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Advances of Artificial Intelligence in Aeronautics

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Abstract. - The use of artificial intelligence (AI) in recent years has allowed the development of a large number of applications in practically all areas of human knowledge. However, the application is relatively new in aeronautics, and products are already optimizing the skills and capabilities of the personnel who command it. This paper reviews the scientific literature on the advantages, disadvantages, and aspects to consider regarding the application of AI techniques in aeronautical processes ranging from construction, navigation, and security against attacks on communications and climate changes that may affect the navigation system. AI developments provide new advantages and challenges for navigation every day. On the one hand, these techniques support flight independence until achieving absolute autonomy. Still, on the other hand, they also incorporate specific vulnerabilities and concerns about the increased use of computer and digital communication media that are prone to attacks by malicious individuals or organizations**.**

Keywords: Aeronautics, Artificial intelligence, machine learning, autonomous navigation.

Avances de la inteligencia artificial en la aeronáutica

Resumen: El uso de la inteligencia artificial (IA) en los últimos años ha permitido el desarrollo de una gran cantidad de aplicaciones en prácticamente todos los ámbitos del conocimiento humano. En la aeronáutica la aplicación es relativamente nueva y ya existen desarrollos que optimizan las destrezas y capacidades del personal que lo comanda. En este trabajo se presenta una revisión en literatura científica de las ventajas, desventajas y aspectos a considerar en torno a la aplicación de técnicas de IA en procesos de la aeronáutica que van desde la construcción, navegación y seguridad ante ataques en comunicaciones y cambios climáticos que pueden afectar al sistema de navegación. Los desarrollos en IA cada día aportan nuevas ventajas y desafíos para la navegación, por una parte, estas técnicas apoyan la independencia del vuelo hasta lograr la autonomía absoluta, así como también, incorporan ciertas vulnerabilidades y preocupaciones en torno a un mayor uso de medios informáticos y comunicaciones digitales que son propensas a ataques por parte de personas u organizaciones malintencionadas.

Palabras clave: Aeronáutica, inteligencia artificial, aprendizaje automático, navegación autónoma.

I. INTRODUCTION

Artificial intelligence has been incorporated into various human activities, also used in the aeronautical and aerospace industry, mainly to improve the efficiency and safety of flight operations. Its use in automation through flight management systems and autopilot has yielded excellent results. Despite the implementations of automatization, the effectiveness and safety of a flight also depend on human decision-making, aspects that remain crucial to ensure flight safety and whose appearance has yet to be replaced.

The aerospace industry has employed artificial intelligence despite uncertainties about the confidence that AI will provide when faced with critical situations, which are currently the responsibility of aviation experts. Guidelines, recommendations, and guidance have been proposed in the Research Manual on Applications of Artificial Intelligence in Aviation and Aerospace; In this work, the applications of AI in aviation and aerospace are addressed. The adoption of AI in this sector is a growing trend and focuses mainly on reducing human error and improving its efficiency[1].

According to Figure 1, artificial intelligence in aviation has been employed in air combat, the aeronautical industry, cognitive systems, aircraft maintenance repair, data analysis, defect detection, and deep learning in defect detection[2].

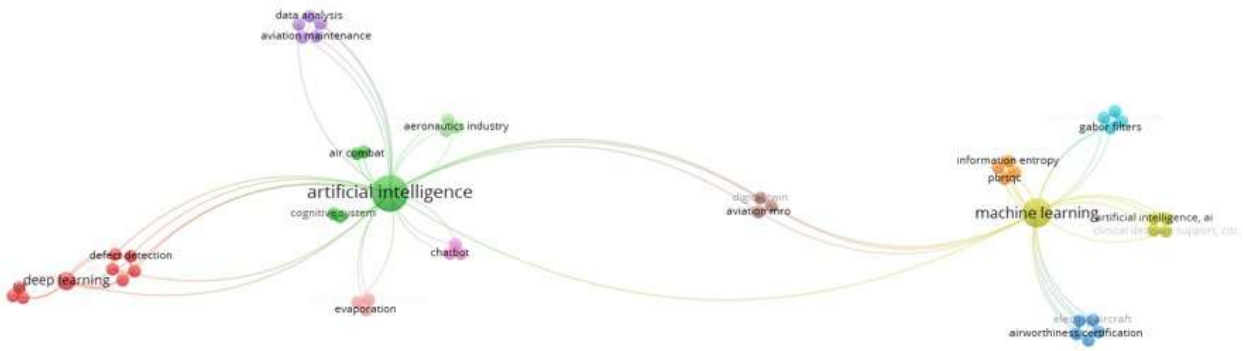

Fig. 1. A bibliometric review of the terms "Aeronautical Artificial Intelligence" in the SCOPUS Base (36 articles) graphed with VOSviewer®.

