the flight safety. The best way to see how the human mind works is looking at the "Human Factors". "Human factors" concept studies how people use technology. In aviation, the equivalent subject is "Human Performance" and its purpose is to gather more accurate knowledge. "Human Performance" represents the contribution of mankind to system performance and refers to how people execute their work. In aviation, humans are at the same time a risk factor and the solution to different problems that can appear. The aspect of risk can be minimized if the 5 principles of Human Performance are understood and applied by the pilot. These are: Capabilities and limitations, Interpretation and sense-making, Adaptation and changing demands, Risk assessments and trade-offs, Interaction with people, technology and environment. In the first principle it is shown and emphasized that the people cannot perform at maximum capacity every time or in every moment of a mission and this is totally normal because their focus is influenced by the amount and quality of their sleep, health status, food they consumed, the stress they feel. All of these influence strength, flexibility, memory, attention and resourcefulness. As it is seen, there are a lot of factors that need to be taken into account, but there are some tricks which help pilots, like some kinds of automation in phraseology and in action like starting up the engine, or setting some specific coordinates. Even if the checklists are used very frequently, if the pilot already knows where all the buttons are placed or what he is supposed to say for a shorter conversation, in this way, he can minimize the resources used by him, being more rested and ready for stepping into the action if needed. Also, this can be dangerous if he is not aware of what is really doing and all is done by his automatic system. If the pilot takes care of himself and is careful with his actions, this potential problem is solved. The second principle explains how the knowledge and practical applications intertwine. If the pilot has more experience and is prepared both practically and theoretically, he will have better intuition and faster reaction time; sometimes he cannot explain why he did something, but it was the key to solving the problem. In practical terms, his mind tries to find a solution and analyze all the context and make connections for finding more situations that have something in common with the one which he is facing. The third principle says that adaptability is necessary for every pilot and in some cases this can be helped by some subjective factors. If the procedures are known well, then adapting is easy, because of all the information which is selected and can therefore manage an unexpected situation, like unpredicted bad weather or a malfunction, almost instantly having a solution that will help him get out of danger. The principle of Risk assessments and trade-offs reveals the differences between humans, their way of thinking, their culture or their goals. In aviation there are a lot of decisions to be made and trade-offs which can be more or less hazardous, like efficiency and thoroughness, speed and accuracy, cost and benefit, short term and long-term benefits, personal and organizational goals. The final principle is about interaction. In a pilot's life everything is about interactions with other people like engineers, mechanicals, ATCs, instructors, professors, crew, interactions with technology, like all the gadgets and instruments in a cockpit, or the environment like the ambient lights, temperature, and space. If the pilot tries to understand all the stuff and take advantage of these, he can be aware and have a good response time. If a pilot is careful about all of these principles, he is prepared for every situation, known or unknown for that time. By analyzing these concepts it is revealed that piloting represents a job fit for humans due to their mind which is a special mechanism. The majority of the next cases will present how more groups of pilots managed some strange situations.

3. SYSTEMS THINKING

What makes humans different from other living bodies or any organism on Earth is the drive to find answers to all of their questions. This is something impressive from a biological standpoint and it allows people to develop and improve day after day and generation after generation. This ability is free to develop itself grace to the complex and unique brain humans have. Every human has a different way of thinking.

Systems thinking represents one of these ways of thinking. Specifically, it presents an approach to viewing problems at a systematic level, and not focusing on each individual piece of the system from the start. In aviation, because humans' work is difficult and in order to make it easier it is better to think of everything as a system, for more efficiency. Systems are very different and variable by size and complexity. Types of systems are: simple, complicated, and complex. The simple ones have a small number of components and activities to do and the causes of malfunction are obvious. Some examples are doors and lightning systems. Complicated ones have a big number of components and are responsible for the interactions between them. The impact of one component can be predictable but it is not that easy to identify the root cause, because one component can cause more damage to other components and the same kind of damage can be caused by different components. Examples comprise the engine, the hydraulic system, the fuel system and the distribution of power, thrust and fuel made by these systems. The final category is the complex systems. The complex system is dynamic and suffers changes on the whole period of functioning. It is unpredictable and the system cannot be understood by just looking at it. Some examples are the operations of an aircraft or the air traffic management. With a constant workflow and constant studying and training, a human can choose the according system he needs assistance with and a solution in a small amount time. Even if the person is not sure about the case, a solution or a backup can be used in order to gain more time for thinking.

4. REAL LIFE

The first relevant case is about United Airlines Flight 232, which was scheduled to fly on 19thJuly, 1989 from Stapleton International Airport (Denver) to O'Hare International Airport (Chicago). The problem was a cracked fan blade that disintegrated in the rear engine and this caused damage to all three hydraulic systems and in the horizontal stabilizer. The airplane started to ascend and turn to the right side violently. In this situation the autopilot and the control were lost. To solve the problem, the captain closed the throttle for the left engine and put all the power on the right one. In their attempt to save the plane, a passenger from first class came and helped them, being a training-instructor on the DC-10 airplane. They succeeded putting the aircraft in a proper position for landing after some spins to the right side. Unfortunately, the right wing struck the ground and broke off. In this disaster, 185 out of 296 people on board the flight survived. There were a lot of casualties, but the number of casualties could have been equal with the number of all passengers and crew without the teamwork, the training of the pilots and their action plan which was based on international safety standards and their flight experience, which helped them to develop skills and habits that resulted in a fast response.

The second case is about Qantas Flight 32 where an A380 took off from Singapore to Sidney on 4thNovember, 2010. After take-off, two explosions took place, one of them being the second engine. The first decision of the captain was to aviate and only after that to announce the ATC about the event. In these explosions the aircraft lost 21 of 22 systems, the only one left being the oxygen distribution system, which was useless because they were below 3000m altitude. This situation was unusual and different from the simulator experience, because in their simulation they have around two or three malfunctions at the same time. All the engines that remained and the hydraulic system had problems. On the ECAM, they saw many errors and they could not physically identify the exact problems because the errors followed each other in seconds. The best decision was to stay calm and focus on the flight and maintaining the flight safe.

The check lists were useless in that moment because there were too many problems. The pilot decided to do a specific procedure used in the Air Force and not commonly found in the civil aviation, but it worked. He did a Control Check and, by doing this, he managed to find a good setup for landing and the minimum speed required. After the crew calculated the fuel remaining, they realized that they had enough time to find a proper solution but still verified the fuel every ten minutes. The next step was to calculate the best configuration for landing taking into account the equipment they can use, using a reverse method of thinking where they focused on what they have, not on what's missing. The landing was a success and everything was possible because of a well-trained crew and a solid teamwork. In this situation 469 passengers were saved.

The third case is Qantas 72 which happened earlier then the second one but shares some similarities in the pilot's actions. This one took place on the 7th October, 2008 and was planned to depart from Singapore to Perth, but it did not land there. In this case, some malfunctions of the system caused serious physical trauma to the passengers and was an uncommon event for the crew. After three hours of flight, ADIRU 1 system started to show the captain wrong information resulting in automatic disconnection of the autopilot. In five seconds, ECAM showed a series of messages, and they decided to start the second autopilot, after on the ECAM they started to see other problems. None of them was showing a malfunction of the aircraft's flight control system. When the second officer tried to call the first officer in the cabin from the resting zone, the first major problem appeared. The airplane had a violent pitch down, which hurt the people who did not wear a seatbelt. The saved data showed a maximum nose pitch-down angle of 8.4 degrees. This action was not commanded by the pilots, they had another input but the aircraft's flight control system countered the pilot's action. After another three minutes, another pitch down was recorded but the captain was vigilant, surging down only 3.5 degrees. The crew realized the problem and decided to land as soon as possible, targeting the Learmonth Airport, which was in the vicinity. Like the previous case, the pilot also started to do a controllability check, learnt in his era in the Air Force. This procedure helping him aware of his required maneuvers. The landing was a success everyone landing safely.

The last case is the US Airways 1549flight. It was planned to fly from La Guardia to Charlotte on 15thJanuary, 2009. There were 150 passengers and 5 members of crew. This case is a first in aviation, reinventing standards for loss of both engines, onboard safety equipment, improvements in pilot training, new checklists and new technologies for reducing the probability of a bird strike. The event itself was around five minutes long. In the beginning, the flight seemed normal while on ground and the take-off was also typical and without problems, which started to appear during the climb, a little below1000 meters, when a flock of birds was hit by the aircraft. They reduced the visibility for the moment, but the main problem was that they hit both of the engines. Immediately, the thrust on both engines was lost and the plane continued to climb for another 19 seconds. After this, the plane started to glide down according to the decision of the captain. Captain Sullenberger decided to start the APU, being a saving action for the following moments, because the APU helps with the electrical power after losing the power generated by engines, and permitting the use of the rest of instruments and electrical parts. The first officer tried to restart the engines, but without getting a good response. Their first instinct was to go back to their departure airport, but the crew realized this was not an option. The second thought was to land at an airport from the vicinity at Teterboro in New Jersey, but they were sure they could not make this possible. So, the best option was to land in the Hudson River, and so they did. At a first view it was an unexpected idea, but after the final reports, it was concluded that the pilots made the best decision they could and the flight attendants had a good reaction in this type of situation.

In the simulations, the only way for landing on an airport was if they acted instantly which was impossible because they did not know the exact reason for losing the thrust at the beginning. All passengers were saved in 24 minutes and no one died. Five of them suffered of hypothermia, but all of them were saved. It was a brilliant idea coming from an impressive experience of the pilots - the captain being an ex-Air Force pilot with an experience of almost 20.000 hours of flying and 4700 hours on this type of aircraft, and the first officer having a total experience the same as the captain, but only 37 hours on this aircraft. Without any doubt, the experience of the pilots was what saved the day.

6. CONCLUSION &ACKNOWLEDGEMENT

In conclusion, the pilot is an important part of a flight, and it cannot be replaced by anyone nor anything for the next long period of time, because the spontaneity of the human mind and its capability of quickly judging the possible outcomes of a situation is still relevant and a must-have on a flight. Even if these cases are not present in media like an aviation accident with lots of casualties, they carry a big contribution for the next generation of pilots, their ways of thinking, safety procedures and for the next era of aviation, because aviation needs to take into account, first of all, safety, and the pilots demonstrate their abilities, experience and concern for safety time and time again.

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THE IMPACT OF COMMUNICATION ERRORS ON AVIATION SAFETY: A STUDY OF PILOT-ATC INTERACTIONS

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Abstract: *Communication errors between pilots and air traffic controllers (ATC) can have serious consequences for aviation safety. The paper investigates the causes, types, and effects of communication errors in pilot-ATC interactions, and proposes effective strategies to prevent and mitigate them. This resource shows that communication errors are mainly caused by factors such as language barriers, workload, stress, fatigue, noise, and equipment failures. The most common types of communication errors are mishearings, misunderstandings, and omissions. The effects of communication errors range from minor delays and deviations to major incidents and accidents. This study suggests that communication errors can be avoided and reduced by improving the language proficiency and communication skills of pilots and ATC personnel, enhancing the quality and reliability of communication equipment, implementing standardised phraseology and procedures, and promoting a positive safety culture.*

Keywords*: communication errors; pilot-ATC interactions; safety; mixed-methods study; communication strategies.*

1. INTRODUCTION

Air traffic controllers (ATCs) and pilots must communicate effectively for air travel to be both safe and efficient. The foundation of aviation safety is the complex combination of directives, acknowledgements, and clarifications that are exchanged during pilot-ATC contacts. This paper explores the substantial effects of communication failures on aviation safety through a thorough investigation, with a particular emphasis on the dynamic interaction between pilots and ATCs.

Communication disruptions can have serious implications in the dynamic world of aviation, where quick judgements and exact coordination are essential. In the event of misunderstandings or misinterpretations during pilot-ATC exchanges, a series of events may occur that could result in operational disruptions, near-misses, or, in the worst situation, accidents. This research aims to clarify the complexities surrounding these errors by illuminating their underlying origins, symptoms, and—above all—many potential preventative measures.

Flying requires a communication system that is both standardised and widely recognised, with a focus on the importance of following established phraseology and best practices. By analysing real-world situations and their effects on aviation safety, the study seeks to investigate the complex issues that emerge when these norms are broken.

Precise and standardised communication is becoming more and more necessary as technology develops and air traffic increases.

This study adds to the continuing conversation about enhancing aviation safety with the ultimate goal of creating an atmosphere in which the skies continue to be a symbol of the best operational and communication standards.

2. FACTORS CONTRIBUTING TO COMMUNICATION FAILURES

2.1 Understanding Communication Errors in Aviation

ATCs and pilots communication breakdowns are caused by a variety of reasons that take into account the effectiveness and safety of air operations in its entirety. A major concern is the possibility of misinterpreting directions, which frequently results from imprecise phraseology. This problem is made more difficult by linguistic and cultural variances, especially when English is not the first language of all those involved. When controllers and pilots have various interpretations of the same message, there is a greater chance of miscommunication.

Stress levels and operational workload represent another significant aspect. In high-stress situations, such as during crucial flight phases, it can be difficult for controllers and pilots to communicate effectively. This is especially crucial in emergency situations where quick decision-making depends on clear and succinct communication.

Radio channel frequency congestion adds another level of complexity. Particularly during times of high traffic, crowded frequencies can cause people to miss instructions or have trouble sending messages. Technological problems, such as equipment failures and radio interference, can cause communication breakdowns and jeopardise the timely exchange of vital information.

An additional problem is the lack of standardisation in phraseology and processes between various ATC areas. Consistent communication protocols are critical for reducing confusion and maintaining a standardised approach throughout the aviation environment. Communication errors and misconceptions are largely caused by human factors, such as insufficient interaction among flight crews and inefficient resource management in the cockpit.

Finally, fatigue is a commonplace problem that influences both pilots and controllers. People who are tired may notice a decrease in their cognitive function, which could impact their ability to communicate. It is essential for both pilots and air traffic controllers to get enough sleep and to plan their time well in order to reduce this influence and preserve their highest level of performance.

2.2 Hearback Errors Type II

Hearback Type II errors occur when a pilot accurately gives the readback of a clearance that was provided, but the controller does not realize that the original clearance was not what they intended to issue. The rare occasions when the pilot advised about a course of action or intent that the controller ought to have recognised as problematic were also included in this category of errors.

This type of error reflects a breakdown in the effectiveness of the controller's communication or situational awareness. Errors may arise from misreading the aircraft's position, being disoriented in a busy area, or not paying sufficient attention when instructions are given.

Hearback Type II errors also include instances in which the pilot makes a statement of intent or course of action that the controller ought to identify as problematic. This covers situations where the controller should have recognised problems in the pilot's declared objectives or intentions, going beyond just repeating clearances.

Addressing Hearback Type II Errors involves a multifaceted approach. Controllers must receive ongoing training in order to issue accurate and unambiguous clearances.

Reducing these errors can also be achieved by strengthening communication protocols and using technology to help controllers stay aware of their surroundings. In addition, minimizing Hearback Type II Errors and improving overall safety in air traffic operations depend heavily on cultivating an environment of open communication between pilots and controllers, where both sides feel empowered to ask questions or voice concerns.

Flying Tiger Line Flight 66 is a notable example of an aviation accident where Hearback Errors Type II played a significant role.

On February 19, 1989, the flight was on its final approach to Kuala Lumpur International Airport, Malaysia, after a short flight from Singapore Changi Airport. The aircraft, a Boeing 747, crashed into a hillside 12 km from Kuala Lumpur, resulting in the death of all four crew members.

The crew was unsure to which point they were cleared, and the cockpit voice recorder (CVR) revealed that the crew argued about which radios should be set to which frequencies and which approach was actually going to be conducted. Even in the last few moments of the flight, the captain referenced the ILS approach for runway 33, which was named as inoperable on the flight release and the ATIS, additionally the crew was told by ATC that the ILS approach was not available.

ATC communicated to the flight, "Tiger 66, descend two four zero zero (about 2,400 ft (730 m)), cleared for NDB approach runway 33." The pilots inaccurately read back their altitude assignments and the controllers failed to identify and correct the mistakes. This led to a controlled flight into terrain due to pilot error.

2.3 No pilot readback

In the aviation industry, communication failures resulting from the lack of pilot readbacks pose a serious threat. There are possible risks and difficulties when pilots fail to repeat or accept air traffic controllers' (ATC) directions. These inaccuracies are caused by several factors.

Pilots may prioritise tasks when faced with high workloads, which are typical in busy airspace or during crucial flight phases. This could result in their overlooking near readback requirements. Misinterpretation of directives can lead to pilots presuming they have correctly interpreted information without providing the necessary confirmation, particularly in complex or routine circumstances.

Another factor is complacency, where pilots may disregard readbacks in ordinary circumstances and underestimate the significance of verifying instructions. A pilot may fail to recognise an ATC directive due to distractions from outside sources or from within the cockpit.

One significant factor is ineffective Crew Resource Management (CRM), particularly when there are several crew members involved. CRM malfunctions can result in poor communication, such as forgetting to send readbacks. In crowded airspace, frequency congestion can dissuade pointless broadcasts, which could lead to readbacks being missed.

