The role of innovation in ensuring the safety of international civil aviation

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Abstract

The paper examines the impact of innovative technologies on ensuring the safety of international civil aviation, on international relations, in particular on the safe use of international airspace, and emphasizes the importance of the participation of each state in the formation of innovation policy.The International Civil Aviation Organization (ICAO) encourages and supports the implementation of innovative technologies, develops sound policies and implements innovative ideas, implementation opportunities, and involves expert scientists in the development of innovative research and projects. The paper examines some of the most important innovations in aviation security and how they are shaping the future of air travel. It analyzes the Standards and Recommended Practices of the Annexes to the Convention relating to the security of international air transport, the role of modern technologies in allowing States to reduce the time for security control of air passengers.Harmonization of new aviation safety technologies is crucial to ensure further improvements in air transport safety and efficiency through innovation. Innovation has been identified as an important factor in achieving environmental protection and the introduction of innovative green aviation technologies, such as electric and solar-powered aircraft, new clean aviation fuels and other climate change mitigation and adaptation strategies.The issue of updating ICAO standards is being considered to ensure the implementation of the latest technologies in aircraft and engine design. Civil aviation safety goals are achieved through innovative technologies of independent experts, which ensures transparency and involvement of all stakeholders. Examples of the application of innovative technologies are analyzed. Particular attention is paid to the analysis of such an important aspect as the volume of personal data of passengers received by international civil aviation entities, on which the safety of civil aviation depends. It is proven that the implementation of artificial intelligence not only simplifies operations, but also significantly reduces the risks associated with human errors. Artificial intelligence can help in such an important issue as detecting foreign objects, debris on the airport runway. Innovations in civil aviation to ensure safety will always be the top priority in establishing general requirements for civil aviation activities when carrying out international flights, proclaiming the principles and rules of flight, aircraft registration and their documentation, air accident investigation, and the procedure for establishing technical standards.

Keywords

civil aviation safety, innovative technologies, artificial intelligence, passenger personal data, ICAO standards

1. Introduction

The International Civil Aviation Organization (ICAO) is a specialized agency of the United Nations, established by governments in 1944 to organize and coordinate international cooperation between states in the field of international civil aviation. In accordance with its mandate, ICAO develops standards and recommended practices for civil aviation, which contribute to the harmonization of national aviation safety regulations, environmental protection in aviation, creating a global aviation network [1]. To date, 193 states have joined it. Flight safety depends on the ability to operate flights without endangering human life and health. As we enter an era of digitalization and incredible modern advances in flight and

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engines, air transport needs the support of ICAO experts to help shape a safe future for international flight. Among the important issues of each ICAO Assembly (in particular, the 40th and 41st, with the 42nd in September 2025), member states and representatives of international organizations have established ICAO priorities in the field of international civil aviation, namely: innovation and digital technologies, improving the safety and efficiency of the international air transport system.

By analyzing the latest trends, aviation authorities can identify patterns that indicate the likelihood of incidents, allowing airlines to take proactive measures to prevent accidents, using flight routing adjustments, maintenance planning. Thanks to such information, the aviation industry becomes safer, which reduces the risk of incidents.

The civil aviation safety system depends on the effective implementation of innovations that contribute to ensuring safety reliability, development efficiency, simplification of formalities, environmental protection and economic development of air transport.

For example, the Civil Aviation Management of New Zealand (AVSEC), responsible for the management of the civil aviation system, provides innovation with innovation, world -class aviation security. AVSEC has the following important main functions: checking and search of passengers, crew, airport workers, luggage, aircraft, cargo, etc.; patrol and support; Management of the person's identity system at the airport; cooperation with other national and international security services and border authorities.

The participation of States in the Convention on International Civil Aviation contributes to the development and adoption of international Standards, which are annexes to the Convention, which contain innovative achievements. Innovations result in efficient and simplified aviation regulatory processes. The International Civil Aviation Organization (ICAO) interacts with States, governmental and non-governmental organizations to exchange experiences on innovation.

International and European civil aviation standards take into account international legal principles and norms that establish typical rules of conduct for subjects of international law for interstate cooperation, in particular for civil aviation. The standards establish certain requirements that must be fulfilled and adhered to by all states that have consented to be bound by an international treaty.

