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IMPORTANCE OF FLIGHT SIMULATION IN THE PRIMARY TRAINING OF COLOMBIAN AIR FORCE PILOTS, FOR THE PROPER MANAGEMENT OF DEFENSE RESOURCES

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Abstract:
Flight simulation has become an indispensable learning tool for developing aircrew capabilities and skills in the aviation environment. In just over half a century, it has earned a reputation for high levels of fidelity and the ability to provide an environment, in which effective flight crew training can be conducted at lower cost and safety, helping to prevent accidents and loss of life and improving the cockpit's decision-making process. This paper aims to verify the importance of simulated flight in the primary training of the Colombian Air Force (hereinafter FAC) pilots. Through the research of documentary review on its evolution, application, technical and operational requirements, and cost-effectiveness to determine the appropriate defense resources management. Consequently, the research is composed of the following sections: first, to analyze the current regulations for flight simulator training for primary pilot training in the FAC; second, to identify the advantages of flight simulator training for FAC crews used in air operations for the security and defense of the Nation; third, to verify the cost-benefit in the adequate administration of defense resources; and finally, to determine if the incorporation of simulated training missions improves the learning process for the training process; third, to verify the cost-benefit in the adequate administration of defense resources, and finally, to determine if the incorporation of simulated training missions improves the learning and decision-making process, which results in the improvement of instruction processes and reduces operating costs for the Institution

Key words: Military education; teaching; learning; simulation; flight simulator; military decision making.

1. Introduction

The complexity, high cost and operational environment of aircraft and modern weapon systems have contributed to the increasing use of advanced flight simulation, which allows for training high-risk maneuvers, providing pro efficiency[2] for different users to face expertise and suitability, serious situations may arise in the aircraft due to military operations and improve the decision-making process in these conditions. These simulators can provide more intense training than existing systems and equipment, framed in a safe and convenient learning environment.

Therefore, the trend in world aviation has been to include automated systems in its air platforms, and Colombia has not been the exception. The objective of these advanced systems has been to reduce the possibility of committing a human error in the development of typical operations

[2] It is to achieve the maximum level of skill in the handling of equipment or aircraft accompanied by the knowledge acquired.

of the FAC doctrine and reduce the operation costs and thus make a correct administration of the defense resources.

Similarly, the capacity achieved in recent years by the Colombian Air Force in terms of interoperability and deterrence against potential regional antagonists requires compliance with high training standards, which in the future may be affected by non-compliance.

Therefore, the following question arises: ¿How to improve the training of Colombian Air Force pilots through the use of flight simulation in order to perform an excellent "cost-effectiveness" management of defense resources and improve the decision-making process? Thus, the general objective of this research is to analyze the importance of flight simulation in the training of FAC pilots and its cost-effectiveness relation. Consequently, an analysis of the importance of flight simulator training for the pilots of the Institution is established, allowing operational efficiency and flight safety in the development of air operations has a remarkable capacity to fulfill the natural objectives in the Constitution: minimizing loss of lives and resources by managing the risks inherent to the military operation and improving the decision-making process by the pilots

2. Regulations in the Force for flight simulator training of aircrews in the Colombian Air Force

The FAC Flight Instruction and Training Manual 7.2-R (MINEV-2020[3]) establishes the general rules and guidelines to be followed in the flight training process with the support of simulators. However, this document is not fully clear as to the type of training a pilot needs to know, in such a way, that the lack of clarity in the requirements causes deficiencies in the training procedures. The main goal is to achieve optimal pro-efficiency conditions in the crews, affecting the operational capacity of the FAC in compliance with the functions oriented to the security and defense of the Nation.

The above situation in flight training with simulators generates the need to define each area to be investigated to follow a proper process in implementing the flight simulator as a fundamental part of the training of FAC aircrews. One of the advantages of using a real-time simulator is that it is possible to train pilots (and future pilots) at a lower cost, improving the management of defense resources. Additionally, allowing to experience situations during the flight that could not occur in a lived environment would involve a risk to human life and improve the decision-making process. In this way, the pilot acquires the necessary skills and knowledge to know what actions to take in an extreme situation during the development of a mission in real circumstances. This means of training is an indirect way of acquiring experience and skills that can be directly transferred to a given flight reality (Limanche, Rojas, & Murillo, 2010).

In that order of ideas, the importance of the use of a flight simulator in the training of FAC pilots lies in the interaction of software and hardware tools that allow the creation of a faithful, precise and similar replica of the behavior of an aircraft in real flight in the most accurate way. This, can be done mainly by using a high-performance computer (Limanche, Rojas, & Murillo, 2010).