A diversified strategy is needed to address these communication failures. Essential actions include highlighting the need of readbacks in pilot training, creating a culture of proactive communication, and stressing the necessity of double-checking instructions - even in everyday situations. Errors related to the absence of pilot readbacks can be reduced by organizing clear communication protocols, creating task management plans, and putting into practice efficient CRM procedures.

By guaranteeing precise, verified, and prompt communication between pilots and ATCs, these steps together improve aviation safety by reducing the probability of communication failures in the dynamic and complex airspace environment.

Avianca Flight 52 (1990) was a tragic example of the critical importance of clear and accurate communication in aviation, including the necessity of pilot readback to Air Traffic Control (ATC).

On January 25, 1990, Avianca Flight 52, a Boeing 707-321B, was en route from Bogotá, Colombia to New York. The flight encountered severe weather conditions and air traffic congestion, forcing it into a holding pattern off the coast near New York. The aircraft was running low on fuel, but two crucial pieces of miscommunication led to a disaster.

Firstly, the local air traffic controllers were not informed that the aircraft had too little fuel to reach its alternative airport. Secondly, the aircraft's crew did not explicitly declare a "fuel emergency" to the local controllers, which would have indicated that the plane was in danger of crashing. The lack of clear communication and readback between the pilots and ATC led to the aircraft running out of fuel and crashing into a hillside in Cove Neck, New York, resulting in the loss of 73 lives.

This incident underscores the importance of pilot readback and clear communication with ATC. In aviation, every instruction from ATC must be read back by the pilot to ensure that the message has been correctly received and understood. This process helps to prevent misunderstandings and misinterpretations that can lead to fatal occurrences.

In the case of Avianca Flight 52, the lack of clear communication and readback contributed to a tragic outcome. This incident serves as a stark reminder of the critical role that effective communication plays in ensuring the safety of air travel. It highlights the need for ongoing training and emphasis on clear, concise, and accurate communication in all aspects of aviation.

2.4 The callsigns problem

Due to the possibility of confusion created by callsigns that sound similar or identical yet are assigned to different aircraft, the callsigns issuing in aviation communication is a serious one. This difficulty mainly occurs during radio communications between pilots and air traffic controllers (ATC), especially in crowded or heavy traffic areas of the airspace.

Realities such as radio interference, background noise, and communication barriers add to the complexity. Misunderstandings resulting from callsigns that sound alike can happen when controllers talk to the wrong aircraft or when pilots follow directions intended for a different flight.

The aviation industry insists on giving each aircraft a unique callsign in order to address this issue. This strategy reduces the possibility of misunderstandings and improves communication clarity in general. To prevent aeroplanes operating in the same airspace from receiving callsigns that sound similar, standardised processes are put in place.

In order to minimise errors, radio transmissions follow precise phraseology, and pilots and controllers are instructed to be alert when identifying callsigns. Transmissions are also made clearer and more dependable by technological innovations like better radio equipment and digital communication technologies.

In May 2004, the crashed aircraft, N304PA, was the fourth in a group of five aircraft from the same company, flying the same route. Aircraft No. 3, N434PA, was ahead of N304PA.

The controller transmitted: "Seminole four papa alpha, descend and maintain five thousand two hundred." The pilot of N304PA responded: "Descending to five thousand two hundred four three zero four papa alpha." This clearance was intended for 434PA, but the controller did not recognize that the wrong aircraft had responded to the clearance.

After N304PA began to descend, the controller received a Minimum Safe Altitude Warning (MSAW). The controller did not notify the sector controller that he was receiving an MSAW alert, as required by the FAA. The aircraft then descended below radar coverage and disappeared from the controller's screen.

The wreckage of N304PA was found on a ridge at 5,537 feet, 200 meters south of Julian VOR. The cause of this accident was determined by the NTSB to be the sector controller's improper use of an abbreviated call sign, the issuance of a descent clearance to N434PA, and the sector controller's failure to detect that the pilot of N304PA had read back the clearance with the full call sign.

3. CONCLUSIONS & ACKNOWLEDGMENT

In conclusion, the study on the impact of communication errors on aviation safety, particularly focusing on pilot-ATC interactions, underscores the critical importance of adhering to good practices and standard phraseology in the aviation industry. Effective communication is the backbone of safe and efficient air travel, serving as a fundamental pillar for successful pilot - ATC collaborations.

The findings highlight that deviations from established communication norms can lead to misunderstandings, confusion, and potentially hazardous situations. Standard phraseology not only enhances clarity but also ensures a common language that all aviation professionals can understand and interpret accurately. The significance of consistent and precise communication cannot be overstated, as it directly contributes to the prevention of errors, the mitigation of risks, and the overall enhancement of aviation safety.

Therefore, promoting and upholding a culture of adherence to good practices and standard phraseology is imperative within the aviation community. This involves continuous training, awareness programmes, and robust communication protocols to reinforce the importance of following established procedures. By doing so, the aviation industry can address communication challenges proactively, mitigate the potential for errors and, ultimately, contribute to the continuous improvement of aviation safety standards.

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DEVELOPMENT OF AN EDUCATIONAL BEAMFORMING SYSTEM

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Abstract: *The purpose of this paper is to develop a beamforming system. To achieve the goal of the study, it is necessary to design and print a 4-element patch antenna. The design and optimization of the patch antenna will be accomplished using the CST Studio Suite application. Using the printed antenna and a USRP N310 software-defined radio device, an educational system will be developed for studying the beamforming phenomenon, and for the development of a graphical interface, the GNU Radio application is used, which will allow us to change the phase and the amplitude individually on each of the 4 channels, in real-time. The experimental validation of the measurements is accomplished using a spectral analyzer for the power level and an oscilloscope for measuring the phase of the signals.*

Keywords*: Beamforming, Antenna, Patch, Software defined radio.*

1. INTRODUCTION

This project's purpose is designing, simulating, developing, measuring the parameters of the 4-element patch antenna and effectively using it in conjunction with a USRP N310 software-defined radio device. This beamforming system is used for educational purposes. The design and realization of a 4-element Patch antenna stemmed from the need to interact with the SDR USRP N310 device, which is equipped with four transmission channels. Each structural element of the antenna will serve as a transmission channel for a distinct sinusoidal signal, thus contributing to the formation of a directional beam, according to the principles of beamforming.

In the current era of advanced radio communications, optimizing the performance of wireless transmissions is of particular importance. Therefore, the implementation of the 4-element patch antenna within a multi-channel SDR broadcasting system aims to demonstrate the principle of beamforming transmission systems, thereby contributing to the improvement of efficiency and precision in radio transmissions.

For the design and simulation of the antenna, CST Studio Suite software was used. The simulation provides a detailed analysis of the antenna components under varying conditions, facilitating the identification and correction of potential discrepancies. Specifically, for the 4-element antenna, the simulation becomes essential for determining the resonance frequency and evaluating the antenna's interaction with the environment at the moment of transmission.

For the realization of the physical beamforming system a USPR N310 was connected to the computer in order to perform the experiment. A graphical interface for real-time control of phase and amplitude was created using the GNU Radio application.

By using controlled variation of the phase of each independent sinusoidal signal and the amplitude, the radiation direction of the main lobe can be altered directly.

The detailed manner of exploitation of the parameters ensures a clear way of understanding the antenna's functioning, guaranteeing that the implementation of beamforming technology will meet the desired standards of efficiency and performance.

Given the above-mentioned, the objectives pursued within this work are:

1. Designing and simulating the characteristics of a 4-element patch antenna in CST Studio Suite with a resonance frequency around 3.6 GHz.
2. Physically realizing the designed antenna and its characteristics through the study of S parameters and the practical determination of the resonance frequency.
3. Experimental validation of phase and amplitude modification from the graphical interface created in GNU Radio.
4. Comparing the radiation pattern simulated in CST Studio Suite with the pattern determined through physical measurements of the beamforming system.

2. SYSTEM FOR STUDYING THE BEAMFORMING PHENOMENON

2.1 Design and Simulation of the 4-Element Patch Antenna

In exploring the theoretical foundations of patch antennas, the basic principles that define these essential components in modern communication systems are highlighted. Patch antennas are characterized by their flat geometry, consisting of a thin radiating element and an extended ground plane. This specific configuration gives patch antennas characteristics such as compact dimensions, ease of integration into electronic devices, and capabilities for directing electromagnetic waves.

Multiple-element antennas allow for the efficient manipulation and coordination of several simultaneous signals, thus facilitating the implementation of beamforming. They contribute to the creation of directional beams, optimizing the efficiency and precision of transmissions. By adjusting the phases of the signals emitted by the multiple elements of the patch antenna, beamforming enables the focused direction of electromagnetic energy towards specific areas in space.

CST Studio Suite was chosen as the simulation platform due to its advanced capabilities in antenna analysis and design. It is a specialized tool in electromagnetic simulation, providing accurate and detailed results.

The design of the 4-element patch antenna in CST Studio Suite begins with a preliminary analysis to determine the dimensions of the elements so that the resonance frequency is around 3.6 GHz, and the antenna's feeder is calculated to have a characteristic impedance of 50 Ohms. After determining the dimensions of the antenna elements, they are introduced into the CST Studio Suite application followed by simulations and optimizations of the antenna dimensions and the spaces between elements, so that the interference from nearby antennas is minimized.

Following the optimization simulations, the size of each element was established as 28 mm in width and 19 mm in height, and the distance between each element was set at 4.42 mm. To ensure proper feeding, each antenna was connected through a feeder with a width of 2.8 mm and a height of 8.32 mm, values that were calculated to achieve a characteristic impedance of 50 Ohms. It was decided that each feeder would be overlaid on the antenna to avoid interruptions in the material during printing.

Additionally, to facilitate practical handling, an extra element of substrate without copper was added at the bottom of the antenna to create a solid handle. This detailed configuration in CST Studio Suite is essential for achieving simulation results as close to reality as possible.

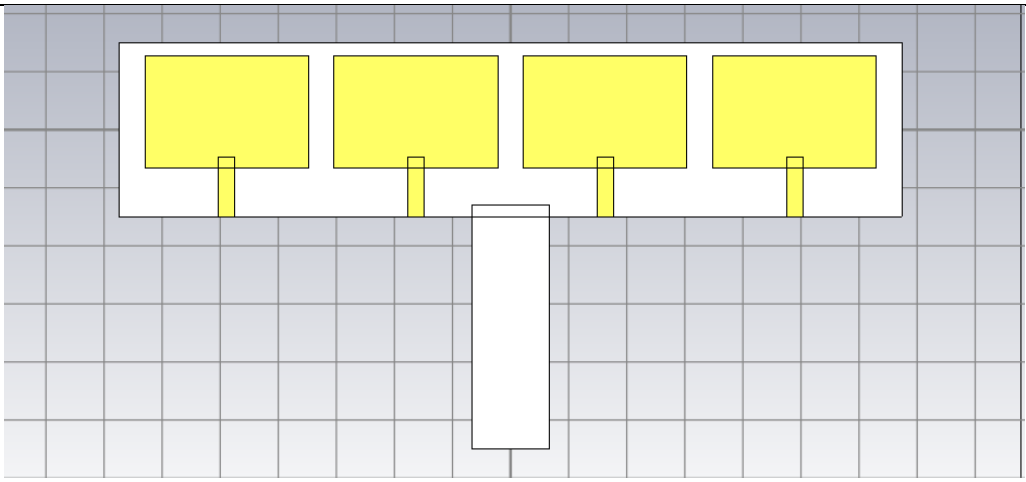


FIG. 1. Geometric Configuration of the Designed Patch Antenna

The simulation in CST Studio Suite represents a crucial stage in assessing the performance of the patch antenna. To conduct the simulation, it was necessary to introduce a feed port, connected to the bottom of the feeder. Each port was configured to be powered with a sine step signal, and the chosen frequency for the feed signal was 3.6 GHz. Figure 2 illustrates the radiation model of the patch antenna.

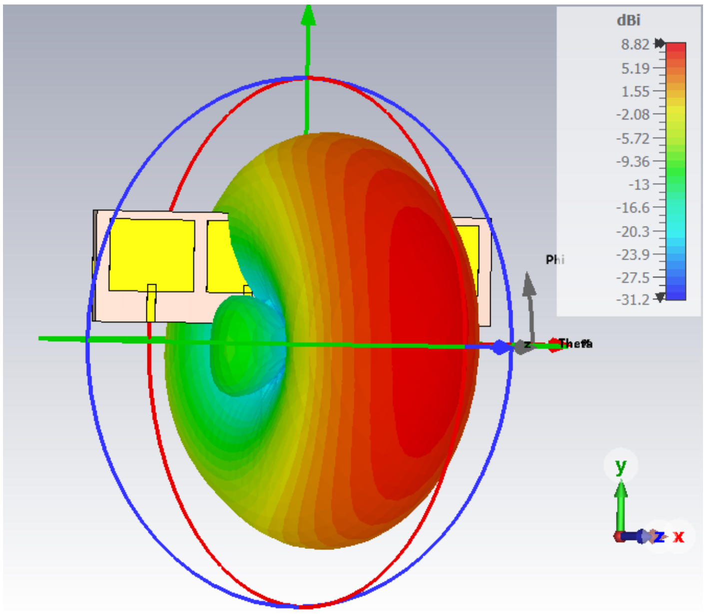


FIG. 2. Antenna Radiation in the CST Studio Suite Application

2.2 Physical Printing and Experimental Characterization of the Patch Antenna

The production process of the patch antenna involved using a laser printing device to translate the conceptual design into reality. The laser device, not having high power, could only cut through the copper layer of the FR-4 board used in the manufacturing process, the result being visible in figure 3a. To bring the antenna to a final state of use, it was necessary to use a metal guillotine for cutting out the antenna, the final result of the antenna's production process is illustrated in Fig. 3b.

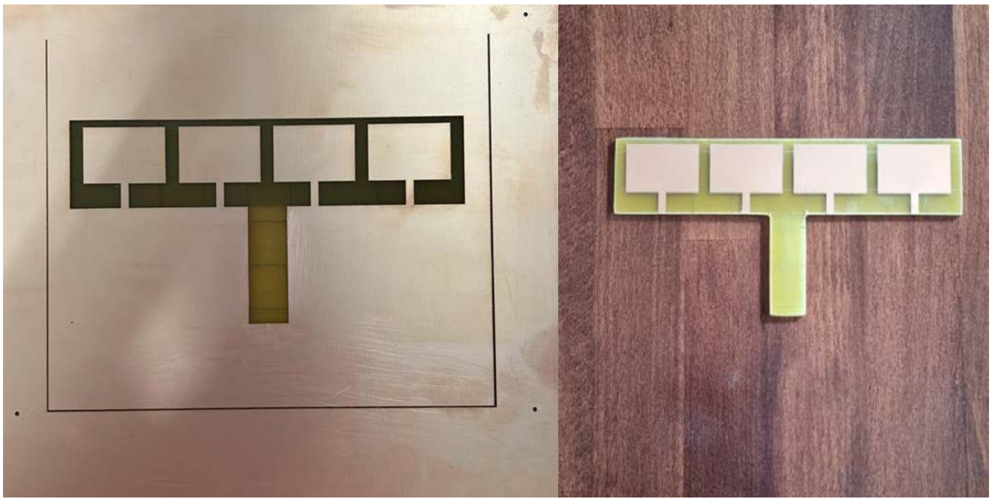


FIG. 3.a. Prototype Resulting from Printing **FIG. 3.b.** Antenna Prototype

The experimental measurement of the antenna parameters and the comparison of the experimental results with the simulated ones represent an important stage in validating the printed antenna and evaluating its performance. The measurement of the antenna's S parameters was performed using a vector network analyzer. Initially, the measuring device was calibrated using an equipment calibration kit. This step ensures the accuracy and precision of subsequent measurements by eliminating the disturbing effects of cables and connectors in the established measurement range (3-4 GHz). Once the device calibration was complete, the measurement of the S parameters began.

Figure 4 provides a detailed analysis of the S11 parameter, comparing the simulated results with the measured ones of the 4-element patch antenna. In the simulation, the antenna's resonance frequency was determined at 3.6 GHz, and the associated power level recorded a value of -12 dB. Subsequent measurements indicated an actual resonance frequency at 3.53 GHz, with a measured power level of -8.5 dB. The difference between the simulated and the measured values are determined by several factors such as: the interferences and reflections caused by the laboratory's walls, the presence of other equipment in the surrounding environment. These factors were absent in the simulation conducted in CST Studio Suit. Moreover, the second important aspects that influence the differences between simulation and reality is caused by the differences in the materials used in the construction of the antenna.

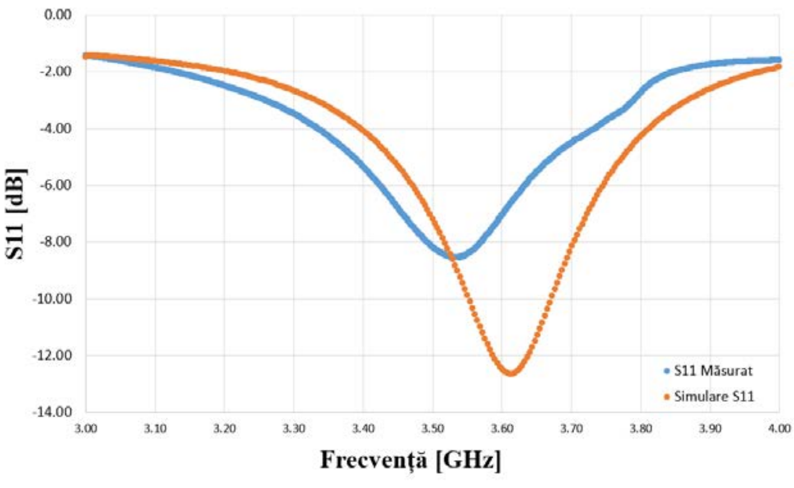


FIG. 4. Comparison of the Measured S11 Parameter with the Simulated One

It is important to understand that these differences are part of the validation and refinement process of the theoretical model. The measurement results provide a realistic perspective on the antenna's behavior in real conditions, and for experiments that will be conducted later in the project, it is important to be able to use the measured values and characteristics of the actual antenna.