The improvement of the national aviation security system through modern technologies and its alignment with international requirements is carried out on the basis of a unified state policy in the field of civil aviation security protection. This policy is aimed at fulfilling the main task of the aviation security system - ensuring the safety of life and health of passengers, aircraft crew members, ground personnel of airlines, security and airport facilities (airlines) in accordance with state norms, rules and procedures applicable to civil aircraft, national and foreign operators (airlines) that carry out domestic and international air transportation.

2. Materials and methods

The work used a systematic approach to study the impact of innovation policy on ensuring the safety of international civil aviation, applied, in particular, a comparative and in particular, the formal-logical method allowed us to analyze the recommendations of ICAO experts and international and European organizations regarding innovative technologies in the field of civil aviation. The system-structural method is used in the study of the approach to innovative achievements, which helps to identify potential anomalies and recommend corrective actions.The comparative legal method was applied in the study of the achievements of modern technologies in various areas of ensuring the security of international civil aviation and in substantiating specific proposals regarding the possibility of their use in world practice, in particular in Ukraine. The method of analysis and synthesis is important for clarifying the essence and effectiveness of ICAO standards in the Annexes to the Convention on International Civil Aviation, in particular No. 17 "Security. Protection of International Civil Aviation from Acts of Unlawful Interference", Annex 18. The Safe Transport Of Dangerous Goods By Air.The forecasting method was used to analyze the feasibility of implementing individual technologies, their advantages and disadvantages, assess risks in the process of combating the negative impact of new achievements, as well as forecasts for the restoration of civil aviation in the world.

3. Results

Safety has always been one of the most important areas of activity. Over the years, new approaches to aviation safety have been introduced that have significantly reduced the risk of accidents and improved the overall flying experience for both passengers and crew. One of the most brilliant historical achievements of mankind is powered flight, innovation has always been a hallmark of aviation since the creation of the first aircraft. Among the historical innovations are unmanned aerial vehicles (UAVs) or drones; urban air mobility; remote/digital towers in air traffic control; the use of e-passports, biometrics and contactless technologies to facilitate air passenger transport; electronic air waybills and cybersecurity, as well as the application of big data, fintech, the Internet of Things, machine learning, artificial intelligence and blockchain and other emerging technologies to ensure that air travel remains one of the safest modes of transport.Great advances exist in aircraft designs and materials, contributing to progress in the aviation field.

The joint work of civil aviation equipment manufacturers and operators of this equipment ensures the safety of civil aircraft flights. At the stage of design, manufacture and testing of aviation equipment, flight safety requirements are embodied in the design of the aircraft and in the technology of its manufacture. At the operation stage, these requirements are ensured through the organization of the work of the relevant services that operate the aircraft on the ground and in the air.Therefore, flight safety depends on the reliability of aircraft and the qualifications of the personnel servicing and operating these aircraft, as well as on modern innovative achievements. Aviation safety is ensured by aviation security services and security units of airports and airlines, as well as specially authorized bodies vested with these rights by law [2].

The International Civil Aviation Organization has adopted a Strategic Plan for 2026-2050, designed to ensure a safe, secure and resilient global aviation system that fosters innovation, enhances safety and creates an even more impactful future for global aviation [3, 4]. The Strategic Plan presents a roadmap for innovation, including new challenges, opportunities and best practices. CAO leads and provides timely guidance to Member States on new innovative technologies and the implementation of necessary changes in regulation. ICAO and Member States should establish more effective consultations with user interest organizations to ensure that appropriate policies and regulations on innovation are developed and implemented. The joint efforts of international and European aviation organizations have resulted in the development of universal standards that provide for significant improvements in the civil aviation facilitation system.

In October 2020, ICAO published the “Guiding Principles for the Development of a Digital Travel Credential” [5]. Effective management of passenger data is a priority for government agencies, which is why they operate under passenger information sharing rules to better detect, investigate and prevent criminal activity.