Thus, different simulators have been developed, focusing on specific topics such as: dynamic flight simulation, aircraft model, human motion perception simulator and the interaction between the visual and vestibular systems (Cistac, Zanni, & Abbate, 2008). As a result, the FAC adopted the spatial disorientation simulator, to determine whether a pilot faces a disorientation condition or realizes how to identify it and react to this event decision-making process in the cockpit.

Therefore, simulation is a technique to understand or imitate how a system works through mathematical models, which reproduce or describe the behaviour of a real-world environment

[3] The Flight Instruction and Training Manual (MINEV) is the document that regulates the operation of flight instruction in the Colombian Air Force (rules, requirements, procedures, powers, prohibitions, etc.).

projected through three-dimensional images, where physical elements can intervene and serve as stimuli for the senses where a person can see, hear and even feel the environment in motion, allowing a proactive interaction in real-time between the pilot and the virtual world (Otálora, 2013).

Furthermore, the diversity of flight simulators exists according to the FAA's current regulations within the Code of Federal Regulations (hereinafter: CFR) and in the ICAO Operations Inspector's Manual SRVSOP, First Edition (2013). The following qualification levels are currently determined for Flight Simulators Training Device (hereinafter: FSTD) for airplanes and helicopters, as follows:

Aviation Training Device -ATD-.

- FAA Basic ATD -BATD
- FAA Advanced ATD -AATD-.

Flight Training Devices -FTD-.

- FAA FTD Nivel 4
- FAA FTD Nivel 5
- FAA FTD Nivel 6
- FAA FTD Nivel 7

Full Flight Simulators -FFS-.

- FAA FFS Nivel A
- FAA FFS Nivel B
- FAA FFS Nivel C
- FAA FFS Nivel D

Hence, the National Transportation Safety Board (hereafter: NTSB), in its International Safety Alert reports, recommends that through simulator training, operators can provide pilots with a valuable tool to ensure proficiency in emergency procedures, including autorotations, use of night vision goggles, recognition of degraded visual conditions, and recovery from unusual attitudes. Consistent and standardized training helps prepare pilots for the unexpected and decreases the risk of an accident (NTSB, 2014).

In this way, we can evidence many elements for use in the training of primary pilots, which have been used in the Air Force but only in the transitions to obtain first autonomy as pilots and co-pilots of the different teams of the Institution. Since 2001 the FAC has slightly implemented simulators in the introductory flight courses only for flight training in instrumental meteorological conditions. However, these missions were not defined in the instruction and training plans. It was only a resource that the student had at his disposal, but not because the Institution contemplated it in these documents, and it was a guiding basis for his training process.

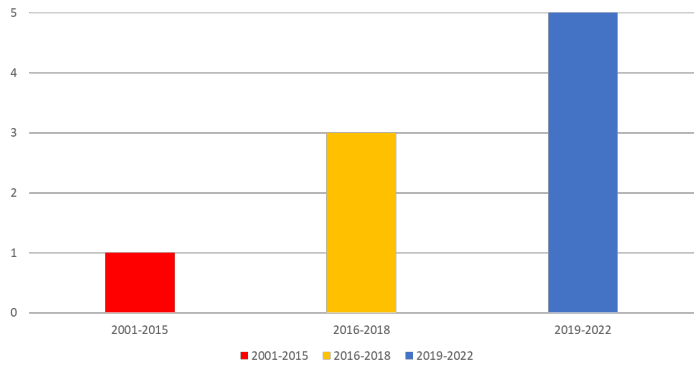

Fig.1 Flight simulator Use 2001-2022

According to Figure 1, since 2019, the organizational scheme of the Simulator Squadron was improved and the Operational Excellence Center[4] was organized for the training of Primary pilots and the instruction and training plans were reformulated for the use and implementation of flight simulators in the Primary flight instruction process.

Moreover, the international pilots training standards preserve air safety, improve the decision-making process, and avoid potential risks that the FAC may generate. Later, due to the lack of training of its crews when using the airspace and adequately managing the defense resources assigned to the Institution.

3. Identification of the advantages of flight simulator training from the correct administration of defense resources.

Firstly, to identify the advantages of simulated training in the development and application of military and civilian operations that contribute to the correct administration of defense resources, it is necessary to outline the time, space and technological environment in which this training is conducted. Therefore, technological advances developed worldwide to optimize the simulation of different scenarios, threats and challenges currently faced by pilots, analyze situations, and make decisions in the environment where it is deepened and thus determine the degree of reduction of operating costs.