2.3 The development of the application in GNU Radio and the validation of phase and amplitude changes.

The development of the beamforming system involves choosing the GNU Radio application for development of the graphical interface of the system. Figure 5a illustrates the flowchart developed in the GNU Radio application, which contains 4 sinusoidal signal generators connected to the USRP Sink block. Figure 5b presents the user graphical interface from which the phase and amplitude can be modified on each individual channel. To modify the amplitude of each individual signal, a "Range" type variable was replaced the Gain value in the USRP Sink block, thus allowing the power of each individual signal to be modified. For changing the signals' phase, a "Range" type block was also used in place of the phase value in the Signal Source block.

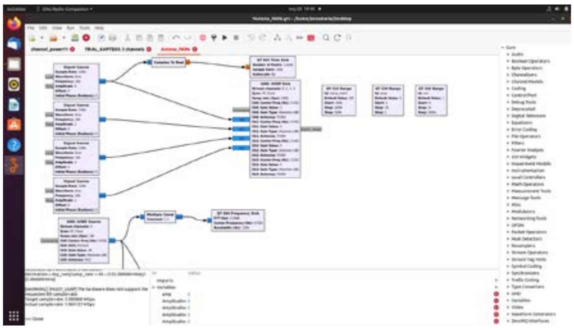


FIG.5.a GNU Radio Flowchart a.

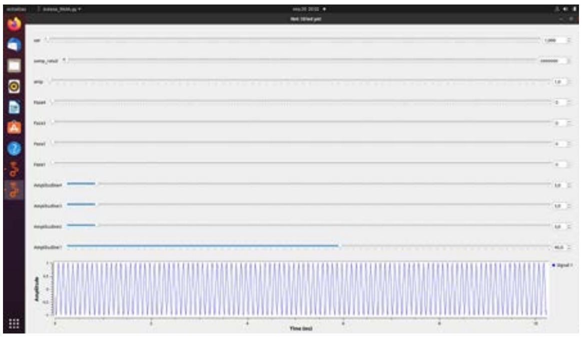


FIG. 5.b. User Graphical Interface

For the experimental validation of the amplitude modification, a channel of the USRP was connected to a spectral analyzer through a radio frequency cable, and by modifying the gain on that channel; the increase or decrease in power level on the analyzer was monitored. Without considering cable losses and connector losses, it was observed that the changes in gain from the graphical interface are instantly visible on the analyzer. Figure 6 illustrates a screenshot of the analyzer during the power measurements. The figure shows the change in the power of the received signal.

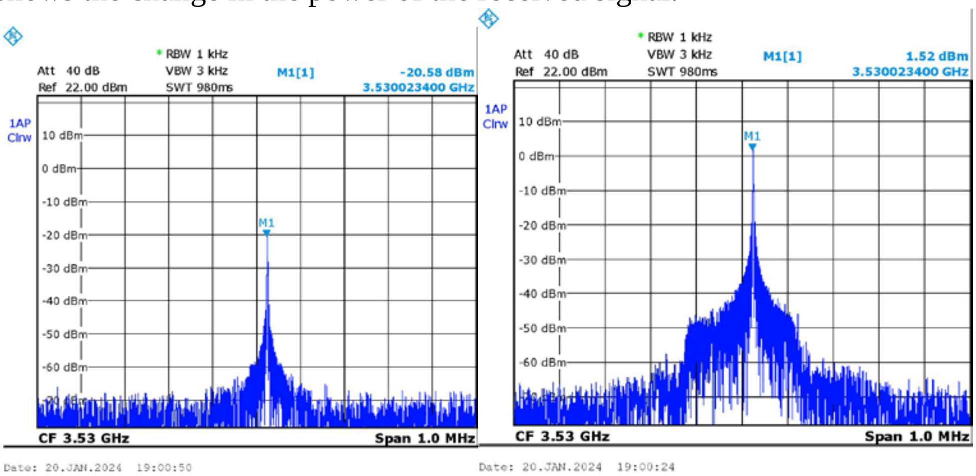


FIG.6. Interface Displayed by the Spectral Analyzer During Measurements

For the experimental validation of the phase change of each channel, an oscilloscope was used. Two transmission ports of the USRP were connected to the oscilloscope through radio frequency cables to visualize the phase differences between channels. Due to the reduced sampling frequency, it was needed to change the working frequency from 3.53 GHz to 100 MHz. This ensured that the working frequency was correctly received by the oscilloscope. In Fig 7a, the reception of the two channels when they are in phase is illustrated, and in Fig. 7b, when the second channel has a phase of 180 degrees.

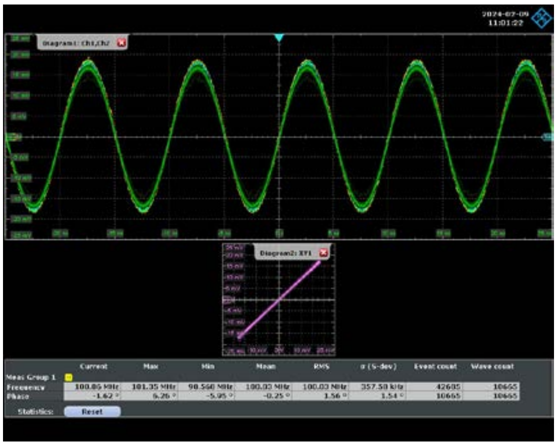


FIG.7a. The Two Channels in Phase

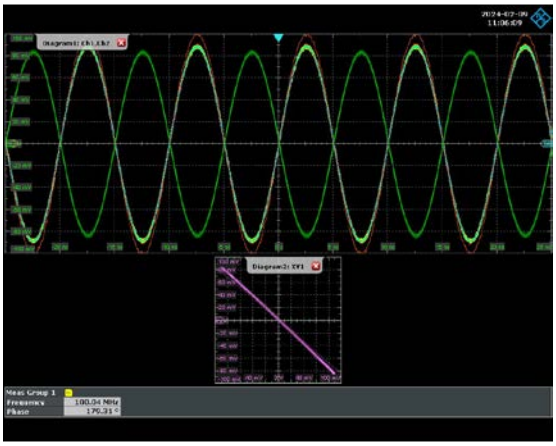
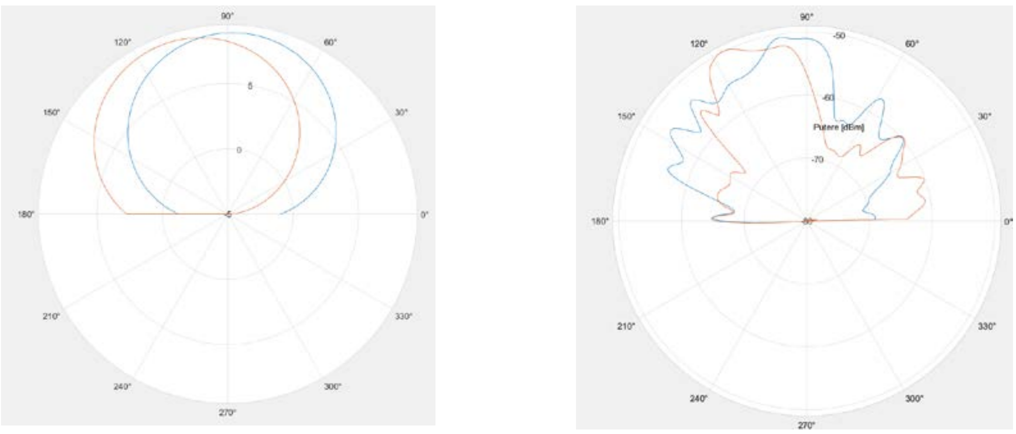


FIG.7.b. The Two Channels Out of Phase

2.4 Validation and Testing of the Beamforming Device

In the final part of this project, with the help of a spectral analyzer, the radiation pattern of the beamforming system was determined over a 180-degree plan and the model determined through measurements was compared with the one simulated in the CST Studio Suite application.

In figure 8a, the radiation lobe at 0 degrees is outlined in blue, while the main radiation lobe oriented at 30 degrees to the left is shown in red. In figure 8b, the radiation lobe of the antenna oriented at 0 degrees is illustrated in blue, while the lobe oriented at 30 degrees to the left is shown in red. To change the lobe by 30 degrees from its initial position, the phases of the signals were modified with the following values: 0 degrees on the first channel, 45 degrees on the second channel, 90 degrees on the third channel, and 135 degrees on the fourth channel. The radiation pattern of the antenna determined through measurements is not perfectly uniform, due to reflections from the laboratory environment where the measurements were conducted.



a. Simulated b. Measured

FIG. 8. Changing the Main Radiation Lobe

3. CONCLUSIONS & ACKNOLEDGMENT

In conclusion, the objectives of the work were fully achieved. The antenna was initially designed and optimized in the CST Studio Suite application, later printed, bringing the simulation into physical form, and validated using a network spectral analyzer, thereby determining the antenna's resonance frequency to be at 3.53 GHz compared to the simulation where the resonance frequency was 3.6 GHz. For the beamforming system, the phase and amplitude changes from the graphical interface were validated, using a spectral analyzer to measure the power level of the antenna on each channel and an oscilloscope to validate the phase changes between two channels. Finally, the radiation pattern of the antenna was determined using a spectral analyzer, which was compared with that from the simulation designed in the CST Studio Suite application, and the ability to change the main radiation lobe by altering the signal phase on each individual channel was validated.

For the future, the goal is to develop a reception system using the same SDR USRP N310 device to measure the power level of the signal emitted by the 4-element patch antenna.

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ESP32 POTENTIAL IN DEVELOPING A QUADCOPTER AS A COMBAT FIGHTER ASSISTANT

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Abstract: *The project focuses on developing a potential drone flight controller powered by ESP32 technology. It explores the benefits of ESP32 in creating a drone flight controller, emphasizing functionality in real-time image transmission and payload deployment. The integration of the ESP32 microcontroller, along with sensors and communication modules, forms the core of our system. Various protocols such as I2C, PWM, and PPM are utilized for efficient communication and control. It also discusses the implementation of a 4S battery configuration for enhanced power efficiency and autonomy. Additionally, the integration of an ESP32-CAM module enables low-range live image transmission, further enhancing the capabilities of our system. Furthermore, it aims to incorporate a remote payload deployment system to transport and launch small payloads. The project's code is inspired by existing online resources and adapted to suit our specific requirements. The objective of this project is a study and the first step in developing an ESP32-powered drone as a combat fighter assistant with AR glasses real-time image projection, AI, and machine learning implementation for providing a real-time overview of the tactical situations and decision alternatives. In conclusion, this project aims to develop a versatile and efficient drone flight controller system, contributing to advancements in payload transportation technology.*

Keywords*: ESP32, flight controller, integrated circuit, image transmission.*

1. INTRODUCTION

Drones became increasingly prevalent in various fields, serving diverse purposes from aerial surveillance to environmental monitoring (Gohari et al.,2022). At the core of these unmanned aerial vehicles lies the flight controller, a sophisticated electronic system vital for their operation. Essentially functioning as the drone's brain, the flight controller integrates an array of sensors, including accelerometers and gyroscopes, to continuously monitor the aircraft's position, velocity, and orientation.

The main objective of this project is to present an original approach for the construction of a drone by building a personalized flight controller. The main benefit of the proposed approach lies in the flexibility of the developed platform, enabling further advancement and personalized functionalities. In addition, the presented idea forms the basis of a low-cost manufacturing project, aimed at potential mass production needs in the future.

The significant progress in microprocessors and microcontrollers highlights the need to grasp their integration into future applications (Leeman, 2005). Mastering this skill enables the development of advanced technologies tailored to specific requirements, enhancing efficiency and adaptability in a rapidly evolving tech landscape.

As technology continues to advance, understanding the intricate workings of microprocessors and microcontrollers becomes increasingly crucial for staying at the forefront of innovation and meeting the demands of emerging applications.

This affordability factor opens doors for various industries, from agriculture to surveillance, enabling widespread adoption and utilization of drone technology for diverse purposes.

Previous studies have explored the use of ESP32 microcontrollers in drone technology (Shah,Ghanchi, Soliya, Patel, 2023; Li, 2022; Jun, Kook, Park, Won 2018). Research has also focused on integrating features like live image transmission and payload systems into drone designs (Harvey, Rowland, Luketina,2016). Additionally, there is emerging interest in real-time object detection algorithms for potential integration into ESP32-based drone systems (Kaur et al, 2021). However, overall, existing literature does not fully present the importance of ESP32 microcontrollers in advancing drone capabilities, providing a foundation for further exploration in this field. This paper completes the aforementioned publications by presenting an original approach aimed towards leveraging ESP32 capabilities in developing a customized flight controller with real-time image transmission capabilities.

2. MATERIALS AND METHODS

To construct the drone, the initial step involved calibrating each Electronic Speed Controller (ESC), sensors, testing the motors and the radio communication. Following this, soldering was performed to connect each ESC to the Power Distribution Board, with subsequent attachment of motors to each ESC. This process was repeated for all four motors.

The assembly process continued by mounting all components onto the drone frame.

Next, an electronic circuit was assembled on a breadboard. This circuit incorporated motion sensors and a receiver.

ESP32 is a development board, that integrates both a microcontroller and a Wi-Fi and Bluetooth modem. It is based on a dual-core microprocessor, clocked at up to 240 MHz, and supports both Wi-Fi and Bluetooth connectivity. ESP32 has two processing cores, which allows it to handle multiple tasks simultaneously.

MPU-6050 is an inertial sensor comprising a gyroscope and an accelerometer, used to measure the motion and orientation of an object in three-dimensional space. It operates by sensing acceleration and rotational rate around the X, Y, and Z axes. It finds applications in various fields including drones, robotics, virtual and augmented reality devices.

The SG90 is a small, lightweight servo motor commonly used in hobbyist projects androbotics. It requires a PWM (Pulse Width Modulation) signal to control its position.

The FSi6 receiver is a component of the Flysky remote control system, designed for radio-controlled vehicles such as drones, airplanes, and cars. It operates on the 2.4GHz frequency band, offering stable and reliable control over considerable distances.

The Tattu 1550mAh LiPo battery offers exceptional performance and durability, making it ideal for powering a wide range of electronic devices. With its compact design and high energy density, it provides extended runtime and reliable power delivery for RC vehicles, drones, and other applications.

I2C (Integrated to circuit) is a communication protocol used between integrated circuits to transfer data. It uses only two wires, a serial data line (SDA) and a serial clock line (SCL), and allows multiple devices to share the same bus. This protocol is commonly used for short-distance communication between devices such as sensors, displays, and microcontrollers. In our case it stands between the MPU6050 and the microcontroller.

PPM (Pulse Position Modulation) is a method of encoding multiple channels of information into a single signal. The ESP32 generates PPM signals to control various functions such as throttle, pitch, roll, and yaw. Each channel corresponds to a specific function: throttle for altitude control, pitch for forward/backward movement, roll for sideways movement, and yaw for rotation.

Each ESC receives a PWM signal corresponding to the desired speed for its associated motor. The PWM signal consists of a series of pulses, with the width of each pulse determining the speed of the motor. A wider pulse indicates a higher speed, while a narrower pulse indicates a lower speed. The ESC interprets these pulses and adjusts the power supplied to the motor accordingly.

The remote control (transmitter) sends control signals to the receiver using RF (Radio Frequency) transmission.

In the case of the FSi6 receiver mentioned earlier, it likely interprets PPM signals, which encode multiple channels of control information into a single signal.

The receiver on the drone decodes the incoming PPM signal from the remote control. It then processes this signal to extract information regarding throttle, pitch, roll, yaw, and other control inputs. The receiver converts these inputs into digital signals that can be understood by the flight controller (ESP32) for further processing.

The ESP32 receives digital signals from the receiver, representing various control inputs from the remote control. Additionally, it receives data from the MPU-6050 sensor, providing information about the drone's orientation and motion.

3. RESULTS

It's important to discuss the analysis and correction of motion sensor parameters.

After examining the uncalibrated values of the gyroscope, it was observed that despite the device being stationary, these values exhibited significant fluctuations away from zero. Consequently, calibration was considered necessary. After calibration, the values stabilized considerably and approché zero. Furthermore, it was assessed the impact of vibrations from a single motor on both the gyroscope and accelerometer. Following both analog and digital analyses, the conclusion drawn eas that the filters are effective.

The project involves live image transmission over a local network. Every network has a delay caused by network equipment processes or cable resistance. It was analyzed the transmission delay in this project using ICMP, by ‘ping’ command.