ICAO Member States are developing modern and innovative strategies to address issues such as airport congestion; reducing risks to aviation safety and national security through robust identity management and border control methods; facilitating the detection and prevention of terrorism and crime by preventing fraudulent use of identity documents; facilitating genuine travellers at the airport through automated check-in processes to increase throughput; reducing staff and training costs by standardising and streamlining document verification processes; ensuring interoperability and the use of standard technologies for identity management for both States and industry, resulting in efficient operations and reduced costs; increasing States’ confidence in their ability to verify that documents have been properly issued and have not been altered.

Aviation professionals are constantly searching for innovative solutions to improve efficiency, safety and passenger service. Artificial intelligence has the ability to process huge amounts of data and identify complex situations. AI applications are bringing revolutionary ideas to various aspects of aviation, including flight optimization and predictive maintenance, and improved air traffic management.

4. Discussion

The International Civil Aviation Organization (ICAO)'s primary role in supporting aviation innovation is to encourage new ideas and accelerate their harmonization so that the industry can take advantage of the new opportunities that innovation brings. Intelligent systems can monitor the performance of new ideas in real time, identify potential anomalies, and recommend corrective actions.

Taking into account the special status of innovative technologies, each State Party shall enact all necessary provisions in its national laws or regulations to make their implementation mandatory for any civil aircraft registered in that State or operated by an operator whose principal place of business or permanent residence is in that State.

It is worth recalling the Preamble to the Convention on International Civil Aviation, which begins: "Whereas the future development of international civil aviation can contribute greatly to the establishment and maintenance of friendship and mutual understanding among the peoples and nations of the world", ICAO seeks to ensure that the future of aviation is a prospect for all the peoples of the world, so that no country is left without assistance. ICAO encourages innovation, which continues to maintain mutual understanding among the peoples of the world. Innovation benefits developing countries. The use of drones expands direct access to aviation for citizens of countries that may never fly or travel through airports, and drones support local businesses and community development. Innovative improvements, cooperation between governments and industry stakeholders is crucial to create the necessary foundation for achieving safety in the era of globalization. Therefore, ICAO plays an important role in innovation, is a global forum for States on important issues. ICAO takes the initiative in providing timely recommendations to Member States, and also ensures more effective consultations with various actors and organizations. States should share experiences among themselves and with the International Civil Aviation Organization.

Annex 17 – Aviation Security [6] containing Standards and Recommended Practices relating to the security of international air transport, the information is regularly updated taking into account emerging threats, as well as recommendations for innovative opportunities.The Annex is a document for implementing security measures and includes supplements with extracts from other annexes, technical instructions for the safe transport of dangerous goods by air, air navigation service rules, dedicated to actions that States must take to prevent unlawful interference with civil aviation or in the event that such interference has occurred.

Given that Annex 17 – Aviation Security contains Standards and Recommended Practices on the general purpose of aviation security measures; measures for passengers and their carry-on baggage; measures for checked baggage, cargo and other items; measures for controlling access to controlled and other areas of the airport; measures for designing airports with security in mind, all these processes depend on new innovative ideas. National aircraft flight programs take into account all safety-related innovations, recommended practices and procedures. Coordinated and agreed actions in the application of modern technologies can ensure continuous improvement of flight safety and aviation security of international air transport. The standard defines the main elements of a national civil aviation safety quality control program, which must be developed, implemented and maintained.

Only by using a systemic approach to innovative chievements can the most important goal of aviation safety be achieved, namely, ensuring reliable human protection by analyzing the interaction of hazard factors with humans and man-made objects.

Given the specifics of the study of the role of innovation in ensuring security, it is important to analyze how modern technologies allow states to reduce the time for controlling the security of air passengers. Checking travel documents is a common stage of international air travel, which requires specialized infrastructure and personnel, as well as time for processing travel data. Facilitation of the document verification process, the installation of appropriate systems meet security requirements.

Here are two examples. Helsinki Airport announced the lifting of strict restrictions on the carriage of liquids on planes from June 28, 2023. Passengers will no longer have to throw away filled containers of more than 100 milliliters at security control to pass through the departure area. The new rules stipulate that each passenger departing from Helsinki will be able to take up to 2 liters of liquids with them. The

lifting of strict restrictions became possible after the airport operator, Finavia, installed CT scanners in the terminal. They check passengers' belongings for dangerous substances and allow them to keep electronics and liquids from their hand luggage for inspection.