For instance, previous to the invention of the flight link trainer in 1992, a pilot learned how to fly by instruction from another pilot. From 1903 to 1917, the pilot's skills were transmitted from instructor to student, where the mission was to shape the student's thinking and behavioral development. However, learning and acquiring both skills and abilities were too costly, time-consuming, and risky. Unfortunately, it was the only one in history which would later be professionalized with experience and operating time (Link, 2000).

From 1939 to the present, positive training transfer has been demonstrated for almost all aircraft simulators, maneuvers, and pilot skill levels. They are effective for training in precise procedural tasks (e.g., instrument flight maneuvers, approach and landing) (Orlansky y String, 1977).

However, in the 1970s and 1980s, the development of interactive 3D computer imaging technology allowed the simulation of the landscape features that a pilot sees and the possibility of interacting with them, which also determined the type of exploration typical of military simulators: first-person flight through a simulated space environment (Marquez, 2010).

Significantly, there are advantages offered by the use of a flight simulator. For example, the possibility of generating and applying unconventional scenarios as routine procedures with which pilots are highly familiar in their daily operations, generating an additional risk such as failure of the aircraft, its systems or components, adverse weather conditions or facing a threat represented by an enemy fighter aircraft or a surface-to-air missile, among others

Meanwhile, the Flight Instruction and Training Group (hereinafter GRUEV), through the use of the flight simulator since 2019, has improved and implemented the instruction and flight training programs in the primary flight courses. Thanks to incorporating five missions previous, starting the flight phase allows the student to know the operational environment and know how to face and correct simple and complex situations during the development of training in the simulator. Likewise, the instrument flight program was improved, which was developed in the C172 aircraft in

[4] The CEO "Operational Excellence Center" or Simulator Squadron is the place where simulated flight training takes place.

real flights but did not cover all the conditions that a pilot may be exposed to in real life, Therefore, 20 real flight missions in the Cessna 172 (hereinafter C172) were changed to flight in the simulator, which contemplate all the environments to which a pilot can be exposed in a real flight. Consequently, maintaining supremely high safety levels since this implementation has reduced real risk, recreating conditions of great danger in its initial phase of control and behaviour and also other conditions such as the failure of the aircraft in flight, either of its main mechanical components like the engine, flight controls and associated systems, among others. Performing the training process immersed in such conditions on board a real aircraft would imply exposing both the crew and the aircraft used to too high a risk.

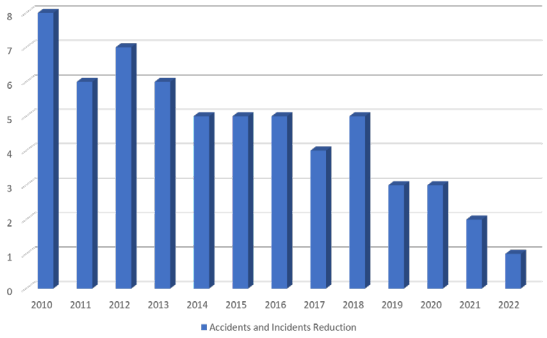

Fig.2 Incidents reduction 2010-2022

Figure 2 shows the number of incidents in primary instruction and training missions, which a significant reduction is observed as of 2019, when the modification of the instruction and training plans (hereinafter PIEs), the incorporation of initial missions in the flight simulator and the improvement of the instrument flight period. Improving instruction techniques and avoiding risks in the flight operation are consolidated this year.

In this way, the flight simulator training received by the primary pilots of the GRUEV demonstrates in a congruent manner his objectives and the FAC can be met. Each pilot's proficiency, skills, and abilities within the high standards to give immediate and safe responses to all security requirements and continue to be a regional reference in air operations with interoperability capacity. For this reason, scenarios known as the map of Colombia are emulated, where crews can train with the reliefs and the predominant heights existing in the national territory, demonstrating their efficiency and effectiveness in the control of the airspace of Colombia.

In addition, the above conditions provide a greater pro efficiency to the different crew members to face expertise and suitability situations that may arise in the aircraft due to the operation. In order to "feel" the same sensations as when flying a real airplane, flight cabins are used that are identical down to the minor details. This platform is in charge of transmitting to the pilot the accelerations that, together with an adequate visual system, produce the "magic" of making us believe that we are really flying (Rebato & Represa, 2015).