After calculations made, it was concluded that the latency is 1152 ms, variations depending on the traffic on the channel and internet connection.

The current consumption of a single motor was analyzed at maximum speed, connected to a source set to provide 12.8V. The circuit, along with a single running motor, consumes 5A, which is the maximum allowed by the power source. Therefore, it's a circuit that entails high current consumption, particularly during short intervals of time, such as during takeoff. The LiPo battery is capable of handling such situations, unlike other batteries.

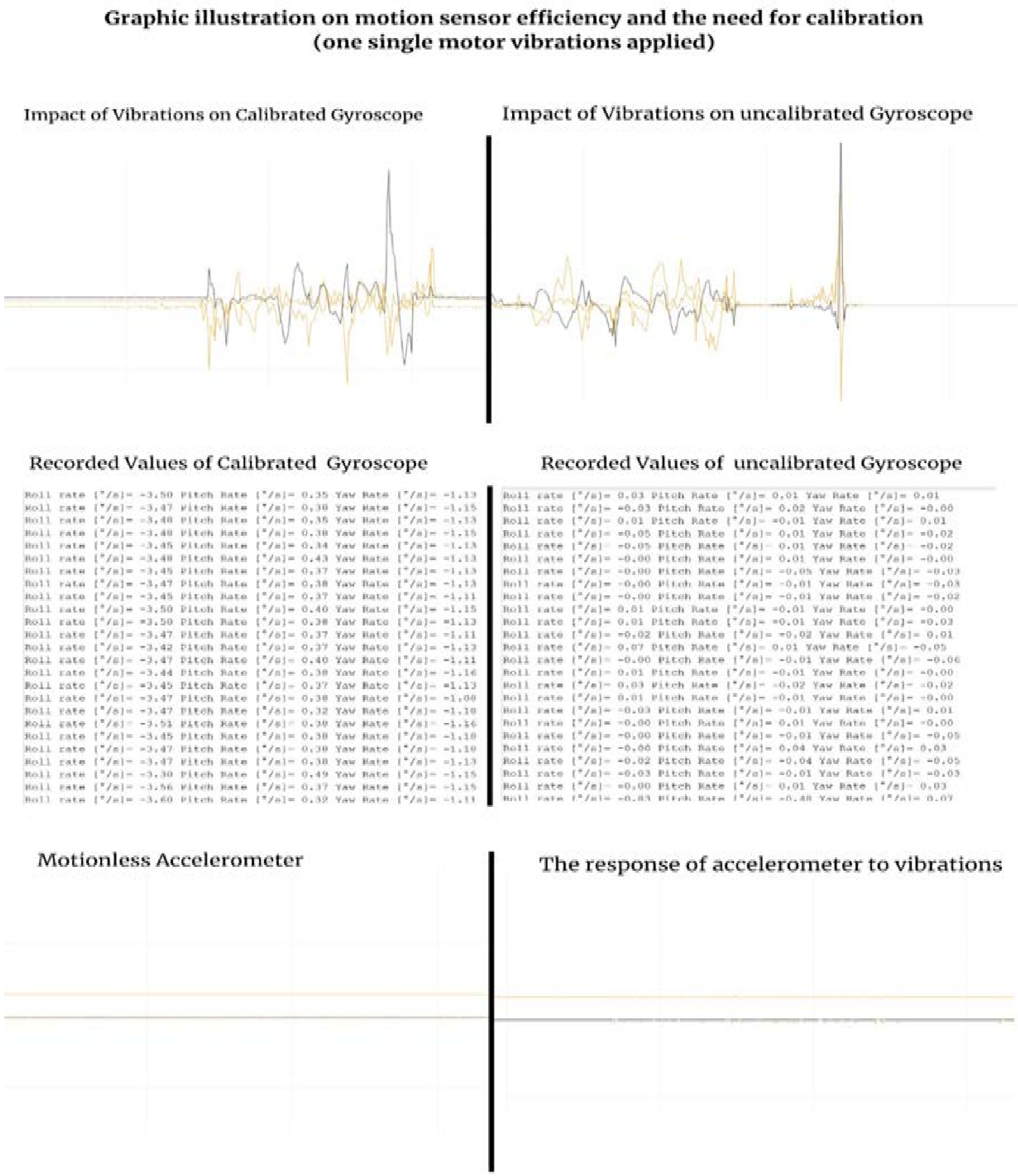

FIG. 2. Sensors calibration evaluation

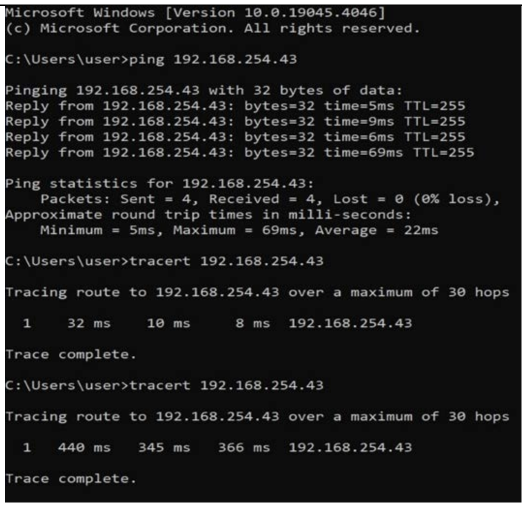

FIG. 3. Network latency determination

Live image transmission can be projected on Hololens glasses, and added different useful information necessary in potential on field applications.

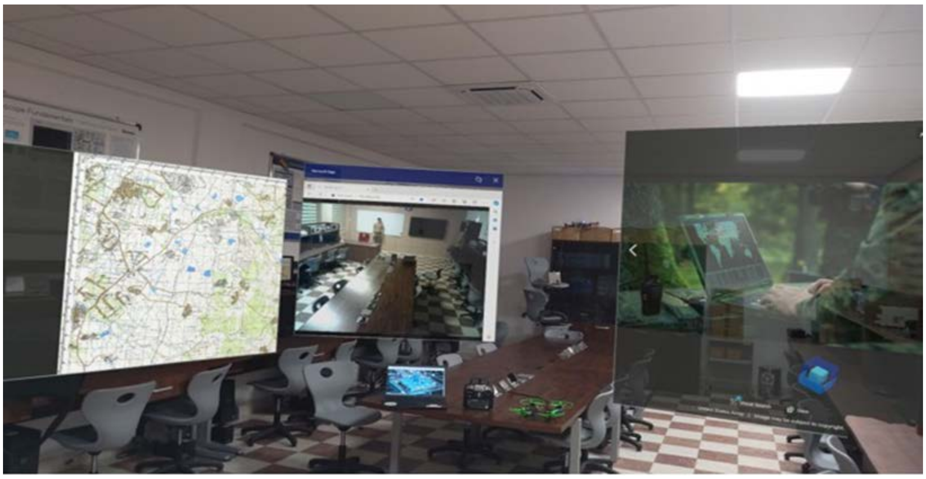

FIG. 4. Augmented reality enhaced with live transmission

A few areas for improvement in the project are related to: live transmission security, moderate latency depending on the network traffic, moderate quality on live transmission, the use of a printed pcb instead of a breadboard to be brought more stability to the system, the use of a much performant vibrations absorber, the use of a barometer for altitude data.

2.3 Specific topics

The proposed project involves a drone that can adjust its position on its own using built-in sensors and responds to commands from a remote control. Currently, it can transmit live images to a web server within the range of the internet connection. AR glasses like Hololens can connect to this server to display the images transmitted from the drone. The project also includes the functionality to release lightweight payloads controlled by the remote control, using a servo motor connected to the microcontroller's I/O pins. A potential application involves object recognition for the live transmitted image, which could be a significant advantage in combat situations. Another application of a drone with built-in AI is cartography, and the transmission of useful and real-time analyzed images to the operator.

The goal of this project is to enable the drone to be controlled through AR glasses, using gestures or head movements, and to serve as an assistant to ground fighters.

This is similar to how pilots can control machine guns with head movements, or how surgical systems assist surgeons with precise movements.

2.4 Specific situation analysis

In a military reconnaissance scenario, a drone equipped with the proposed technology is deployed into hostile territory.

Drawing upon its advanced sensors and object recognition capabilities, the drone identifies enemy positions, fortifications, and potential threats. The continuous transmission of real-time images allows for ongoing assessment of the situation, with crucial data communicated to the command center.

As required, the payload release system is engaged to deploy distraction devices or deliver essential supplies to isolated units. Functioning as a discreet airborne asset, the drone provides vital intelligence and support, all while minimizing personnel risk.

This military application underscores the drone's significance as a pivotal tool for reconnaissance and support missions in hostile environments.

Furthermore, a drone equipped with capabilities similar to the proposed one but with increased dimensions can replace certain functions of a helicopter, such as transporting ammunition, food, water, and other consumables. In a hostile situation, this would limit the risk to human personnel and their exposure.

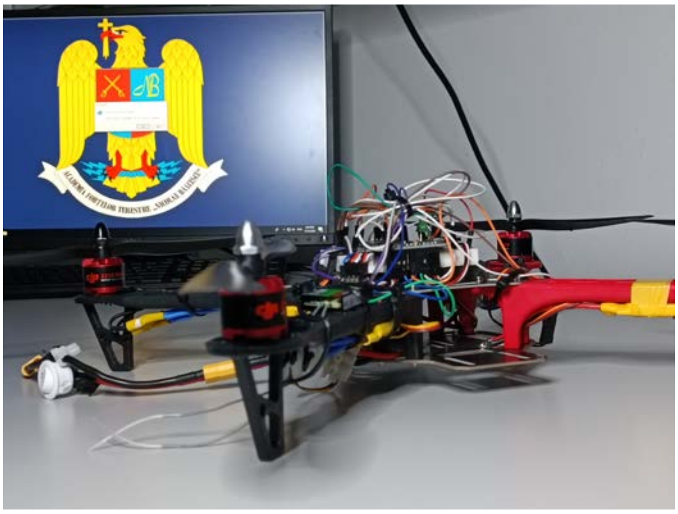

FIG. 5. ESP32 powered quadcopter

3. CONCLUSIONS & ACKNOLEDGMENT

In summary, the ESP32 is an advanced development board with a powerful microchip capable of interpreting and processing information from sensors like the MPU6050, along with the commands from a remote control receiver used in this project. It also provides enough I/O pins for project enhancements such as incorporating a servo motor for launching small payloads. Additionally, another development board, such as ESPCam, has been developed on the same concept. In the proposed project, ESPCam offers live image transmission within the internet connection range, forming a local network with the router. A pair of augmented reality glasses like Hololens is connected to this network, projecting real-time images obtained from ESPCam.

The project achieves its goal of integrating multiple intelligent platforms, including microcontrollers and AR glasses, based on different communication media such as serial and radio.

It has potential and serves as the first step towards a larger project with enhanced capabilities. The aim is to implement AI functionalities, where the drone could act as a ground fighter's assistant, constantly monitoring them. The remote control would be replaced with a system integrated into the fighter's equipment, allowing drone control through arm movements and providing tactical field information through AR glasses.

Furthermore, this project marks the beginning of a study aimed at developing integrated systems to enhance and develop intelligent human assistance systems. For example, there are already helicopter-mounted machine guns that track the pilot's helmet movement and can be operated through it. Additionally, there are surgical assistants for doctors that interpret their movements and perform precise micro-level actions.

Integrated systems offer immense potential for the development of complex and integrated projects. Whether utilizing specialized systems like ESPcam or general-purpose ones like ESP32, they provide versatile solutions tailored to specific needs. The calibration of motion sensors is not only necessary but also highly efficient, ensuring optimal performance. Furthermore, the proposed project supports diverse applications such as payload launching, leveraging the extensive range of control provided by the remote. Additionally, the utilized platform enables network communication with augmented reality glasses, like HoloLens, offering significant potential for on-field applications. This integration of advanced technology enhances the project's capabilities and opens up new avenues for innovation. Future upgrades will concentrate on refining the object detection algorithm, improving the live image transmission system, and exploring additional functionalities to meet evolving application requirements.

This project signifies an important advancement in ESP32-based drone technology, showcasing its potential for practical applications such as aerial surveillance, environmental monitoring, and disaster response.

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SIMULATION OVER THE IMPACT OF A TORPEDO AGAINST A SUBMERGED MEDIUM-SIZED SUBMARINE

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Abstract: *One of the promising acquisitions within the Naval Forces' Acquisition Program consists of two non-nuclear diesel-electric Scorpène submarines produced by Naval Group. These acquisitions would significantly enhance the Romanian Naval Forces' presence in the Black Sea. However, before entering in our Fleet's service, it is imperative to thoroughly research their defensive capabilities.*

Hence, the idea of simulating the impact of a torpedo on the mentioned submarine emerged, with the aim of assessing the efficiency of both the current torpedoes in service and the resistance of these modern submarines to impacts. The geometries were created using Ansys Discovery, followed by describing the materials used, as well as their resistance and proper characteristics, meshing and the final setup.

External factors were also taken into account during the simulation. Factors such as hydrostatic pressure, depth, temperature, and salinity of the water significantly influenced the impact of the torpedo on the submarine's body.

Keywords*: Ansys; Simulation; Torpedo; Submarine; Engineering*

1. INTRODUCTION

To make the idea of an impact simulation between the *STING-RAY TORPEDO* and *SCORPÈNE SUBMARINE* reality, one must first find a simulation software that manages the domain we study. So, what was found to be the best choice was Ansys, using Explicit Dynamics. Modelling the structure of both the torpedo and submarine, thus creating a geometry is the next step. Geometries were created with a subprogram of Ansys, which is called Ansys Discovery, a process followed by the description, the resistance and proper characteristics of the materials used, but also the rules the model has to respect, creating a setup. External factors were also put into account, because, on the actual simulation, the hydrostatic pressure of the water, the depth, temperature and salinity mattered and greatly influenced the impact of the torpedo with the submarine's body.

2. OVERVIEW OF THE BODIES INVOLVED IN THE SIMULATION

2.1 The sting ray torpedo

The *STING RAY TORPEDO*, is a British torpedo initially developed by GEC-MARCONI which has been later bought by BAE SYSTEMS, in service since 1983. The appearance and development of it were driven by the desire of British policymakers not to be dependent on torpedo acquisitions from the United States, action that led to the beginning of the research program in this domain in 1964, with the aim to create a 100% British-made torpedo.

This torpedo is an Acoustic Homing Lightweight Torpedo with active and passive tracking capabilities, autonomous operation and capable of being launched from different platforms such as submarines, warships, UAV's, and last but not least, helicopters.

With a weight of 267 kg, a length of 2.6m, a speed of 45 knots which is approximately 83km/h, a warhead of 45 kg and a range of 6 nautical miles, this torpedo has become a proficient weapon against submarines and warships both, being used throughout Romania, UK, Norway, Thailand's Navies.

2.2 The „Scorpène" submarine

The *SCORPÈNE SUBMARINE* is a non-nuclear submarine developed by NAVAL GROUP and it stands as a pinnacle of modern naval engineering, embodying cutting-edge technology and unmatched stealth capabilities. Developed by a consortium of international experts, this submarine represents a fusion of innovation, reliability, and versatility in underwater warfare. With its design and advanced systems, the SCORPÈNE sets a new standard for underwater operations, ensuring naval superiority for the nations that deploy it. It is now currently in the Romanian Navy's Acquisition Program and it is stated that 2 submarines will be bought in the future.

This submarine is suited with a hydrodynamic Albacore shape and stealth platform, a MAGTRONIC electric propulsion motor, an automated diving safety control and navigation system, high performance and comprehensive sonar suites, batteries, SUBTICS Integrated Combat Systems, fast reloading weapon handling subsystem, torpedo tubes, and OPTRONIC mast and periscope.

Its main characteristics are the displacement of 1600 to 2000 t, a length of 61 to 82 meters, a submerged speed of more than 20kts and a diving depth of more than 350m. These characteristics were inputted in Ansys for the model which later has been used in the setup process and generating solutions.

2.3 Developing the simulation in Ansys 2023 R2 student suite

The project is structured in multiple parts. After importing the Geometry from Ansys Discovery, inputting the materials, the coordinate systems and setting up the connections, the mesh has been done, respecting all initial conditions imposed by the analysis settings, also taking into account Earth's Gravity. Furthermore, two velocities were created. One corresponding to the submarine's speed, which was set up to be 20 knots, and respectively, the torpedoes, which was set up to be 45 knots.

Taking into account the hydrostatic pressure created by the bodies of both the torpedo and the submarine, detonation points have been created, so that the point of impact can be defined.

The solution received takes into consideration four important information: "Total Deformation", "Equivalent Stress", "Equivalent Plastic Strain" and last, but not least, "Maximum Principal Stress" which all result from Resistance of Materials. These solutions come as graphs but also as a table of values which will be shared during the presentation.