In 2024, the Netherlands' largest airport, Schiphol in Amsterdam, was able to reduce the time it takes to inspect passengers and their luggage to 3 seconds. Schiphol has upgraded all 53 scanners that screen passengers for dangerous items. When installing the new scanners, the safety and comfort of travelers and security officers were of paramount importance. The new equipment assesses in just 3 seconds whether a passenger is carrying anything dangerous. It also reduces the number of travelers who need to be directed for a more detailed inspection with the participation of a security officer.Schiphol previously purchased modern hand luggage scanners that use computed tomography technology. These devices also allowed passengers not to remove electronics from their suitcases for separate inspection. In addition, the airport lifted strict restrictions on the transport of liquids. Thus, modern technology has allowed states to reduce the time for security control of air passengers.

The ICAO Facilitation Conference (2025) in Qatar adopted the Declaration on the Facilitation of International Air Transport, setting the stage for the transformation of global air transport as the industry prepares for unprecedented growth [7]. The facilitation of civil aviation regulations to enhance global security reflects the need for ICAO recommended practices for aviation security and related border security issues. The ICAO Council adopted the Global Aviation Security Plan to improve international cooperation, response and planning to counter threats to passengers, cargo, aircraft and civil aviation facilities [8, 9].

ICAO experts provide recommendations to specialists from participating countries on the application of innovative technologies, implementation of certain measures to counter cyber threats in this area: adopt and implement a cybersecurity strategy; organize state-industry partnerships and mechanisms at both the national and international levels, exchange information on cyber threats, preventive measures and incidents that have already occurred; develop principles and attract resources to ensure the structural security of systems and their resilience, methods of data transmission, as well as implement methods for monitoring systems and detecting incidents with subsequent reporting, etc.

The improvement of the national aviation security system through modern technologies and its alignment with international requirements is carried out on the basis of a unified state policy in the field of civil aviation security protection. This policy is aimed at fulfilling the main task of the aviation security system – ensuring the safety of life and health of passengers, aircraft crew members, ground personnel of airlines, security and airport facilities (airlines) in accordance with state norms, rules and procedures applicable to civil aircraft, national and foreign operators (airlines) that carry out domestic and international air transportation.

Innovation is essential for the safe transport of dangerous goods by air, as regulated by Annex 18 to the Convention on International Civil Aviation. Annex 18, The Safe Transport of Dangerous Goods by Air, provides Standards and Recommended Practices for determining the acceptability of goods and substances for carriage in passengers' carry-on and checked baggage [10].Taking into account the changes brought about by innovation, this information is provided in accordance with the standards and recommendations of the International Civil Aviation Organization (ICAO), the Safety Advisory Committee of the International Air Transport Association (IATA). The Technical Instructions supplement the main provisions of Annex 18 and contain all the detailed innovative ideas necessary for the safe international air transport of dangerous goods.

Dangerous goods can be safely transported by air, provided that modern technologies are used that are designed to facilitate transportation while ensuring a level of safety that allows dangerous goods to be transported without risk to the aircraft or its passengers, provided that all requirements are met. Airport staff must be confident that, should an incident occur, it will not lead to an accident.

In the European Union, the EU Cyber Solidarity Act (2023) came into force, which provides for the coordination of actions between EU member states. It is logical to create a European early warning system and an emergency cyber mechanism that will combine capabilities to increase preparedness to respond to significant and large-scale cyber incidents. It is necessary to improve the technology of cyber defense systems in key areas of governance and the economy, for example, in energy and

transport.The so-called EU Cybersecurity Reserve is to be created, which will provide backup services in the event of serious breaches, at the request of member states, European institutions, or associated third countries. The document provides for mutual financial support of EU members in the event of serious cyber incidents, as well as the provision of technical assistance to countries affected by them.