Among the determining aspects to be taken into account in the use of flight simulators for crew training is the "economic" factor, since the operating costs of a real aircraft in all areas of development are higher, taking into account training, technical support, workforce and fuel, among others. These aspects are much higher than the costs generated and required by a flight simulator for its operation. Simulator training aims to save time and money and get the best training for pilots to save lives in critical moments. "As we usually say in aviation to those who fail to understand: If safety seems expensive to you [...] try having an accident" (Rebato & Represa, 2015). A way of increasing pilot productivity drom an economic point of view is to increase the revenues/pilot, by maintaining the same revenues and reducing the inputs (number of pilots, with negative consequences of increasing the workload for the remaining staff) or maintaining the same level of inputs, but increasing the revenues. (Constantinescu, 2011)

It is well known that the cost of maintaining the Military Forces is currently high and that it is becoming more expensive day by day. Needs are increasing, and so are shortages. This is due to the complexity, high technology, and sophistication of current weaponry and the need for more qualified, knowledgeable, and professional personnel (Martinez, 1992).

When pilots train, they acquire the ability to improve their performance due to simulations; they learn to react to any event through experience development (Jones, 1993). This activity is known in the aeronautical world as Crew Resource Management (hereinafter: CRM), which is defined by the International Civil Aviation Organization (hereinafter: ICAO) as the effective use of all available resources (equipment, procedures and personnel) in order to optimize the safety and efficiency of flights (Martin, 2008).

Virtual simulations are potentially a powerful scientific tool, a novel form of entertainment, an extraordinary vehicle for education and communication, and a stimulating means of artistic expression (Levis, 1997).

Analyzing the above, one of the main arguments in favor of the use of simulators in flight training is the result of studies related to the transfer of knowledge and skills from the simulator to the aircraft. For instance, the study developed by Gavan Lintern, Stanley Roscoe, Jefferson Koonce and Leon Segal, called "Transfer on Landing Skills in Beginning Flight Training," published in 1990, analyzes the degree of transfer of landing skills from the flight simulator to the aircraft, at the beginning of a pilot's flight training in his primary flight phase. He describes two groups of trainee pilots; the first group had two training sessions in the simulator where they practiced the skills required during landing, before performing the practical maneuvers in an aircraft in flight. The second group did not receive this type of training prior to the practical maneuvers in a flying aircraft. The results showed that the first group of trainees needed about one and a half hours of flight training less before the first solo flight, compared to the second group that did not perform the sessions in the simulator (Kozuba and Bondaruk, 2014). Although flight training comprises several elements, the study was framed in only one for this particular case due to its importance and complexity, such as learning how to land an aircraft.

Subsequently, the instructor's behaviour can be focused only on supervising the trainee's aptitude during a specific scenario and evaluating how long it takes to correct a given error. In this case, it is an advantage to show the student or trainee what consequences his human error can cause to both the crew and the aircraft. Now in a real flight, allowing this same situation can trigger very high potential risks or be in positions that are physically outside the training standards

In order to expand on this aspect, the following is an explanation of some of the advantages that make selecting this type of training as the best option at present stand out:

High training effectiveness.

Tests related to measuring the effectiveness of flight simulation training showed that students develop knowledge and skills at a level similar to that achieved in a real flight. Due to the lack of need to physically control the aircraft, the instructor can fully concentrate on the student and the activities performed by the student. Similarly, they have the technology to record and obtain data from the simulated aerial maneuvers performed (Kozuba and Bondaruk, 2014).

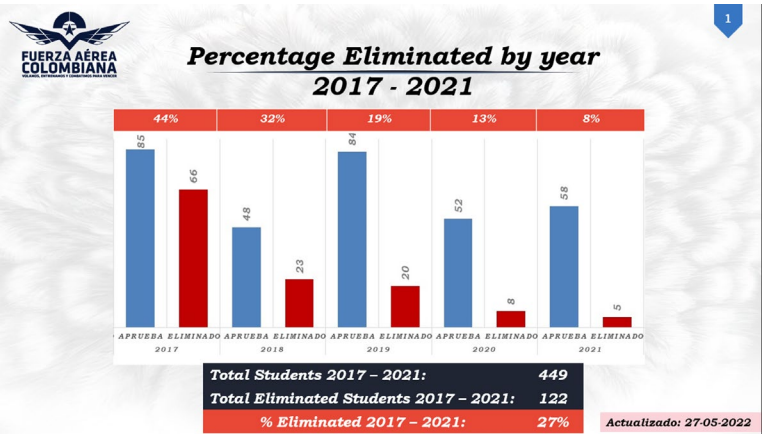

Fig.3 Percentage Eliminated students by Year

Minimizes risks.