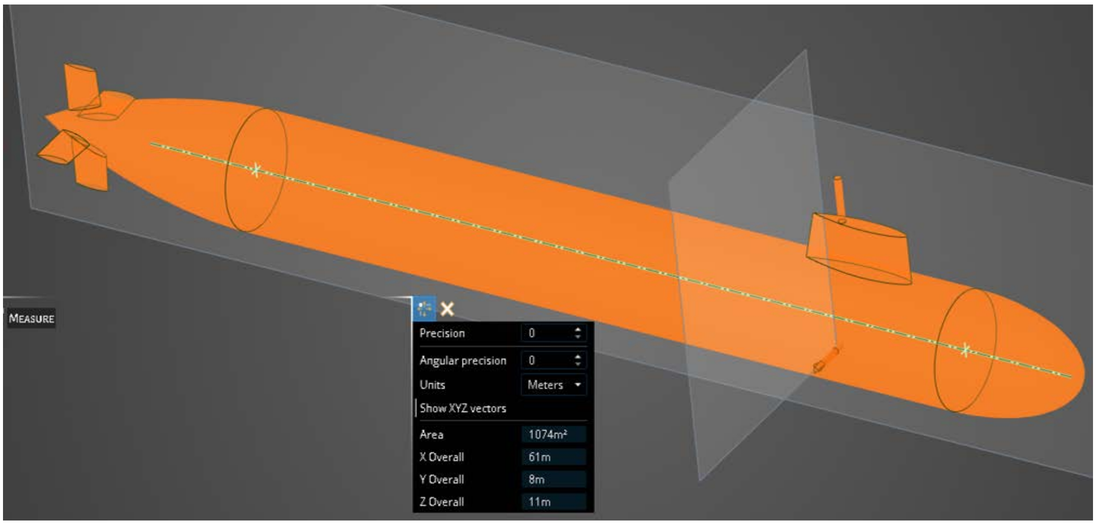

FIG. 1. Initial Conditions and Model generated in Ansys Discovery

In the picture above, the model can be seen, especially how it has been set up, the torpedo and the submarine. The longitudinal square is the surface of the water displaced by Archimedes' Force, and the other, the transversal one, is the hydrostatic pressure created by both the torpedo and the submarine. The initial conditions are as stated in the picture, where X stands for length, Y for width and Z for height. The next step was introducing it in Ansys Simulation Software.

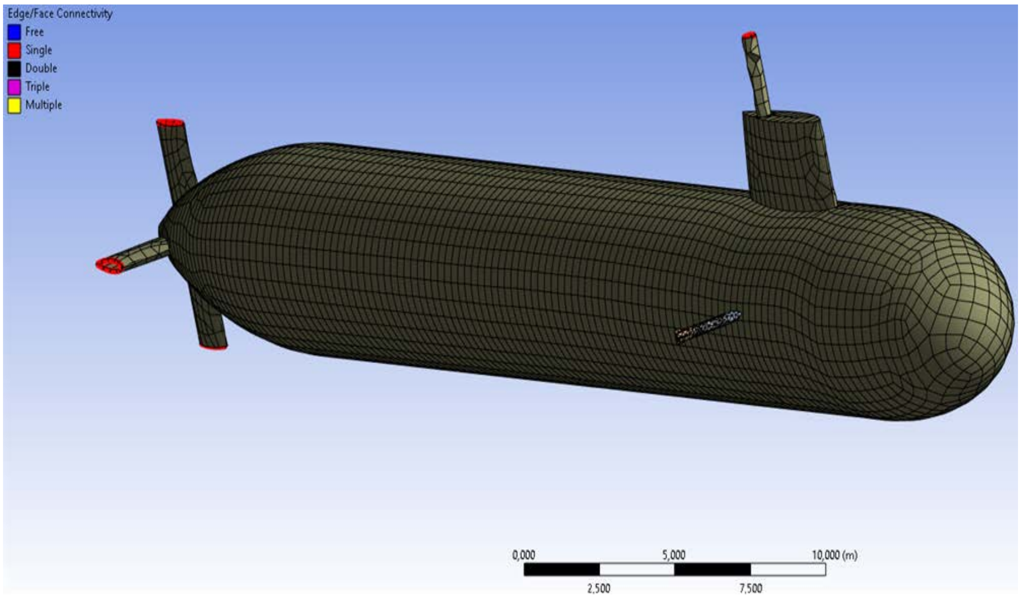

FIG.2. Meshing and introducing the body in Ansys Simulation Software

Ansys Simulation Software granted the possibility to integrate all the bodies together and make the final steps to the setup process, followed by solving and generating solutions. Meshing the bodies of the torpedo and submarine together, the final model ready to setup is ready for generating solutions, after setting up what each of it will do. As it can be seen in the image, there are 6 vectors, each corresponding to a characteristic inputted for the model. The first one, A, is the velocity of the torpedo, set to its maximum capacity of 45 knots, the second one, B, is the velocity of the submarine, set to 20 knots, C and D stand for the hydrostatic pressure generated by the torpedo and submarine both, the detonation point E is where the torpedo will strike, and the final one is the gravitational pull.

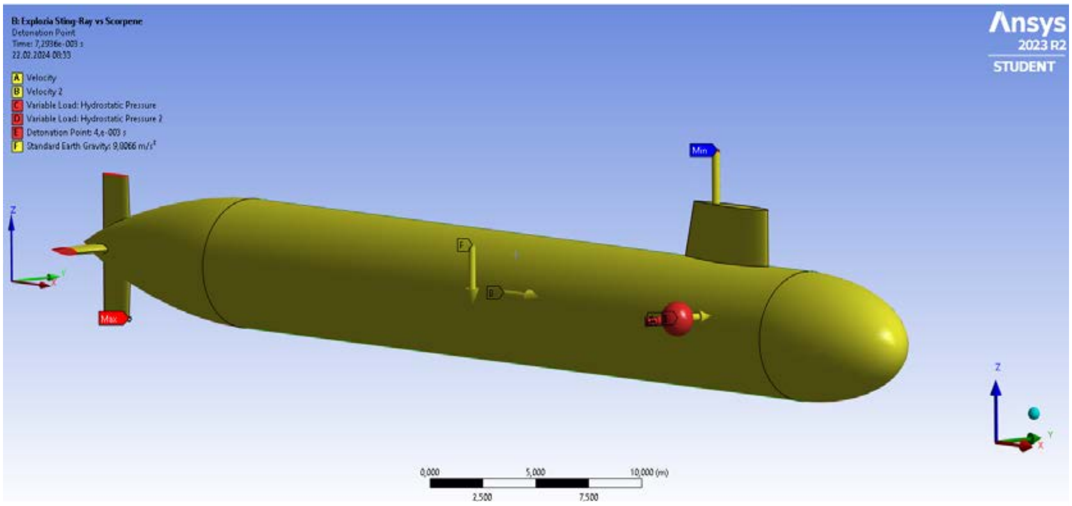

FIG. 3. Setup

2.4 Simulation output

After the setup has been completed, the solutions, as stated before, are "Total Deformation", "Equivalent Stress", "Equivalent Plastic Strain", "Maximum Principal Stress", inserted via the Solution menu, as follows.

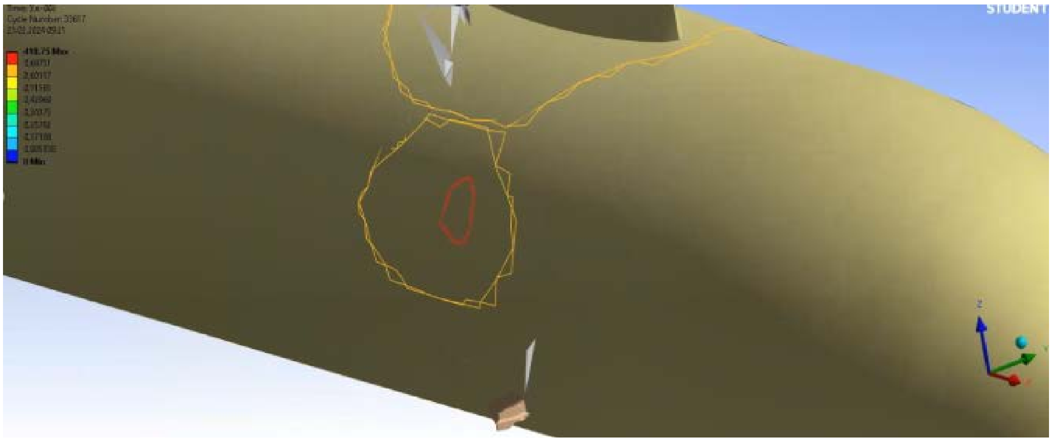

FIG. 4. Total Deformation Solution

The picture above is referring to "Total Deformation" status. These results show the real-time situation that happened in 20 frames in just 2 seconds after the simulation began, taking into account the minimum, maximum and medium deformation in meters of the submarines and torpedoes' bodies. The results show exactly the deformation of the submarine's hull after the impact and are generated in graphics and tabular data.

The results come in a matter of milliseconds and even subdivisions of it, and in the graphic, the values form 2 sketches that represent the overall deformation in the given time.

This solution is very important as it shows exactly how the hull will be modified after the strike and it is a great way to understand the processes that happen during the impact.

On the other hand, the picture above shows the "Equivalent Stress", measured in Pascals, also in the course of those same 2 seconds and 20 frames, with regard to the minimum, maximum and average values.

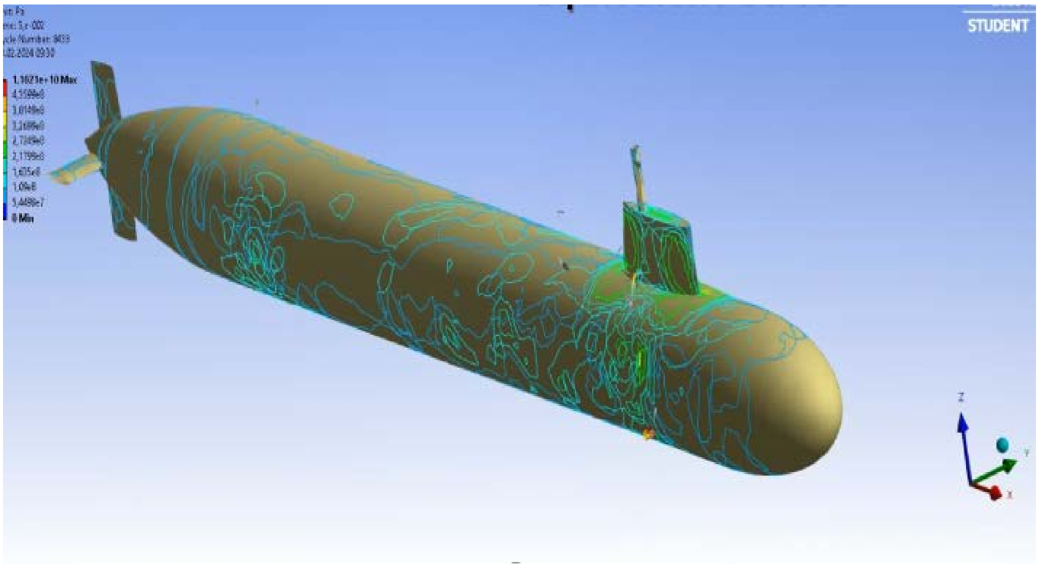

FIG. 5. Equivalent Stress over the submarine's body

As it can be seen from the image itself, it shows the shockwave that the submarine has to encounter after the explosion. It first seems like the submarine is affected only in the part where it is hit, but it is certainly not the case, as the shock wave follows the entire submarine structure and this way, receives damage.

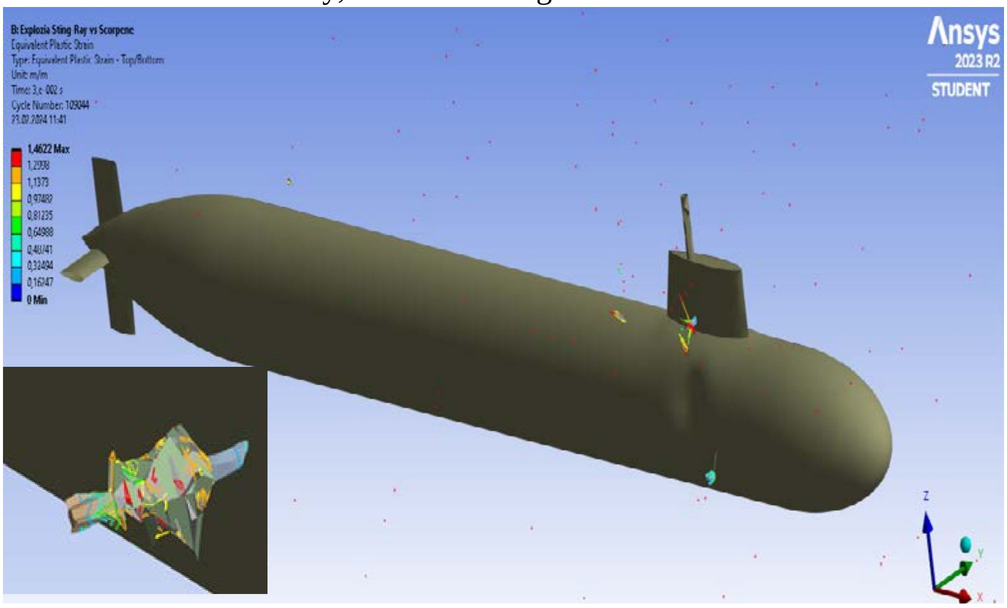

FIG. 6 Equivalent Plastic Strain

On the flipside, the "Equivalent Plastic Strain" shows the minimum, maximum and the average Plastic Strain in meters per minute, in the course of the same frames and duration of time. This one is measured in mm per mm, which is a unit for strain, and it shows exactly how the submarine's body has deformed and exactly the amount of the deformation, as it will be showcased during the presentation, where the breach will be shown.

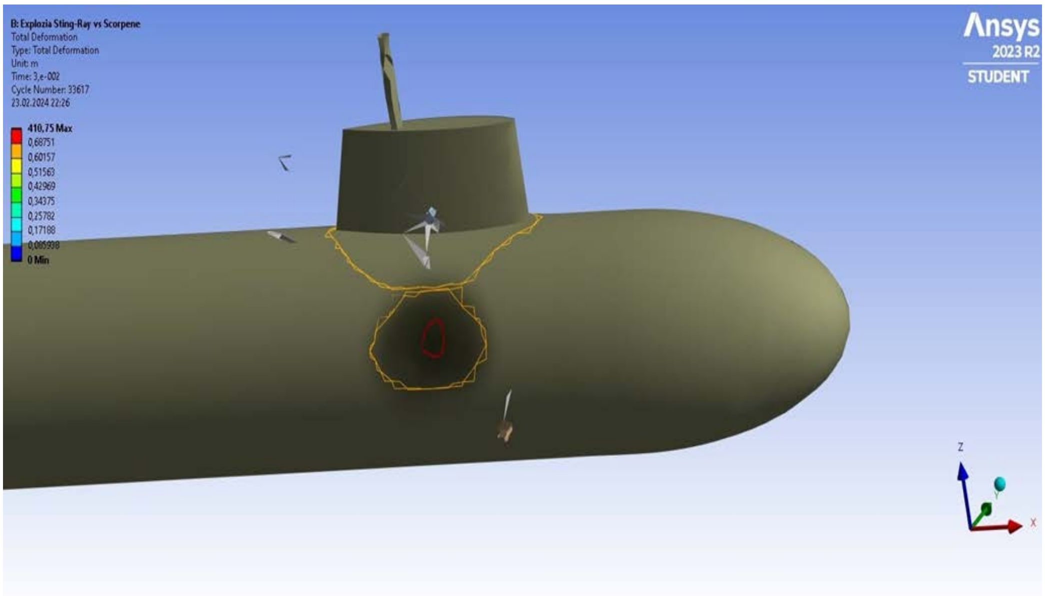

FIG. 7 Maximum Principal Stress, maximum damage dealt to the submarine

Finally, the “Maximum Principal Stress”, shows the same minimal, maximum and average stresses of the bodies in the same duration of the time, amounting the total damage dealt to the submarine.

It is also measured in Pascals, and it shows the final result, the breach, which is the red one, the area most affected contoured in black and the torpedo immediately as it blew up. The yellow lines show the overall areas of the damage as the torpedo hit from an angle below the submarine, pushing the explosive and the impact upwards, to the mask area.

3. CONCLUSIONS & ACKNOLEDGMENT

All in all, the simulations’ output strongly support the efficacy and dependability of the Naval Group's submarine model. The incorporation of dual armor layers has proven instrumental in enhancing the vessel's resilience, effectively thwarting potential sinking incidents post-attack. Additionally, the performance of the Sting Ray torpedo within the Romanian Naval Forces' arsenal and for over four decades in service globally, underscores its enduring capability to counter modern submarine and warship threats across national and international maritime domains.

In regards to the simulation, the torpedo hit the Automated Diving Safety Control and Navigation System and the Integrated Combat System, areas that are very important for the submarine’s capacity to float and defend itself. With those compartments blown up and flooded, the submarine cannot apply defense countermeasure and is most likely to sink to the bottom of the ocean if the crew cannot evacuate the flow of water coming inside the submarine’s body, calculated with a certain formula to determine the exact water flow after the torpedo strikes. Moreover, this impact will affect the submarine’s maneuverability and thus, leaving the “fully operational status”, becoming more vulnerable, increasing the chances of sinking it.