AI technology also supports the detection and resolution of onboard problems during flight, reducing the risk of falls and accidents by influencing the predictive stability behavior of aircraft. In addition, implementing advanced monitoring and tracking systems, such as predictive maintenance, allows airlines to identify and fix logistical issues before they cause flight disruptions. As a result, technology has been essential to ensure a better experience for the crew and in the operation of the aircraft.

Information collected on an aircraft is stored and used in air accident cases to generate reports and obtain evidence. The analysis of data and knowledge of the flights are already carried out efficiently with artificial intelligence applications, which are capable of performing very complex studies that involve all the electronic data of the entire aircraft allowing to provide a better result in the determination of evidence in accidents or causes of accidents[3].

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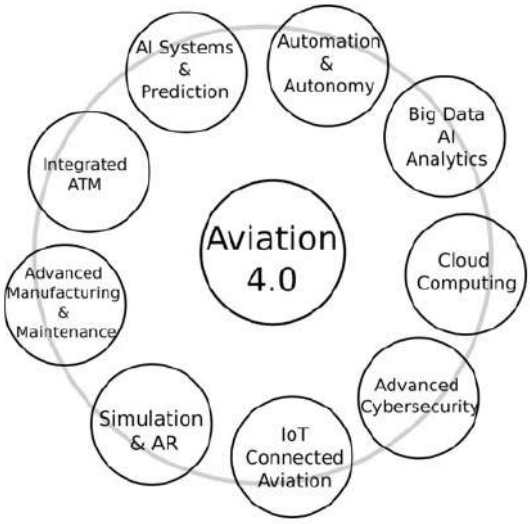

Fig. 2. Technological aspects addressed by Industry 4.0 in aviation.

This document describes applications that use AI and corresponds to the field of the aeronautical industry in the development section. Then, in the Methodology section, it is detailed how the reference information was obtained. Then, in the Results section, an analysis of the findings and trends in the use of AI in the field of aeronautics is presented; finally, the conclusions are offered.

II. DEVELOPMENT

This section describes some current applications implemented in the aviation industry according to an overview of the advances and applications that use AI to solve problems in aviation and its previous manufacturing processes. The information provided in this section allows researchers and professionals to know the state and influence of AI in aircraft navigation, control, manufacturing processes, management, and maintenance systems.

From the review of scientific literature, it was evident that the most relevant topics in which AI is used are machine learning and neural networks. The use of AI allows for improving the efficiency of the tasks. In addition, the functions and applications are also evolving, such as new projects under development, such as the implementation of autonomous air taxis and air transport of large and small objects.

Artificial intelligence has had a significant impact on the aviation industry. It has made it possible to improve flight safety by detecting potential problems and providing proactive solutions for securing them, as well as increasing operational efficiency by optimizing routes and reducing fuel consumption in the face of factors such as unfavorable weather conditions or others[7].

Flight safety has been improved with AI, enabling more accurate and faster real-time inspections of aircraft and equipment and detecting anomalous patterns in maintenance data. AI allows for optimizing air traffic management, flight planning, and fleet management, ensuring more efficient and safe air travel [6]. The aviation industry faces challenges of unscheduled maintenance, repair, and overhaul (MRO) costs. It is turning to advanced technologies such as artificial intelligence to improve efficiency and reduce costs by providing predictive analytics to identify problems before they occur, reducing unscheduled repairs and thus revolutionizing multiple aviation industry processes[6].

Tabla 1. Influence of AI on multiple aspects of the field and development of aeronautics.