Avoids accidents or incidents during the most critical training stages, minimizes and provides predictability in reducing aircraft adaptation times during the beginning of ground courses, checklist procedures, and initial knowledge, and generates confidence when interacting between man and machine.

Comprehensive training.

It allows associating through the intervention of other areas linked to the integral training of the pilot (other instructors, psychologists, pedagogues, evaluators, others), making possible a personalized and multidisciplinary follow-up adjusted to each student to guarantee the best possible performance.

High safety standards in training.

Due to the need to maintain a certain level of safety in the development of instruction, simulators allow not only to learn maneuvers related to air operations and aircraft performance in adverse weather conditions (strong wind, turbulence, icing, etc.), but also to perform maneuvers in critical failure events of any aircraft component, including, among other things, failures related to the engine, instrument control systems (Kozuba and Bondaruk, 2014). In this way, primary pilot training is operated safely and without risks associated with the actual operation of the aircraft in these conditions.

Improved Decision-Making Process.

The implementation of simulator missions and the improvement of the decision-making process in the cockpit are highlighted, developing through models and checklist structures. This process proposes two processes for pilots called 5P and 3P for problem solving and decision making (FAA, 2015). The 5P model means: "Plan", "Aircraft", "Pilot", "Passenger" and "Programming", where the pilot is expected to analyze each situation based on his experience and training, making his own decisions (FAA, 2008). Likewise, there is the 3P model, used in all phases of operation; with its words "Perceive" what is happening, "Process" and evaluate its impact on the flight, and "Perform" and implement the best course of action (Doskow, 2012). Consequently, thanks to this implementation and the models mentioned above, the decision-making process in the cockpit by Primary Pilots is reflected in the development of satisfactory missions. It prepares this future pilot to improve this process profoundly over time and improve the safety environment in the institution.

Cost reduction.

"The optimization of the military capability production process is considered analogue with the production of goods and services, the basis of the market economy. Each military capability can

be considered as a mix of resources which will be used to perform a certain mission. This mix of resources must consider first of all the purpose of its existence and generate the maximum benefit. At the same time, because of the resource scarcity, the use of this mix must be considered in the economic context". (Constantinescu, 2012) Training costs are significantly reduced since the flight simulator has more straightforward maintenance cycles and low costs. They are significantly reducing downtime and the advantage that the mechanical systems of the simulator are easily accessible, facilitating quick and precise technical interventions in a short time without the use of sophisticated tools, thus reducing maintenance times to a minimum (Martin, 2016)

TYPE	OPERATIVE CHARACTERISTIC	TECNICAL CHARACTERISTIC	ACQUISITION	OPERATION COST	INSTRUMENTS FLIGHT (*20)	OVERALL EFFECTIVENESS
C172	0,270	0,160	$ 500.000,0	$ 80,0	$ 1.600,0	0,430
SIMULADOR	0,480	0,300	$ 197.000,0	$ 59,0	$ 1.180,0	0,780

Fig.4 Matrix 1

TYPE	ACTUAL NUMBER OF MISSIONS	TOTAL COST	60 STUDENTS PER YEAR	PROPOSED NUMBER OF MISSIONS	TOTAL COST	60 STUDENTS PER YEAR	PERCENTAGE REDUCTION COST
C172	100	$ 8.000,00	$ 480.000,00	80	$ 6.400,00	$ 384.000,00	
SIMULATOR	20	$ 1.180,00	$ 70.800,00	40	$ 2.360,00	$ 141.600,00	
TOTAL	120	$ 9.180,00	$ 550.800,00	120	$ 8.760,00	$ 525.600,00	
					REDUCTION COST	**$ 25.200,00**	**4,5%**