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THE QUEEN OF THE AIR, SMARANDA BRĂESCU

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Abstract: *May 21, 1897 is the date of birth of Smaranda Brăescu, the date on which a new page is written in the grandiose book of the history of national and world aeronautics. The Queen of the Air becomes an emblematic figure for Romanian parachuting and beyond, being the first woman from Romania to hold an international parachutist's license and the fourth woman in the world. Smaranda also acquired the international pilot's license. Her life brings to light the courage, determination, belief in her own dreams and the grace she has always had. The Queen of the Air or "Air Defier", as she was called by the press of the time, is, par excellence, the image of the woman fighter, the fearless jumper and the skilled pilot who did not limit herself to proving her potential, but showed the world that she is "broken from the sky". Smaranda Brăescu broke record after record, being at the time the holder of the national record for parachute jumping, both for women and men, as well as the holder of the women's world record. The queen of the air penetrated the mysteries of aviation with great ardor, leaving a unique legacy in the sky and on earth.*

Keywords*: parachutist; queen; pilot; record; sky.*

1. INTRODUCTION

Smaranda Brăescu came into the world on May 21, 1897, in Buciumeni, Galați County. Even from a tender age, she expressed her fascination with the sky and aviation. In an era where the role of women in society was often constrained, Smaranda had the courage to pursue her passion, opening new horizons for women in the field of aviation. The portrait of Smaranda Brăescu delves into the life of this remarkable woman who defied the conventions of her time.

Smaranda Brăescu did not dream of becoming a parachutist but aspired to be an aviator. Originating from near Tecuci, in a family of peasants from Hănţeşti, Buciumeni commune, she witnessed one of the first flights of a Romanian military pilot, Lieutenant Gheorghe Negrescu, in May 1912. This moment, when Negrescu flew the Bucharest-Bârlad route, inspired her desire to fly. In 1928, 16 years after this event, Smaranda announced her wish to become an aviator, a first for a Romanian woman at that time. After months of perseverance, despite the obstacles posed by the era's mentality that considered aviation an exclusively male domain, Smaranda found a way to get closer to the world of flight: through parachuting.

2. THE FIRST STEPS TOWARDS A GREAT FUTURE

To follow her dream, she borrowed money and went to Berlin, to the famous Schröder factory, to learn parachuting under the guidance of Otto Heinecke. Here, she purchased a white silk parachute, marking the beginning of a remarkable career in the field that brought her international recognition, as well as near-death experiences. In Berlin, after learning the parachute folding techniques, she made her first jump on July 5, 1928, experiencing intense emotions until she managed to launch at the instructor's command. This courage placed Romania among the first European countries with a female parachutist, alongside France, Czechoslovakia, and Switzerland.

Her success in Romania was perceived as a violation of natural norms. For the majority of Romanians who read about her in newspapers, she was seen as a peculiar and challenging entity to comprehend.

Nevertheless, not everyone was constrained by prejudices. Between 1929 and 1930, Smaranda (or Măndița, as she was affectionately called by her family) was invited to participate in several airshows held in major cities across the country, where adventure was always present. For instance, in Cluj, upon landing, she remained suspended in the branches of a tree for over an hour, becoming a subject of interest for the press. In Brăila, during the summer of 1929, after her jump, she was carried by a strong current towards the Danube. Unable to swim, she considered herself fortunate to land on the riverbank. For Smaranda, however, luck was secondary to her deep faith; she was convinced she was under divine protection, mentioning that if she hadn't pursued aviation, she would have lived in a monastery. But a significant trial was yet to come.

3. TRIUMPHS AND TRIALS

On August 30, 1930, in Satu Mare, during a new aerial show, Smaranda appeared sad, confessing her fears to those close to her, stating she feared she would be "collected with the broom." A premonition? After the opening of the white parachute, a strong east wind began pushing her obliquely towards the Hungarian border. Transforming the descent into a dizzying slide, it caused panic among spectators. Cars attempted to chase the parachute, but without success. Smaranda was struck by a tree and then thrown onto the roadside, with shattered bones.

Smaranda Brăescu survived. Discovered in critical condition, she was taken to the Satu Mare hospital, where doctors found she had a double femur fracture, another in the pelvic bones, and two broken ribs. She spent six months hospitalized, during which she reflected on her future and made the decision to pursue performance parachuting.

As spring of 1931 approached, Smaranda was discharged from the hospital. Her plan was to break the national record, which required modifications to her parachute. Upon returning to Bucharest, she spent the summer attending audiences, requesting an aircraft to lift her beyond six thousand meters. Eventually, she received support from Gheorghe Negrescu, the person who, in 1912, had instilled in Smaranda the desire to become an aviator.

4. REACHING NEW HEIGHTS

In the fall of 1931, Negrescu, now a colonel and commander of the Aeronautics Training Center at Pipera Aerodrome, ordered Lieutenant Alexandru Papană to take her on board a Potez XXV aircraft and raise her as high as possible. The two started with several acclimatization flights, then set the jump date for October 2, 1931. On that day, Smaranda boarded the plane. Two other aircraft took off with Papană to accompany her. At approximately 6,200 meters above sea level, two other planes were forced to abandon the flight; one due to technical issues and the other due to high fuel consumption.

Smaranda recognized the opportunity: if she jumped at that precise moment, she could shatter both the national and world female altitude records, previously set at 4,800 meters.

Summoning her courage, she plunged into the void. Her parachute deployed immediately, and the descent lasted 21 minutes. This marked her inaugural achievement and the first international record broken by a Romanian woman. The acknowledgment of her accomplishments ignited a fire within her. It came as little surprise when the determined young woman announced her ambition to break the absolute parachute jumping record, held by an American who had descended from an airplane at 6,450 meters—just 250 meters higher than Smaranda's planned jump. Her proposal garnered public attention, with the "Universul" newspaper endorsing her cause and initiating a subscription list. With the funds raised and an additional thousand dollars from the National Bank of Romania, Smaranda departed the country on December 14, 1931, bound for the United States. She arrived in New York on Christmas morning aboard the Leviathan.

5. THE QUEEN OF THE AIR IN THE FIGHT FOR DREAMS, RECORDS AND VICTORIES

On December 28, Smaranda journeyed to Washington, where she rang in the New Year, and on January 1, 1932, she boarded a train headed for Florida. She arrived there knowing that aeronautical festivities were scheduled for January 7, 8, and 9, hoping to find an airplane to take off and break the world record. However, she was informed that she couldn't parachute jump because there were no planes capable of reaching high altitudes. Even jumping from a lower altitude was discouraged, as it would jeopardize the reputation of a record holder. For a month, the Romanian was unable to find an airplane. She began to believe that, in reality, the jovial individuals who praised her were only waiting for her to deplete her financial resources and return home. Thus, the Americans would keep their record.

Eventually, the young woman was informed that the authorization for her flight would only be possible if she found a vast plain to land on, as the plains in Florida were wild, inhabited by venomous snakes and other dangerous creatures. Fortunately for her, someone sent her a telegram informing her that in California, in Sacramento, there is a plain that meets all the necessary conditions. She just had to cross the entire continent to the Pacific coast. Upon reaching San Francisco, she contacted the authorities at Bay aerodrome, near Alameda. However, even after five attempts over the course of two months, Smaranda failed to make the jump at the desired altitude. The first two failures resulted from the fact that the plane did not reach the necessary altitude, between 6,000 and 6,500 meters. After changing the plane to a more powerful one, various problems arose. In the first flight with the new plane, she reached an altitude of 6,800 meters, but the pilot had to land quickly, explaining that the oxygen in the bottle had run out. On the second attempt, Smaranda's bottle ran out of oxygen. Convinced that someone was sabotaging her attempts, the parachutist sought the help of Ion Petrescu, a Romanian in San Francisco. She asked him to load the oxygen bottles together and transport them to the plane, where he would guard them until takeoff. However, even on the fifth attempt, Smaranda Brăescu failed to make the record jump because darkness fell before the plane could turn towards Sacramento, casting doubt on another attempt. At that moment, Smaranda also faced a lack of funds but sought support and received a loan of one hundred dollars.

On May 19, 1932, Smaranda Brăescu was once again at the Bay aerodrome near Alameda. She arrived, as usual, accompanied by Ion Petrescu.

While they were filling the oxygen tanks, journalists appeared. Ironically, they asked her what she would do if something unexpected happened again. She replied that this was her last attempt, and if it failed, she would jump anyway, but without a parachute.

Smaranda took off for the sixth attempt to set a new world record for parachute jumping. The plane reached 7,000 meters, then climbed to 7,100. She made the jump.

Smaranda Brăescu broke the world record for parachute launch, jumping from 24,000 feet above the Sacramento plain in California. A farmer immediately approached her after witnessing Smaranda's descent. He found her exhausted and assisted her in unfastening the belts of the two parachutes. It was challenging for her to remain conscious, and it took several minutes for her to fully recover. The farmer waited until Smaranda managed to articulate a few words, then drove her to his farm using his personal car, from where he called the nearest aerodrome.

The news spread across America. Telephone, telegraph, radio, and special editions of newspapers talked only about the record set by Miss Brăescu. The height of 7,233 meters was officially recognized for the Romanian aviator.

After breaking the world record in parachute jumping, Stelian Popescu, the director of the "Universul" newspaper, initiated a new fundraising campaign in Bucharest. The collected funds reached Smaranda at the end of June, constituting a substantial amount that allowed her to extend her stay in America and fulfill her dream of becoming an aviator. Thus, on October 8, 1932, at the flight school at Roosevelt Field, New York, Smaranda Brăescu obtained her pilot's license, becoming the third female pilot in Romania.

From that moment on, Smaranda entered a new stage in her life. Returning to Romania King Carol II bestowed upon her the "Virtutea Aeronautică" Order, Golden Cross class, in recognition of her feat.

6. ADVENTURES IN FLIGHT

In March 1933, she decided to give up parachuting (her last jump took place in the summer of the same year in Constanța) and purchased an airplane for international flights. In the fall of 1935, she became the owner of a Miles Hawk Major aircraft, manufactured in England, which she named "Aurel Vlaicu." With this aircraft, in the spring of 1936, she achieved her most significant accomplishment as an aviator: the crossing of the Mediterranean Sea.

The adventure is worth recounting in detail. On April 27, when she set out on her journey, Smaranda had no idea she would end up in Africa. The initial itinerary of the raid followed the classic route București-Roma-Paris-London. The departure from Băneasa was marked by incidents. Arriving at the airport at dawn, she delayed takeoff due to a lack of fuel. Eventually, Major Mihai Pantazi managed to provide her with 300 liters. Smaranda couldn't rejoice too much as she noticed that, while searching for fuel, someone had stolen her flying goggles, gloves, and boots. Nevertheless, she headed west, planning to reach Rome in a single stage. It wasn't an ideal flight; the air currents were so strong that Smaranda could barely control her plane. Fearing a crash, she changed direction towards the northwest. The emotions subsided, and soon she spotted the coastline. She landed at a military aerodrome near the town of Rimini, where she was warmly welcomed. The Italians knew her and held her in high regard. The next morning, she received a telegram from the Ministry of Air in Rome, requesting full support for the continuation of her journey. She covered the remaining 400 kilometers to Rome in less than two hours. During the flight, she noticed some suspicious vibrations in the engine.

She landed in Littoria, a newly built city near Rome (in 1946, the city's name was changed to Latina). She planned to stay for a more extended period. In the following days, the aviatrix explored the city and decided to abandon the European raid to cross the Mediterranean Sea and reach Libya, Tripoli.

Discussing with Italian aviators the plan to cover, in a straight line, the 1100 km from Rome to Tripoli with a single-engine plane, only raised doubts and dissatisfaction. She was advised to split the journey into three stages: Rome-Syracuse-Palermo, Palermo-Tunis, Tunis-Tripoli, following the coastline, but the Romanian woman was unwilling to listen. Mrs. Brăescu decided that the departure day would be Tuesday, May 19. Upon arriving in Tripoli, the consul was curious to learn how the flight went; the direct route chosen by the Romanian managed to defy many. On May 21, Italo Balbo organized a reception in honor of Smaranda Brăescu. As she lacked funds to buy proper clothes, the aviatrix arrived at the palace dressed in traditional Romanian attire.

The return from Africa to the home country took place on May 30. This African expedition marked the end of Smaranda Brăescu's glory period. From then on, major achievements eluded her, and the press turned its attention to other Romanian aviatrixes.

7. FALLING STAR

At the time of Romania's entry into the Second World War, Smaranda was one of the instructors in the first parachute company of the Romanian army. Due to lingering pain from old fractures, parachute jumps were no longer part of her activities. In the fall of 1942, she was assigned to the renowned medical squadron on the Stalingrad front, alongside other Romanian aviatrixes. Their mission was to transport the wounded from the front to field hospitals using aircraft.

During the bombing on April 4, 1944, she was in the Bucureștii Noi neighborhood, and the bombs fell near her house. After this event, she decided to leave the capital.

The end of her life remains somewhat unknown. According to her file at CNSAS, on June 20, 1946, she was put under general police surveillance, which had sided with the communist government. She was accused of being part of a group of military personnel intending to fight against the Groza government.

Smaranda Brăescu passed away in Cluj on February 2, 1948. With her departure, God took from Romanian ground a symbol of the sky, a falling star that used a parachute.

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TRAIAN UDRISKI, TRAINING PILOT OF THE ROMANIAN ROYAL WINGS

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Abstract: *The present study is a research of a less known personality of Romanian aviation of the last years of Romania under the reign of King Mihai. Mainly, the research brings forward biographical aspects from the life of the pilot through whom the King discovers his passion for aviation.*

In the years of the attempt to establish the communist regime in Romania, the royalty faced up to political and military countless attemps. In this way , in all this accumulation of difficulties an unparalleled passion is born , royalty's love for aviation . This field ranks in the life of the King for the first time as a calling, and later represents for him a source of livelihood born from the lacks related to his abdication.

Therefore, in this context, the research also presents the way of making connections and the relationship of pilot Traian Udriski with King Mihai. Traian Udriski, little known to the general public of the time, remains in the memory of the former monarch as "a wonderful flight instructor, a true master". (Ciobanu, 2008 : 102)

The research records the study of the life of this training pilot and how his by chance presence in the King's life transforms through the power of his passion for flight into a relationship between the Romanian Royalty and aviation.

Keywords*: aviation; king; pilot*

1. INTRODUCTION

Aviation: hobby, profession, career, a word with so many meanings, it is among the words of the Romanians starting with Traian Vuia, it gains more meaning with the interventions of Aurel Vlaicu and it becomes increasingly common and more often used with the establishment of the first schools of this type in Romania.

It becomes indispensable in the vocabulary of the military with First World War, it broadens its horizons in the interwar period and it leaves its mark on humanity during World War II.

Aviation also conquers the heart of the pilot Traian Udriski. Although he is a less known personality, we know that he was a navy officer with a heart conquered by the love of flight and aircraft. He cultivates his passion and becomes a pilot. His exceptional skills transform him into training pilot.

Fate brings him to the handle of the plane carrying King Mihai of Romania, a moment that connects the destinies of the two.

Although too little data is known about this pilot, the testimonies of His Majesty in his numerous interviews with famous journalists create an exceptional portrait of Traian Udriski. This is the one who gave life and wrapped the Romanian royalty in the wings of aviation in one of the crucial historical moments to which the Romanian people were subjected.

2. KING MIHAI: ROMANIAN EDUCATION, PASSIONS REFLECTED THROUGH NATIVE INTELLIGENCE

King Mihai was born on October 25, 1921, at Foișor Castle in Sinaia.

Mihai was the only child of Prince Carol and Princess Elena of Greece, and his birth was a great joy for the entire royal family.

He first took the oath as King of Romania at the age of not even six in 1927, following the death of King Ferdinand. His father reclaimed his throne after returning to Romania in 1930. Thus Mihai received the title of Grand Voivode of Alba Iulia.

He received his first car at the age of six, an english electric car called "Red Beetle". At the age of eight, his uncle, Prince Nicolae, gave him his first real car, a 1927 Morris.

In 1930, Mihai was enrolled honorarily at the "Nicolae Filipescu" Military High School at the Dealul Monastery.

In 1931, he is enrolled at the aeronautical high school in Mediaș, to learn aviation technique.

On October 16, 1931, he became the class chief, then he was transferred to the control of the students of the Technical School of Aeronautics.

During these years, Mihai developed technical inclinations, for which King Carol II of Romania established a mechanics workshop at the Royal Palace.

The future King had a quality Romanian education under the fierce coordination of his father.

On September 6, 1940, his father abdicated, and on the same day Mihai took the oath as King of Romania. He stated at the time of his coronation that he lacked the political qualities necessary to lead the state.

Concerning his interests, he developed a passion for engines from an early age. The King owned an impressive collection of 38 vehicles throughout his life, being attracted by mechanics and its secrets. He also had an affinity for World War II military off-road vehicles.

The King did not stop only at cars, and his passion extended to airplanes. At the age of 12, he had his first flight as a passenger, on the Bucharest-Ploiești route.

Based on his title, he was imposed numerous restrictions in this area, because this branch had its risks, and the country could not afford to lose a successor. Therefore, he is not allowed to board such a means of transport for a long time.

3. TRAIAN UDRISKI: FROM AIRMAN TO AIRLINE PILOT

Traian Udriski was born on February 23, 1906 in the family of a vineyard owner from Focșani, Vrancea, Romania.