Topic	Description
Efficiency optimization	AI is used to optimize efficiency in air traffic, route planning, and fuel management. AI algorithms can process large amounts of data and help air traffic controllers make more informed decisions. In addition, AI can help reduce airport waiting time and improve flight punctuality.
Improved security	AI is used in predictive aircraft maintenance, which means sensors on the plane can detect potential problems before they occur and alert the maintenance team so they can take preventative action. It also improves object detection on the track, reducing the risk of collisions and other accidents.
Development of autonomous aircraft	AI is being used to develop autonomous aircraft flying without a human pilot. These aircraft can be used for military, search and rescue missions, and commercial flights. In addition, autonomous aircraft can be safer and more efficient than crewed aircraft.
Advanced analytics capabilities	AI enables aeronautics data analysts to process large amounts of data and extract valuable insights. For example, machine learning algorithms can detect patterns in data that humans may miss and can help engineers design better aircraft and navigation systems.
Pilot training	AI is being used to develop advanced flight simulators that can help train pilots in different flight situations, from takeoff and landing to extreme weather conditions. Flight simulators can be a valuable tool for improving pilot safety and training.
Maintenance and repair management	AI is also used to optimize aircraft maintenance and repair management, as machine learning algorithms can analyze large amounts of maintenance and repair data to identify patterns and trends. This can help maintenance teams make more informed decisions and repair more efficiently.
Quality control and testing	AI is being used to improve quality control and aircraft testing. For example, machine learning algorithms can analyze large amounts of flight and component test data to detect problems and predict potential failures. This can help aircraft manufacturers improve the quality of their products and reduce warranty costs.
Aircraft design and simulation	AI is used in aircraft design and simulation to improve efficiency and reduce costs. Machine learning algorithms can analyze simulation data to identify the most efficient and secure designs. In addition, AI can help engineers design components.

The table above highlights eight aspects artificial intelligence has dramatically impacted aeronautics. Most of these aspects focus on improving efficiency, safety, and quality in the aviation industry. One of the highlights is optimizing efficiency in air traffic management, route planning, and fuel management. Artificial intelligence has enabled air traffic controllers to make more informed decisions and has helped reduce airport waiting time and improve flight punctuality. Security has also been an important area where artificial intelligence has significantly impacted aeronautics. AI-based predictive aircraft maintenance technology can detect potential problems before they occur, reducing the risk of accidents. In addition, the detection of objects on the track has been improved with AI, reducing the risk of collisions and other accidents. The development of autonomous aircraft has also been possible thanks to artificial intelligence, which has led to greater efficiency and safety in the aviation industry. In addition, AI has been used in advanced data analysis, pilot training, maintenance and repair management, quality control and testing, and aircraft design and simulation.

AI is used in various applications, from optimizing flight planning to improving safety and efficiency in air traffic management. AI assists managers (airline/airport managers, air traffic management) in a wide range of air traffic and aviation system applications (pilots, air traffic controllers, airport operators, flow controllers), also faces new tasks, energy transition, integration of new air traffic components and system difficulties in the face of traffic disturbances [8]. For example, optimizing flight planning using AI enables airlines to improve aircraft utilization and minimize delays. In addition, AI can also aid in air traffic management, where it is used to improve the safety and efficiency of flight management by analyzing data in real time and providing helpful information for air traffic controllers[9] [1].

AI is also being used to improve security at airports, for example, to identify suspicious objects by analyzing images obtained from surveillance video cameras and scanning systems. In addition to military pilots, the safety of the airspace system also depends on technology and equipment used in the aerospace industry, including radars, communications systems, and navigation and good coordination among employees of the air traffic control system. Furthermore, the implementation of advanced technologies such as satellite air traffic control (SATCA) and flight information systems (FIS) help improve the efficiency of the air traffic control system by providing excellent safety for passengers and flight teams[10].

Education and training of ATCS employees are essential to ensure the safety of the airspace system. Continuous training in the latest techniques and technologies is critical to keep employees up-to-date and able to respond to emerging situations. Artificial intelligence has great potential to improve air traffic management. AI can help improve efficiency in air traffic, increase infrastructure capacity, reduce delays, and improve safety. Some AI applications in Air Traffic Management (ATM) include route optimization, congestion forecasting, and runway capacity improvement[11].

Air traffic management will become increasingly complex due to the growth and increased complexity of aviation and must be improved to maintain aviation safety. However, with significant improvement in this area, the safety objectives defined by international organizations can be achieved, and the risk of new incidents or accidents can be anticipated [12].

It is also important to note that introducing AI in ATMs raises some challenges and concerns, especially concerning data privacy and security, liability in case of errors, and the need for proper regulation. It is, therefore, essential to address these challenges to ensure an effective and safe implementation of AI in air traffic management. Furthermore, since AI can analyze large amounts of data and improve flight planning, fleet management, and cost optimization, it can also help airlines deliver better customer service by personalizing offers and resolving issues more efficiently.