Another area of the agreement is radiation research and information exchange for radiation protection in civil aviation, especially on the effects of space radiation on flight crews. Closer mutual cooperation creates a favorable environment for countries to exploit the benefits of peaceful uses of nuclear technologies to achieve the UN Sustainable Development Goals, and will help prepare the ground for deeper cooperation in the near future. Harmonization of new aviation security technologies is crucial to ensure further improvements in the safety and efficiency of air transport through innovation.

Innovation is an important factor in achieving environmental protection and implementing innovative green aviation technologies, such as electric and solar-powered aircraft, new clean aviation fuels and other climate change mitigation and adaptation strategies. Environmental protection is a priority for international and European civil aviation organizations. With the growth of air traffic and the possibilities of innovative technologies, it is necessary to think about ensuring environmentally friendly airspace [11].

The European Union's LIFE Programme for Climate and Environment [12], which Ukraine has joined, provides funding for the application of innovative technologies in the field of civil aviation after the destruction caused by the Russian invasion, in particular, the restoration of airport infrastructure, obtaining Airport Carbon Accreditation from the Airports Council International. It is worth paying attention to climate change, which requires environmental protection, as air transport affects its condition. Through constant innovation, collaboration and advanced technologies, the aviation industry ensures that air transport always remains one of the safest modes of transport.

When analyzing innovative technologies in aviation, it is appropriate to take into account the achievements of recent developments in the field of improving aircraft and engine technologies, implementing economic measures, improving air traffic management (ATM) and aircraft operations [13]. ICAO monitors the development of new engine concepts, such as electric, hybrid and hydrogen. ICAO regularly sets technology goals to promote the development of modern innovations for cooperation with Member States. Once modern technologies achieve these goals, the issue of updating ICAO standards is considered to ensure the implementation of new technologies in aircraft and engine design.

An important issue in improving aviation safety is aircraft design and materials. Manufacturers are focusing on creating more fuel-efficient, safer, and longer-lasting aircraft. Advanced composite materials, such as carbon fiber and alloys, are used to create lighter, stronger, and more stable structures. These materials improve performance in extreme conditions, making aircraft more resistant to structural damage.

Experts recommend developing modern aircraft with reinforced cabins, crumple zones, and improved fuselage structures that can better absorb impact forces during an emergency landing or crash, potentially saving lives. The researchers say these innovations reflect the industry's commitment to reducing fatalities and increasing safety worldwide. By continually improving these designs, manufacturers are creating safer flights [14].

Scientists recommend that airport operating companies apply modern innovative technologies by creating local councils on certain issues, which involve all participants of a particular airport. Thus, airports will take an active role in stimulating sustainable development. However, more importantly, the councils they unite can coordinate complex actions that really effectively affect the safety of civil aviation [15].

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Let's examine innovations in air traffic control. Innovations in air traffic control systems are essential to improving safety. Systems using radar and radio communications have been effective, but they

have limitations, such as limited range and susceptibility to interference. In recent years, innovative developments in air traffic control systems have emerged, incorporating satellite technologies such as GPS. Satellite communications allow controllers to monitor aircraft with greater precision and predict potential conflicts before they occur. These systems also allow for more efficient routing and reduced delays, which increases safety and minimizes the risk of collisions.

Innovative fuel concepts that can provide environmental benefits are a key issue at every ICAO Assembly. Given the expected growth in air travel, innovation is essential to achieving ICAO's goals, as set out in Assembly Resolutions A41, as well as aviation's contribution to the United Nations Sustainable Development Goals.

Clean aviation fuels (SAF) are a reality, as evidenced by the various conversion processes and feedstock available for SAF production, as well as the large number (over 200,000 flights) of commercial flights that have been flown with SAF. Research projects are underway to demonstrate the feasibility of hydrogen propulsion and overcome these challenges, thereby contributing to the long-term environmental goals of civil aviation [16, 17].

ICAO closely monitors innovation [18]. New innovative technologies and energy sources for aviation are being developed at a rapid pace. Innovative technologies for the introduction of new fuels require ICAO to carry out environmental certifications for mandatory consideration of such technologies.