He graduated from the Naval School in Constanța. He was initially a navy officer in the Romanian Royal Navy. During his career he worked on Navy seaplanes in the Techirghiol area. Thus he realized that he wanted to become a pilot, and in 1931 he fulfilled his dream and became an airman. His impressive skills turned him into training pilot at the Buzău Training Center.

Around the same years, the Romanian State ordered four Lockheed Electra 10 planes. Therefore they decided to send four Romanian pilots to study abroad to become airline pilots. So Traian Udriski was sent against his will to Warsaw, Poland to do the Lufthansa airline pilot school.

In these circumstances, Traian Udriski made the best airline pilot school of that time, together with three other Romanian pilots, namely: Ion Popescu, Ștefănescu Anton and

Ion Dincă. Accustomed to fighter jets and aerobatic flying, Udriski called airliners "trucks". (Iliescu, 2018)

Although he became an airline pilot out of obligation, he succeeded in becoming one of the most experienced airline pilots of that time and became training pilot. One of his students was the pilot Constantin Cantacuzino, a famous name in Romanian aviation during the Second World War.

Among the four pilots, Traian Udriski got to operate the Lockheed plane on the Italian line, Dincă on the Prague line, and Popescu and Ştefănescu on the Warsaw line. The exhausting work and the incessant flights took away one of their comrades, Dincă, who died of galloping phthisis due to physical exhaustion. However, Traian Udriski reached the number of 250 flight hours per month, an extraordinary number, compared to the other two pilots who worked half as much, operating the same line.

At that time, LARES was under the protection of Andrei Popovici and had as chief pilot Paul Dumitrescu. The LARES company ordered another type of plane, namely the Lockheed 14. Traian Udriski transported all these planes to Romania from Gdansk, the Polish port where they were assembled after arriving by ship from America. He noticed during his flights that the plane represented a danger, therefore he informed Andrei Popovici about the bad performance of the plane. Because of this, the pilot refused to give a favorable report to civil aviation and leaved the LARES company.

But the pilot's skill in the art of flying came to the surface at the beginning of the war, because Udriski's assumption about these planes was confirmed by the fact that a Lockheed 14 carrying journalists crashed at Băneasa airport.

This event resulted in the dismissal of Andrei Popovici and Paul Dumitrescu. In their place, General Scarlat Rădulescu was appointed as director of LARES, and Traian Udriski was appointed as director of civil operations.

During the war the company maintained international lines and made transports for the front, transporting ammunition and dismantled cannons, and on the way back it transported wounded from the front on straw mattresses.

4. TRAIAN UDRISKI INITIATE A NEW PASSION IN THE SOUL OF THE KING

In 1942, during the war, Marshal Antonescu insisted that King Mihai assist him during a visit to the front. So, the King leaved by plane from Bucharest to Crimea. After visiting several points on the front, Mihai returned to the country on the same plane.

On the route back to Romania, the weather was not bad, but the wind in gusts shook the plane strongly, which made the King to feel airsick. At that moment, Mihai decided to take seat in front. Thus he reached the visual range of the pilot, Traian Udriski noticed that the King was pale and suggested that he take the co-pilot's seat. The king did exactly that, at which point Udriski gave him the opportunity to control the plane from the co-pilot seat.

Although the King had never touched the controls of an airplane before, he managed to distract himself by performing a few maneuvers, being supported of course by the pilot Udriski throughout their execution, and the airsickness dissapeared.

This incident brought the King in front of a new passion, flying. Therefore, during his visits to Săvârşin, to Constanţa, he chose transport with the planes of the Romanian Air Line Exploited by the State (LARES) instead of traveling by train, and every time the King was on the right side, on the co-pilot seat, next to the pilot Traian Udriski.

The King formalized Udriski as pilot of the Royal House. He wanted to start his own flying lessons with Udriski, thus the two come to the conclusion that they needed a plane. They found a school plane at the Romanian Aerodrome and started the flight lessons.

The King kept this matter hidden because both Antonescu and others considered it too dangerous for a king. Later, he bought a modern German plane built in Czechoslovakia, a Klemm 35. To reach Săvârsin, the two had to land in Arad, and from there go by car. Therefore, King Mihai decided to set up an airfield at Vărădia de Mureș, where he brought his plane and conducted his fligt lessons, with the pilot Traian Udriski as his flight instructor.

However, his status required certain safety measures during his flights, namely: the King should never be left alone at the runway, so he was always supervised by the people in the safety car. At one point, during the flying lessons, after a landing, Udriski offered the King the opportunity to fly the plane by himself.

"Yes, I can tell you... Indeed, I had two students in my life who were extraordinary: an officer, whose name I no longer remember, I have forgotten, whom I let fly alone after a instruction of four or five hours or so... and the second was the King. The King had extraordinary sports qualities! I let it fly by itself, in less than three hours of instruction, I think 2 hours and 50 minutes, something like that... It flew very nicely! Then I trained him seriously for this and in the end the king had been to America, representing the Lear (Lear Jets and Co) aviation company in Geneva, I think that's what it was called... he flew them, the Lear planes, and presented them as many or they were buyers..."(Iliescu, 2018)

Traian Udriski later confessed to the King that in order for this to be possible he had to create a diversion to distract those in the safety car. So he told them that they had a reconnaissance mission to do, and for that the safety car had to be over to the sidethe other of Mureș hidden in a green area.

King Mihai then took full command of the plane, took off alone, made a tour and then landed. The moment deeply impressed Udriski, who took him in his arms and kissed him on both cheeks.

The relationship between the two strengthened throughout this period, and soon after, the King appointed Traian Udriski as aide-de-camp. Meanwhile, due to the tense political situation, the English and the Americans had come to Romania, and the English had a mission that involved an American plane, given on loan. Udriski had the opportunity to see this plane at Băneasa airport, and on his advice, King Mihai bought it as American military surplus before the expiration of the restitution period. This was the plane with which he flew to London for the wedding of the Queen of England, part of the way piloting the King, and the other piloting Udriski.

But King Mihai's life took a dramatic turn in 1947, the year of his exile from Romania. After the departure of the King, Traian Udriski did everything possible to get the King's plane out of the country and also succeeded this time through a diversion. He said that he wanted to move the plane from one hangar to another, and after he slowly took it out of the big hangar, took his wife and some aviation technicians and he did not stop the engines anymore.

Udriski's intelligence and skills in the field of aviation came to light this time as well. He took off in bad weather, when no one would have expected that someone getting up from the ground. He arrived in Munich and from there to Geneva, carrying out his mission.

Traian Udriski did not stay long in Switzerland, he found work in Lebanon and then moved to Cyprus. He reached the age of 80 years, having thousands and thousands of flying hours.

During the years of his exile, the King went through difficult moments, and aviation became from passion a profession. On one of his trips to Florence, Mihai stopped in Switzerland, where he had the opportunity to meet William Lear.

The two discussed as if from pilot to pilot, and when parting they realized that both was heading to Florence. Lear invited the King to fly with him, and he accepted the invitation, being the one who would fly the plane on a tour of Florence. The coincidence was that William was opening a small European Lear Company in Geneva at that time, for mounting and repairing instruments on airplanes, and he invited Mihai to work with him.

In 1956, the King moved to Switzerland and started working at the airport. Although the King had a Swiss pilot's license, it was of own use, this is why Lear send him to America in order to take an advanced flight course without visibility. In addition to this, he obtained the American professional pilot's license.

After four months the King returned to Switzerland and worked as a test pilot to check flight instruments. He often delivers aircraft to customers in Switzerland, France or other places.

The King described all these years as years of intense work, but the fact that this profession was born from passion turned his hardship into an interesting experience.

5. CONCLUSIONS & ACKNOLEDGMENT

We know and study great names of our aviation, we also know King Mihai, a servant of Romania by birth, but we have not known the connections between the two elements until now. A Romanian exiled from his country for decades, finds his hope and moves forward through the passion for aviation born in the same lands of his birth, together with one of the lesser known names of Romanian aviation, Traian Udriski.

"What was pleasure and joy later became a profession, that was my livelihood. Who would have imagined? In the beginning, it was a simple passion. Because in the end, everything I learned from passion can be used in my everyday life." (Ciobanu, 2008 : 98)

Flying for the last King of Romania was passion and profession, and during the years of troubles with the Soviets, relaxation. For him, the flight was never dangerous, although over time he also had small incidents. He had one of the best instructors, who became with time one of the few people who risk their lives for a King in exile.

"He was a wonderful flight instructor, a true master, he fell in love with his job with each new student who was entrusted to him. [...] He was a flight instructor for both the military and civilians. He loved his job and made others to love it. He was born to fly." (Ciobanu, 2008: 102)

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WINDS OF CHANGE: THE EVOLUTION OF AIR FORCE TACTICS, STRATEGIES AND TECHNOLOGY DURING THE VIETNAM WAR

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Abstract: *A paradigmatic transformation in tactics, techniques, and technology resulted from a seismic shift in air force dynamics that occurred in the crucible of the Vietnam War (1955–1975). With great care, "Winds of Change: The Evolution of Air Force Tactics, Strategies, and Technology during the Vietnam War" delves into this revolutionary period and reveals the tremendous effects of war on aerial combat.*

This article traces the development of air force tactics across time, beginning with the early 1960s and the dominance of conventional dogfights. Operation Rolling Thunder (1965–1968) was a critical turning point in the tactical environment as persistent bombing campaigns forced a reevaluation of tactics. As a result, tactics became more subtle and asymmetric, reflecting the difficulties presented by the hostile terrain and elusive opponent, as demonstrated by operations such as Operation Bolo (1967), in which air forces were able to defeat North Vietnamese MiG aircraft by using deceitful tactics.

During this time, technological advancements also flourished simultaneously. Design and avionics advances were demonstrated with the advent of aircraft such as the F-4 Phantom II and the A-7 Corsair II. Systems for electronic warfare, most famously the Wild Weasel missions (1965–1973), demonstrated how technology could be integrated to overcome enemy air defenses.

The use of precision-guided weapons as the war went on, most demonstrated by the accomplishments of Operation Linebacker (1972), highlighted the development of air force capabilities. This article skillfully traverses the historical terrain to offer a comprehensive picture of how the Vietnam War turned into a testing ground for tactical and technological innovations, permanently altering air force doctrine in the process. "Winds of Change" allows readers to navigate through the histories of war, exposing the entwined tales of dates, incidents, and their lasting effects on the trajectory of modern air power.

Keywords: *Vietnam War; Air Force Evolution; Tactical Innovations; Technological Advancements; Asymmetric Warfare.*

1. INTRODUCTION: ATTACKERS AND DEFENDERS' CAPABILITIES

The Vietnam War, which lasted from 1955 to 1975, was a seminal struggle that fundamentally altered the character of contemporary warfare, especially in the area of aviation. Both the attackers and the defenders had unique technologies and capabilities at the beginning of the war, which influenced the future of aviation combat in Southeast Asia.

With the support of its strong air force, the United States came into the war with a considerable technological advantage thanks to its possession of cutting-edge aircraft like the F-4 Phantom II and the F-100 Super Sabre. With their advanced guided missiles, radar systems, and precision bombing capabilities, American planes were the epitome of aviation technology at that era. Furthermore, the US commitment to using air power to accomplish strategic goals in Vietnam was emphasized by the advent of strategic bombers like the B-52 Stratofortress. To oppose American air superiority, North Vietnam and its Viet Cong allies used a mix of local resources and weapons supplied by China and the Soviet Union. The North Vietnamese Air Force faced American air supremacy over Vietnam thanks to the powerful aerial defense capabilities of Soviet-built MiG fighter jets, especially the MiG-21. Surface-to-air missile (SAM) systems, like the SA-2 Guideline, also presented a serious threat to US aircraft, requiring pilots to maneuver through a dangerous environment of missile defenses and anti-aircraft fire.

In this technologically advanced and strategically driven environment, the Vietnam War saw the convergence of inventions, human experiences, and aerial combat techniques that shaped the aviation domain of the fight. The development of aerial warfare in Vietnam demonstrated the fortitude, adaptability, and inventiveness of both the attackers and the defenders in the face of extreme difficulties and unrelenting misfortune, from the early days of conventional bombing campaigns to the strategic precision of later operations.

2. AERIAL OPERATIONS FROM 1964 TO 1972

Mostly carried out in Laos, OPERATION BARREL ROLL (1964–1973) sought to obstruct communist supply routes along the Ho Chi Minh Trail. The operation, although classified as covert, turned into a long-term aircraft campaign that included missions of interdiction in addition to conventional bombing. Barrel Roll aimed to disrupt the supply and personnel flow into South Vietnam by impeding North Vietnamese logistical networks. Tactically, it necessitated creative methods for locating and interacting with targets, frequently in difficult terrain and inclement weather.

Over 580,000 sorties piloted by a variety of aircraft, including fighter jets, B-52 bombers, and surveillance planes, were part of the actions during Barrel Roll. By destroying a large number of enemy convoys, supply depots, and infiltration routes, these sorties successfully cut off communist supply lines. Furthermore, the ferocity and scope of the operation were demonstrated by the fact that nearly 2.5 million tons of munitions were used during Barrel Roll. The air force's determination to obstruct enemy supply routes and damage their logistical infrastructure was demonstrated by this enormous firepower. Operation Barrel Roll demonstrated the air force's ability to change course and go from conventional bombing flights to maneuverable interdiction missions. The variety of aircraft used, including bombers, fighters, and reconnaissance planes, demonstrated the adaptability needed to succeed in unconventional warfare.

Barrel Roll propelled technological breakthroughs in the areas of precision-guided weapons and reconnaissance equipment. Precise targeting was made possible by the combination of advanced sensor technology and forward air controllers, which reduced collateral damage and increased operational efficacy. The strategic fallout from Operation Barrel Roll was felt for the duration of the Vietnam War, highlighting the mutually reinforcing relationship between tactics, strategy, and technology in aerial warfare.

In reaction to growing communist aggressiveness, the United States launched its first major aircraft bombardment operation against North Vietnam in 1965 under the banner of OPERATION FLAMING DART. The purpose of Flaming Dart, which was launched on February 7, 1965, was to show American commitment in the face of escalating hostilities and to exact revenge for a Viet Cong attack on the American air base in Pleiku, South Vietnam. Flaming Dart's strategic objectives were to weaken North Vietnamese capabilities and discourage additional aggression. Tactically, it used a mix of strategic targets, such as supply depots, transportation infrastructure, and military installations, and precision airstrikes.

American aircraft, such as F-105 Thunderchiefs and F-100 Super Sabres, made about 200 sorties over the course of the five-day operation, dropping almost 400 tons of ordnance on specific targets. Although the operation damaged North Vietnamese assets, it also demonstrated how ineffective conventional bombing campaigns are in producing clear-cut outcomes. Operation Flaming Dart brought to light the difficulties in using air power to sway political decisions. The war continued to escalate as a result of the North Vietnamese determination to not back down in the face of the aerial assault. The operation's constrained scope and length further highlighted the necessity of a more comprehensive and long-term plan to meet goals. Operation Flaming Dart highlighted the significance of target identification capabilities and precision-guided weapons from a technology perspective.

It also exposed shortcomings in target selection and intelligence collection, raising worries about collateral damage and civilian casualties. Laying the foundation for the larger Operation Rolling Thunder, Operation Flaming Dart prepared the way for further aircraft operations in Vietnam. It proved the strength of American air power, but it also brought to light the difficulties and complications of utilizing aerial bombardment as a coercive measure in asymmetric warfare.

During the Vietnam War, the United States launched one of the largest aerial bombing campaigns in history against North Vietnam, known as ROLLING THUNDER (1965–1968). Rolling Thunder was a movement that was started on March 2, 1965, with the intention of pressuring the North Vietnamese government to stop supporting the Viet Cong insurgency in South Vietnam and to force peace talks. Rolling Thunder aimed to accomplish a number of goals, such as blocking communist supply lines, demolishing buildings, reducing military power, and disheartening the adversary. It used a methodical, long-term bombing campaign to strategically hit a variety of military and commercial targets.

The operation was carried out in stages, each of which involved a slow increase in force. Target selection was initially restricted in order to prevent inciting a wider war with the Soviet Union or China. But as the war dragged on, the bombing campaign's reach and intensity grew, covering a wider spectrum of targets like transportation hubs, industrial sites, and urban centers. American aircraft, comprising F-105 Thunderchiefs, B-52 bombers, and carrier-based aircraft, conducted over 300,000 sorties and dropped over 643,000 tons of bombs on North Vietnam during Rolling Thunder. The mission failed to force negotiation or capitulation, as planned, since North Vietnamese resolve held firm in the face of a heavy aerial bombardment.

There were also major ramifications for air force tactics, plans, and technology from Operation Rolling Thunder. It emphasized the value of close air support techniques, electronic warfare capabilities, and precision-guided weapons. It also brought to light the difficulties of carrying out protracted aerial missions in a hostile environment, including anti-aircraft defenses and unfavorable weather. Rolling Thunder demonstrated, from a wider angle, the difficulties of relying solely on air power to advance political objectives in asymmetric battles. Even though it severely damaged North Vietnamese military hardware and infrastructure, it was ultimately unable to change the direction of the conflict or force the desired concessions.