NASA aviation research is exploring the possibility of using XAI technology to improve safety and efficiency in air transport of the future. Explainable AI (XAI) allows humans to understand how decisions are being made in autonomous systems, increasing trust in them and reducing the risk of unwanted errors. In addition, explainable AI can also be useful for the certification of autonomous systems and to ensure that appropriate regulatory standards are met. NASA aims to create a future in which autonomous vehicles can operate safely and efficiently in airspace, reduce congestion, and improve flight safety. XAI technology plays a crucial role in this goal by enabling humans to understand how decisions are being made in autonomous systems and providing greater transparency and trust in them [13, 14].

As the century has progressed, systems with AI have been more accepted and implemented for their versatility and relatively low implementation costs. The most representative benefit is the time gained with AI allowing tasks that previously required hours of manual work to be solved with algorithms quickly. The aerospace industry will also adopt the trend described above, so the lines of research in AI for autonomous applications may stand out with a more significant impact in academia[15].

In aeronautics, there are innovative technical and organizational systems called intelligent aviation systems, which provide more safety during the flight of an aircraft. The reason behind its development is the need to collect statistics on the leading causes of air accidents, such as the human factor, equipment failure, and external factors. A scientific problem related to assessing and predicting the threat of an accident is addressed. To solve this, it is suggested to use artificial intelligence to identify and prevent the immediate causes of an accident. These systems' technical characteristics, properties, and operating principles are described in detail, including intelligence, information, speed, controllability, the interdependence of subsystems, threat identification, accident prediction, and stopping [6].

With the introduction of new aviation technologies and new concepts of airspace organization, it seeks to provide communication between the airport and the aircraft. GSM technology checks weather conditions, runway parameters, and air traffic to reduce human errors and manual efforts. Then, before landing, the aircraft's arrival time is announced automatically [12]. The prospects of military aviators It is claimed that advanced technology in autonomy and artificial intelligence will likely result in the creation of pilotless aircraft and that this technological change could make military pilots a thing of the past.

Another important application of AI in aviation is data analytics. For example, AI can analyze large amounts of flight and aircraft maintenance data to identify trends and patterns, which can help predict failures and improve maintenance efficiency [12]. In the future, AI is expected to play an increasingly important role in aviation, helping to make air travel safer, more efficient, and more sustainable. With AI, it is possible to imagine a future in which airports run more smoothly and efficiently, flights are safer and more comfortable, and the aviation sector has a much smaller environmental impact.

Tabla 2. Examples of AI in applications and projects in different countries around the world.

Country	Areas of AI application	Examples of applications/project names
United States	Air traffic management, the workload of pilots and air traffic controllers	NASA Airspace Technology Demonstration 3, Federal Aviation Administration's Route Automation Modernization, Boeing Airpower Teaming System
China	Navigation and maintenance of commercial aircraft, autonomous drones	China's Commercial Aircraft Corporation C919, Autonomous Aerial Refueling
United Kingdom	Predictive aircraft maintenance, pilot training simulation, air traffic management	Rolls-Royce IntelligentEngine, NATS-iTEC Programme, Mixed Reality Training for Aircrew
Singapore	Management of aircraft maintenance and repair operations, design and production of more efficient and safer aircraft	Singapore Airlines Maintenance, Repair and Overhaul (MRO) Hub, Development of High-Performance Electric Propulsion System for Small Aircraft, Development of Supersonic UAV
France	Flight data analysis, air traffic planning optimization	SESAR Joint Undertaking, Thales Flight Management System, Data-driven Control and Surveillance of Air Traffic
Russia	Threat detection and security at airports, optimization of flight route planning	Sputnik, GLONASS, Integrated Security System for Airports
Australia	Aircraft maintenance, identification of faults and component problems	Qantas Group's Integrated Operations Centre, GE Aviation's Digital Collaboration Centre
Germany	Optimization of air traffic controllers' workload, air traffic planning	German Aerospace Centre's Digital Tower Solution, Electronic Flight Strips
Japan	Flight information management, flight route planning	Air Traffic Control by Augmented Reality, Route Control with the Support of AI and Big Data
United Arab Emirates	Airport security, threat detection, aircraft maintenance, component problem identification	Abu Dhabi Airports' Autonomous Wheelchair, Predictive Maintenance for Aircraft Systems, Enhanced Safety and Security Features in Dubai Airports

Table 2 provides valuable information on implementing artificial intelligence in aviation in different countries worldwide. Leading countries in the aviation industry, such as the United States, China, and France, are leading the way in implementing artificial intelligence in aviation. Most AI projects in aviation focus on improving safety and efficiency, including optimizing air traffic management, detecting anomalies, and monitoring aircraft health. AI-powered projects are being carried out by market-leading airlines and aircraft manufacturers, suggesting that the industry is leading innovation in this area above academia.