The ReFuelEU aviation regulation set a minimum mandate for the supply of sustainable aviation fuel (SAF) in Europe, starting at 2% in 2025 and increasing to 70% in 2050. As of 2024, SAF production accounted for only 0.53% of global jet fuel use. A significant expansion of production capacity is needed to meet future mandates and targets [19, 20]. SAF must meet international standards to ensure the safety and performance of aviation fuel. Civil aviation safety goals are achieved through innovative technologies from independent experts, ensuring transparency and involving all stakeholders.

National authorities of States should share their experience with ICAO and other civil aviation authorities. They should seek opportunities for regional cooperation, as innovative technologies are increasingly used in cross-border operations. ICAO develops relevant regulations (SARPs) and regularly provides recommendations to Member States. To achieve success, coordinated efforts of the entire aviation industry (airlines, airports, air navigation service providers, manufacturers) and significant public support are required. Member States of international and European civil aviation organizations should continue to adapt national legislation to ensure civil aviation safety, taking into account current advances in innovative technologies.

It is important to note that the implementation of innovative technologies occurs through the consideration of reliable fundamental principles, such as intellectual honesty; technical, economic, social, and environmental progress; respect for human rights, confidentiality, and protection of personal information and data; ethics, and equality of access. The introduction of new initiatives and innovative technologies is accompanied by amendments and additions to the ICAO Annexes and Recommended Practices, and the rulemaking processes of national legal systems include changes to all innovative processes. New rules provide appropriate guarantees of safety, security, confidentiality, liability and other risks. For example, given that the acceptable level of safety for a small drone may differ from the level of safety of a passenger aircraft, rulemakers must take into account the importance of all innovations that will be important for the future development of social relations.

To explore the topic, it is important to analyze several examples of innovative technologies. According to Airbus, it is developing a new aircraft that will run on hydrogen stored at a temperature of -253°C, and is also developing new cryogenic hydrogen storage tanks for future aircraft that will run on liquid hydrogen, which are at the heart of its new hydrogen aircraft, the ZEROe. Hydrogen is key to the mission to bring zero-emission aircraft to market, but it must be stored at an extremely low temperature of -253°C. Airbus explains that there are two main technologies that allow an aircraft to fly directly on hydrogen: powering an engine that burns hydrogen through modified gas turbine engines or using hydrogen fuel cells to generate electricity. Another option is a hybrid approach, which uses a combination of both technologies [21].

Using innovative technology, SE Aeronautics has unveiled a new concept for a giant jet that takes an unusual approach to all aspects of wide-body aircraft design and performance, including the rarely

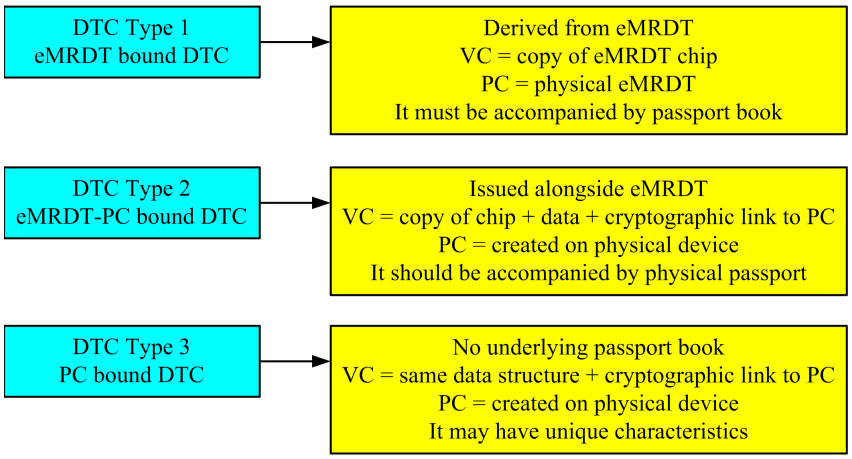

Figure 1: DTC types.

seen: three pairs of wings, a double tail fin, and two rear engines. The new prototype, called the SE200, can carry 264 passengers and consume 70% less fuel than other aircraft of similar size.

Jet Zero Blended Wing has designed a new aircraft using innovative technologies to improve aerodynamic efficiency. Jet Zero announced that its blended wing demonstrator has received FAA approval to begin test flights. A blended wing aircraft is one in which the fuselage and wings are fused together to form a sleek shape that is somewhere between a conventional airliner and a flying wing. Jet Zero claims that its blended wing will use 50% less fuel than a standard jet aircraft.