Fig.5 Matrix 2

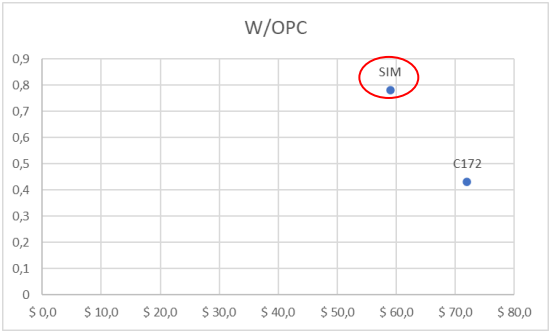

Fig.6 W/OPC

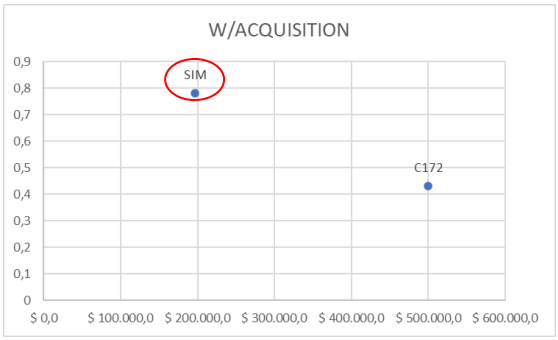

Fig.7 W/ACQ

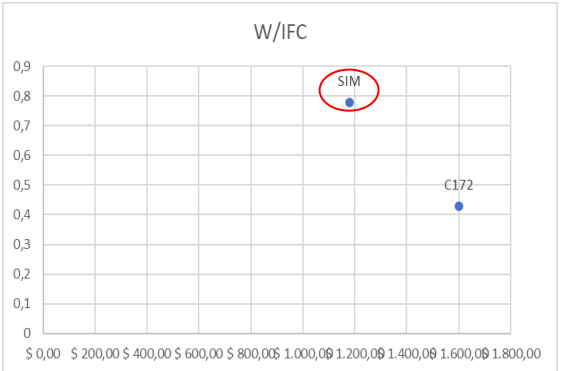

Fig.8 W/IFC

According to figure 4, we observe the analysis of the cost-effectiveness of the operation of the simulator compared to the C172, for which the simulator as shown in figures 6, 7 and 8 (cost of operation-effectiveness, acquisition-effectiveness, instrument flight-effectiveness, respectively), respectively), demonstrating that in all the comparisons the flight in simulator offers better effectiveness without demerit or disqualify the real flight in the C172 since it is of vital importance this flight in real form, which will be the evaluation of the process of the flight in simulator carried out in real form.

Figure 5 (Matrix 2) shows the percentage reduction in operating costs based on the proposal already implemented by GRUEV since 2019, showing a savings of 4.5% in the administration of defense resources, with no reduction in the number of instructional missions for the same number of students who are part of the flight program.

5. Conclusion

According to the research, it was determined as a first indicator that the FAC Flight Instruction and Training Manual 7.2 (MINEV) is not fully clear as to the type of flight simulator training that a pilot requires during his primary training phase. Likewise, the lack of minimum standards in this type of training could cause deficiencies in the training process and affect the operational capacity of the FAC, in compliance with its functions.

As a second indicator based on the above and after identified the problem, GRUEV for the year 2019 implemented in the PIEs initial adaptation missions in the flight simulators before their first contact with the aircraft and likewise improving the instrument flight program, as well as continued support flights for students who had low performance in the development of the program, causing an increase in the pro efficiency in the instruction reducing in a large percentage the number of pilots who did not successfully complete the flight program

Overall has demonstrated that the implementation of simulator flight for the training of primary pilots is satisfactory and decisive for the development of skills, abilities and attitude of the FAC pilots. Likewise, it has been shown that facing the different risks and threats inherent to the aeronautical profession within the highest safety standards and norms, provides relevant advantages concerning the experience on board an aircraft, such as the practice of high-risk scenarios. Additionally, the possibility of including an interdisciplinary team in the training process by not being limited to the physical space of the aircraft cabin and not being dependent on weather conditions due to being indoors.

In summarizing, a flight simulation is a teaching tool that uses technology and represents a laudable means from an educational perspective, effectively allowing the possibility of building, maintaining and optimizing cognitive skills quickly and safely in environments supervised by instructors without exposing both the student and the aircraft to unnecessary risks.

As a third measure, flight simulators are considered an essential tool for selecting and training flight crews. As well as to evaluate the knowledge and skills of pilots to operate the aircraft and accomplish the mission, which ultimately results in the Cost- Effectiveness since incorporating this system, the GRUEV reduced operating costs by 4.5%, directly impacting the resources allocated to the institution and allowing a better management of defense resources.

These devices play a crucial role in forming the necessary competencies to achieve the desired level of knowledge by the pilot at various stages during the execution of the mission. Therefore, the use of these devices for the training of aircrew members in the FAC is vital for maintaining operability, air safety and national defense and security.

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