III.METHODOLOGY

The reference information was obtained from scientific literature obtained in repositories and scientific journals in the fields of engineering. In addition, a PRISMA review was carried out in which 15 documents were included for the study from a review of 116 papers from 4 scientific bases Web of Science, Science Direct, SCOPUS, and IEEE Xplore. The workflow is visualized in Figure 3.

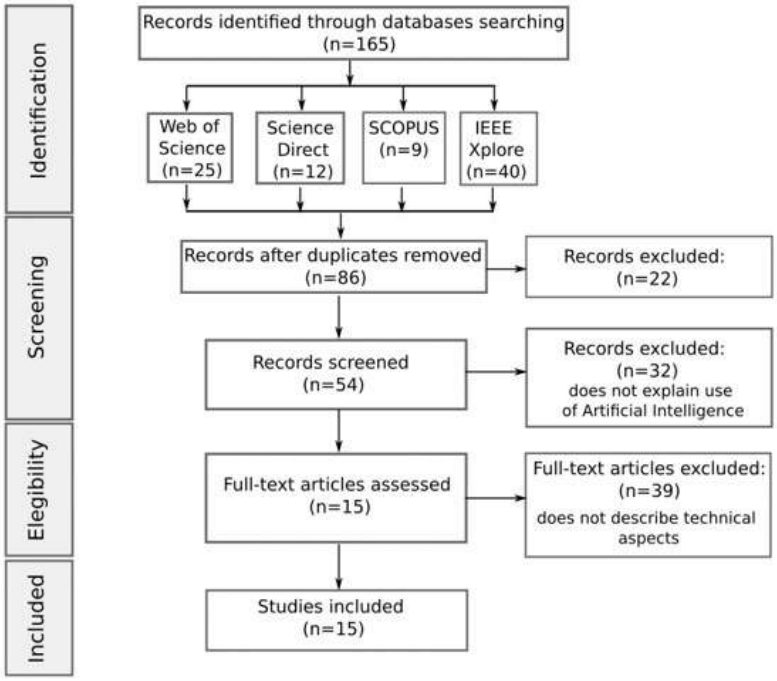

Fig. 3. Review workflow according to PRISMA methodology.

IV. RESULTS

The information presented in this paper presents essential findings on implementing artificial intelligence (AI) in the aviation industry. It is generally recognized that AI has significantly impacted aeronautics, improving efficiency, safety, and quality in the industry. AI can process large amounts of data and perform complex analyses to make accurate and fast decisions. However, the importance of supervision and regulation in implementing AI in aeronautics is also highlighted. Furthermore, it is recognized that AI can present risks if its use is not adequately monitored, and it is necessary to ensure the safety and well-being of all those involved in the aviation industry. Therefore, emphasis is placed on the need for proper regulation and close supervision to ensure that the implementation of AI in aeronautics is safe and effective.

The findings presented indicate that AI can be a valuable tool to improve efficiency and safety in the aviation industry. Still, its implementation must be adequately monitored and regulated to minimize potential risks.

Text in Calibri number 10. They must be those aspects product of the objectives set. The figures must have a description in the paragraphs near them. This same section includes the discussions of each result. Everything must be written in a harmonious and organized way.

CONCLUSIONS

The implementation of artificial intelligence in aeronautics has significantly improved the industry's efficiency, safety, and quality thanks to its ability to process large amounts of data and perform complex analyses. However, it is essential to note that aeronautics implementation requires close oversight and regulation to ensure the safety and well-being of everyone involved in the aviation industry. AI can present risks if its use needs to be adequately monitored.

Proper regulation and close oversight are necessary to ensure that the implementation of AI in aeronautics is safe and effective. This implies that regulatory authorities and aircraft manufacturers must work together to establish clear standards and robust oversight policies to ensure aviation safety and the well-being of those involved in the aviation industry.

Future applications of artificial intelligence in military aviation represent a significant advance in capability, efficiency, and operational safety. For example, AI can potentially improve the accuracy and speed of target reconnaissance and tracking systems, allowing military forces to identify and neutralize threats more effectively. In addition, AI algorithms can optimize flight paths and strategic resource deployment, maximizing the efficiency of military operations.

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