There are ongoing discussions concerning the efficacy, morality, and strategic reasoning of Operation Rolling Thunder, making it one of the more contentious episodes in American military history. It is nevertheless a powerful reminder of the difficulties and complications involved in using air force in contemporary conflict, in spite of its flaws.

During the Vietnam War, the United States carried out a secret aircraft campaign known as OPERATION STEEL TIGER (1965–1968), which was mainly directed towards communist supply routes in Laos and Cambodia along the Ho Chi Minh Trail. Steel Tiger was launched in tandem with Operation Rolling Thunder with the intention of obstructing enemy logistics and preventing the entry of soldiers and supplies into South Vietnam.

Steel Tiger's strategic objective was to strategically deny North Vietnamese soldiers essential resources, which would diminish their capacity to continue the insurgency in the south. Tactically, it used airstrikes, interdiction missions, and reconnaissance to locate and destroy enemy infrastructure, supply depots, and convoys. Whereas Rolling Thunder concentrated on targets inside North Vietnam, Steel Tiger mostly operated in the border areas of Laos and Cambodia, where communist forces exploited the rough terrain to hide and defend their supply routes. This geographical difficulty demanded creative methods for engaging and acquiring targets, frequently including tight cooperation between ground and air forces.

American aircraft, comprising fighter jets, bombers, and surveillance planes, carried out hundreds of missions during Operation Steel Tiger, dropping substantial ordnance on enemy sites. The disruption of communist supply routes and the impediment to their capacity to maintain military operations in South Vietnam were major outcomes of these actions. Significant effects of Operation Steel Tiger were also seen in air force technology and tactics. It emphasized how crucial intelligence-gathering and reconnaissance skills are to locating enemy targets and weak points. It also sparked improvements in aerial surveillance and precision-guided weapons, making it possible to target and engage enemy assets more successfully.

Operation Steel Tiger, although clandestine, had a major influence on the Vietnam War's outcome by denying enemy forces vital supplies and adding to the overall strain on North Vietnamese logistics. But like past air missions in Southeast Asia, it also sparked debate regarding the propriety and effectiveness of employing air force in unconventional warfare.

During the Vietnam War, the United States launched a massive bombing operation known as OPERATION ARC LIGHT (1965–1973), mostly using B-52 Stratofortress bombers to target enemy objectives in South Vietnam, Laos, and Cambodia. Arc Light was launched in reaction to growing communist aggression with the goal of delivering heavy firepower quickly to opposing forces and infrastructure. Arc Light aimed to undermine communist capabilities in the area, destroy military structures, and interfere with enemy activities. In terms of tactics, it depended on the B-52 bombers' enormous firepower and long-range skills to conduct precise strikes on pre-selected targets, such as enemy troop concentrations, supply depots, and logistical centers.

The use of several B-52 bomber squadrons operating out of facilities in Guam and Thailand defined Arc Light operations. These planes were equipped with a powerful load of conventional bombs, which could cause enormous damage over a large area. The bombs normally weighed between 500 and 2,000 pounds each. Millions of tons of bombs were dropped on enemy objectives during the thousands of missions that were flown during Operation Arc Light. These bombing strikes were crucial in demoralizing the opposing forces, obstructing the movement of troops and supplies, and disrupting hostile operations.

Air Force tactics and technology were also significantly impacted by Operation Arc Light. It emphasized the adaptability and strength of strategic bombers in contemporary warfare, demonstrating their capacity to launch lethal precise strikes against adversary objectives.

Arc Light sparked improvements in command and control systems, logistical support capabilities, and aerial refueling, allowing for long-term, efficient operations.

Operation Arc Light created concerns about the morality and strategic sense of employing such tremendous weaponry in densely populated regions, even though it was successful in weakening enemy capabilities. Even so, it continues to be an important chapter in the history of aerial combat, illustrating the vital role that air power plays in determining how wars turn out.

One of the best examples of creative air force tactics used in the Vietnam War is OPERATION BOLO (1967). Operation Bolo, conceived and carried out by the USAF in January 1967, was to lure North Vietnamese MiG fighters into aerial combat with the intention of misleading and destroying them. Bolo's strategic goal was to eliminate the threat that North Vietnamese MiG-21 interceptors posed, as they had been obstructing bombing operations and harassing American planes. Tactically, it took a daring and cunning strategy, imitating the radio communications and flying patterns of F-105 Thunderchief fighter-bombers to trick adversary MiGs into attacking what they thought were easy targets.

Under the daring and exacting leadership of Colonel Robin Olds, a squadron of USAF F-4 Phantom II fighter-bombers carried out Operation Bolo on January 2, 1967. The Phantoms successfully intercepted and engaged a group of North Vietnamese MiGs while flying in formation and using radar-jamming devices to conceal their true identity. As a consequence, seven enemy aircraft were destroyed and no American aircraft were lost.

The triumph of Operation Bolo was credited to the careful preparation, creative strategies, and excellent implementation. By taking advantage of the enemy's weaknesses and expectations, US forces won handily, severely impairing North Vietnamese air power and boosting American pilot morale.

Operation Bolo demonstrated the technological significance of radar-jamming apparatus and electronic warfare systems in attaining air superiority. It also demonstrated the F-4 Phantom II's adaptability and deadly nature, which made it a dangerous opponent in air combat. The strategic ramifications of Operation Bolo persisted throughout the war, impacting later air force actions and affecting the development of air warfare techniques. It continues to be a monument to the bravery and inventiveness of American aviators, demonstrating the critical role that innovation plays in contemporary aerial warfare.

During the Vietnam War, the United States carried out a secret aircraft interdiction campaign known as "COMMANDO HUNT" (1968–1972), with the primary goal of obstructing communist supply lanes in Laos and Cambodia along the Ho Chi Minh Trail. Commando Hunt, which was launched in reaction to North Vietnamese forces' growing reliance on these logistical networks, aimed to obstruct the movement of soldiers and supplies into South Vietnam. The objective of Operation Hunt was to disrupt the enemy's supply chain and impair North Vietnamese forces, therefore diminishing their capacity to maintain military activities in South Vietnam. Tactically, it identified and destroyed enemy convoys, supply depots, and infrastructure along the Ho Chi Minh Trail by utilizing a combination of aerial reconnaissance, sensor technologies, and precision airstrikes.

There were several stages to the operation, each with increasing complexity and ferocity. While Commando Hunt was initially carried out by traditional aircraft, such as bombers and fighter jets, it eventually included specialized aircraft fitted with sensors and observation gear to improve target identification and evaluation.

Thousands of sorties were conducted during Operation Commando Hunt, dropping substantial ordnance on enemy sites.

The ability of the communists to maintain military operations in South Vietnam was severely hampered by the disruption of their supply lines caused by these aerial bombardments. Significant effects of Operation Commando Hunt were also seen in air force technology and tactics. It emphasized how crucial aircraft reconnaissance and surveillance are for locating enemy targets and weak points. It also sparked improvements in aerial surveillance and precision-guided weapons, making it possible to target and engage enemy assets more successfully.

Operation Commando Hunt, although clandestine, had a major influence on the Vietnam War, denying enemy forces vital supplies and adding to the overall pressure on North Vietnamese logistics. Like past aerial campaigns in Southeast Asia, it did, however, bring up ethical and practical concerns concerning the use of air power in unconventional warfare.

During the Vietnam War, the United States carried out a crucial aerial operation known as OPERATION LINEBACKER I (1972), which marked a major increase in air power against North Vietnam. Launched on May 10, 1972, Linebacker I sought to seriously harm North Vietnam's industrial and military capacities in order to force their leadership to engage in peace talks.

From a strategic standpoint, Linebacker I aimed to accomplish multiple goals, such as upsetting North Vietnamese supply routes, demolishing military installations, and lowering enemy spirits. To accomplish these objectives, it used a tactical mix of strategic bombing raids, interdiction missions, and precision attacks. The Easter Offensive, which saw the North Vietnamese invade South Vietnam, and the breakdown of peace talks contributed to the increased tensions that surrounded the operation. In retaliation, the US launched Linebacker I in an attempt to revers the conflict's momentum and demonstrate air supremacy.

During Linebacker I, thousands of sorties were carried out by aircraft from the United States Air Force (USAF) and Navy, including B-52 bombers, F-4 Phantom II fighter-bombers, and A-6 Intruder attack aircraft. Numerous enemy assets, such as airfields, ammunition depots, supply lines, and industrial sites, were the focus of these sorties. The widespread use of precision-guided weapons, such as television-guided missiles and laser-guided bombs, which allowed for more precise and effective targeting while reducing collateral damage, was one of the distinguishing characteristics of Linebacker I. Additionally, in order to improve the security and performance of American aircraft, electronic warfare capabilities were used to interfere with enemy communications and radar systems.

The United States forces accomplished notable tactical and strategic victories during Operation Linebacker I. Important objectives, including as the Thanh Hoa Bridge and the Paul Doumer Bridge in Hanoi, were successfully destroyed, cutting off essential transit routes and obstructing the movement of North Vietnamese forces and supplies. In addition, Linebacker I severely damaged vital infrastructure, severely wounded North Vietnamese soldiers, and made it more difficult for the adversary to carry out the battle. In the face of resolute opposition, the operation also showed the capability and resolve of US air power. Linebacker I highlighted the significance of electronic warfare technologies and precision-guided weapons in contemporary aerial warfare from a technological perspective. It demonstrated how cutting-edge weapons and strategies can accomplish military goals with little danger to allies.

Following the restart of peace talks between the US and North Vietnam, Operation Linebacker I came to an end on October 23, 1972. Even though the operation did not result in a ceasefire right away, it did play a part in the signing of the Paris Peace Accords in January 1973, which put an end to American involvement in the Vietnam War.

Operation Linebacker I was a pivotal moment in the Vietnam War that showed the strength of American air power and its capacity to change the direction of the war. The bravery, talent, and resourcefulness of the men and women who served in the US Air Force and Navy during this turbulent time in history are still evident.

One of the most significant and intense air campaigns of the Vietnam War was OPERATION LINEBACKER II (1972), which saw a sharp increase in American air power against North Vietnam. Linebacker II, also referred to as the Christmas Bombing, was launched on December 18, 1972, with the intention of forcing the North Vietnamese leadership to agree to a truce and resume talks.

Targeting vital military and industrial facilities in North Vietnam, such as airfields, bridges, power plants, and ammo depots, Linebacker II aimed to produce immediate results. In terms of tactics, it used a protracted and large bombing campaign, delivering enormous amounts of firepower on specific targets with the help of fighter jets, electronic warfare aircraft, and B-52 Stratofortress bombers.

The operation took place in the context of broken diplomatic attempts to settle the conflict and stagnant peace talks. As a last-ditch attempt to force North Vietnam to the negotiating table and secure advantageous terms for the United States and its allies, President Richard Nixon responded by authorizing Linebacker II. American planes carried out more than 700 missions during Linebacker II, dropping around 20,000 tons of bombs on targets in North Vietnam. Major cities like Hanoi and Haiphong were among the targets of the bombing strikes, along with important military outposts and transportation hubs.

Linebacker II was exceptional in its ferocity and scope, involving B-52 bombers operating nonstop missions while confronting intense anti-aircraft fire and surface-to-air missile threats. American aircrews performed their missions with incredible bravery and professionalism in spite of the hazards and difficulties. The widespread application of electronic warfare techniques and precision-guided weapons to improve the precision and efficacy of bombing attacks was one of Linebacker II's distinguishing characteristics. To reduce the threat to American planes and remove enemy defenses, laser-guided bombs and radar-jamming devices were used. Linebacker II had a significant and wide-ranging effect. The North Vietnamese military and industrial infrastructure suffered severe damage as a result of the bombing strikes, severely impairing their capacity to conduct the war.

By successfully demolishing important targets like the Paul Doumer Bridge and the Hanoi petroleum storage facility, enemy logistical and communication networks were hampered. The psychological effects of Linebacker II were so great that the North Vietnamese leadership was forced to reevaluate their resistance and go back to the bargaining table. North Vietnam consented to continue peace negotiations in Paris on December 29, 1972, which ultimately resulted in the signing of the Paris Peace Accords on January 27, 1973, and the end of American bombing operations.

An important turning point in the Vietnam War was marked by Operation Linebacker II, which showed the commitment and ability of US air power to accomplish strategic goals. It's still up for discussion and dispute, with some disputing the morality and efficacy of the bombing campaign. Still, in the end, Linebacker II was essential in ending American involvement in the Vietnam War and influencing Southeast Asian history.

3. THE EXTENSIVE USE OF THE HELICOPTER

The Vietnam War's widespread use of helicopters transformed combat operations, military tactics, and transportation, permanently changing the face of modern warfare. Throughout the fight, helicopters proved to be invaluable assets for both American and Vietnamese forces, serving in a variety of roles from troop transport and medical evacuation to close air support and reconnaissance.

Helicopters were used extensively in the Vietnam War for personnel insertion and extraction, a function best represented by the legendary Bell UH-1 Iroquois, also referred to as the "Huey." These adaptable helicopters allowed infantry groups to move quickly and covertly into and out of battle zones by offering them flexible and quick transportation.

The Battle of Ia Drang, also known as Operation Silver Bayonet, took place in November 1965 and was a pivotal moment in the conflict, emphasizing the vital role that helicopters play in air mobility. Huey helicopters proved their capacity to operate in dangerous areas under enemy fire throughout this combat by airlifting troops into landing zones and evacuating wounded personnel.

In medical evacuation, or "dustoff," missions, helicopters were also essential, saving many lives by quickly transferring injured soldiers from the front lines to field hospitals. In order to minimize casualties and deliver medical care in a timely manner, dustoff missions' efficiency and haste were essential. During large-scale offensives like Lam Son 719 in 1971, which was supported by American air power, helicopter personnel heroically evacuated wounded soldiers during fierce fighting.

Helicopters also played a crucial role in close air support operations, giving ground forces fighting on the ground direct fire assistance. Gunships such as the Bell AH-1 Cobra and the Boeing AH-64 Apache provided ground forces with airborne weaponry and reconnaissance capabilities, delivering deadly firepower against enemy positions. Combat missions like Lam Son 719 and the Battle of Hamburger Hill in 1969 demonstrated how well helicopter gunships could suppress enemy fortifications and help ground forces advance.

Specialized helicopter units also emerged during the Vietnam War; two such units were the 101st Airborne Division, which invented air assault operations, and the 1st Cavalry Division (Airmobile). These forces conducted reconnaissance missions, carried out search and destroy operations, and quickly deployed troops deep into enemy territory using helicopters. The 1966 joint American-South Vietnamese offensive Operation Hastings against North Vietnamese forces in Quảng Trị Province demonstrated the strategic adaptability and mobility that air assault techniques could provide.

The figures highlight how important helicopters were to the Vietnam War. During the battle, American and Vietnamese forces used about 11,000 helicopters of various models, performing over five million operations. These missions showcased the adaptability and efficiency of helicopter-based operations, including troop transport, medical evacuation, close air support, reconnaissance, and resupply operations. Helicopter operations in Vietnam were not without difficulties and dangers, despite their vital role. Helicopters had to operate in a dangerous environment that included rough terrain, dense forests, and determined enemy forces equipped with anti-aircraft weaponry.

Because of this, helicopter crews were always in danger from surface-to-air missiles and gunfire from the ground, which resulted in heavy losses and injuries during the conflict. The Vietnam War's widespread deployment of helicopters transformed military operations and significantly altered the course and result of the fight.

Helicopters became invaluable tools that gave ground forces vital help during battle, from air mobility and medical evacuation to close air support and reconnaissance. Their adaptability, velocity, and lethality revolutionized contemporary warfare and made a lasting impression on military strategy and tactics.

4. CONCLUSION. LESSONS LEARNED

The Vietnam War provides evidence of the increasing significance of helicopters and the development of airborne operations in contemporary conflict. Air power was important in determining how the war unfolded, from the precision strikes of Linebacker II to the strategic bombing missions of Operation Rolling Thunder. Activities like Steel Tiger, Barrel Roll, and Commando Hunt showed how adaptable and successful aircraft interdiction can be in sabotaging enemy supply routes and infrastructure.

The creative use of helicopters, however, was what really transformed military strategy and operations in Vietnam. Helicopters were essential tools on the battlefield, used for everything from close air support and reconnaissance to troop transport and medical evacuation. Combat support and air mobility are made possible by helicopters, as demonstrated by the actions of Ia Drang and Hamburger Hill, which allowed for quick troop entry and extraction under fire.

Expert units such as the 101st Airborne Division and the 1st Cavalry Division (Airmobile) invented air assault techniques by using helicopters to carry out lightning-fast raids deep into enemy territory. These missions, including Operation Hastings and Lam Son 719, illustrated the tactical adaptability and mobility that helicopter-based air attack missions provide. Helicopters were essential to medical evacuation, or "dustoff," operations during the war, helping to save many lives by quickly moving injured soldiers from the front lines to field hospitals. Their quickness and dexterity were crucial in reducing casualties and delivering medical attention on time.

Looking back, the Vietnam War was a pivotal time in the development of aerial combat, emphasizing the role that helicopters and air power play in contemporary military operations. The lessons from this combat are still relevant in modern warfare, highlighting the necessity of creativity, flexibility, and teamwork in the face of changing dangers and difficulties on the front lines.

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