Innovation therefore plays a necessary role in ensuring the safety of civil aviation, with the industry applying new approaches to the market launch of hybrid and electric aircraft, improving environmentally friendly aviation fuels and battery technologies. The development of innovative technologies indicates that by 2035 aircraft with highly efficient power plants and 30% lower fuel consumption may appear. The development of more fuel-efficient aircraft, engines and optimized range and capacity of hybrid-electric rotorcraft and regional aircraft will reduce CO2 emissions per flight by 50% compared to 2018. Aircraft with hydrogen engines and hybrid-electric helicopters and regional aircraft require special technological readiness by 2027–2030 at both the aircraft and power plant levels [22].

An important aspect on which the safety of civil aviation depends is the huge volume of personal data of passengers, which is received by subjects of international civil aviation.

Back in 2003, the International Civil Aviation Organization, taking into account modern technologies, adopted standards for automatic reading of travel documents (eMRTD). This became the foundation for building an extensive infrastructure, simplified document verification at the airport. Starting with Belgium (2004), governments of various countries began to issue electronic passports compatible with ICAO. The importance of electronic passports lies in the legal issuance by states, as well as in the digital biometric and biographical information stored on the electronic passport chip [23]. This allows airports, airlines and inspection agencies to verify the authenticity of documents using automated border control tools.

The unique nature of the digital travel certificate (DTC) of the International Civil Aviation Organization provides an exceptional opportunity to create a next generation passport issuance and check, setting a new standard to serve travelers. EntRust fully supports Isao's ideas on technological progress from the current EMRTD standard for electronic passports to future state when only virtual MRTD virtual electronic are available. But the path to paperless passports will last for many years. DTC types are shown in Figure 1.

The ICAO "Guidelines for the Development of Digital Travel Credentials" is essential for improving digital identity, as a digital copy of the information in an e-passport provides a reference for the required credentials. The ICAO "Guidelines for the Development of Digital Travel Credentials" [24] is essential for improving digital identity, as a digital copy of the information in an e-passport provides a reference for the required credentials.

Airlines are implementing additional measures to ensure the security of personal data, which are directly related to cybersecurity. There have been changes in the organizational structure of airlines, a data protection officer has appeared, the main purpose of which is to ensure the performance of functions for regulatory and organizational support of business processes related to the processing and protection of personal data [25]. All entities in international civil aviation receive a huge amount of personal data of passengers. One airline can process tens of millions of pieces of data about passengers, cargo, and the technical condition of aircraft equipment, so there is a need for measures to protect technical and personal data of customers.

The basic rules of air transport on the confidentiality of aviation data are aimed at improving the global security of passengers, protecting borders from illegal transit and monitoring the health of passengers. Data privacy legislation is constantly evolving and improving around the world. A global analysis shows that 66% of countries currently have data privacy legislation, 10% are preparing draft legislation, 19% do not have legislation, and 5% have not provided any data. Global threats such as illegal migration, travel document fraud, illicit drug trafficking, and the spread of infectious diseases and everyday realities are important to consider.

The facilitation of civil aviation regulations as a strategic objective to enhance global security reflects the need for ICAO recommended practices for aviation security and related border security issues. The ICAO Council adopted the Global Aviation Security Plan to improve international cooperation, response and planning to counter threats to passengers, cargo, aircraft and civil aviation facilities [25].

ICAO places great importance on the cooperation of its Member States in implementing innovations in the field of aviation safety. Regulators, airlines, aircraft manufacturers and pilots work together to identify the best ideas, share safety data and ensure compliance with the highest safety standards in the industry. The International Civil Aviation Organization ensures compliance with global safety rules, consistent implementation of safety measures worldwide. One common safety initiative is the Safety Management System, which encourages organizations to systematically identify, assess and mitigate risks. Safety Management System structures exist to improve communication and coordination between stakeholders, allowing for more effective safety management. Through such initiatives, the aviation industry is making significant progress in promoting a safety culture so that safety remains a top priority for all participants. The aviation industry should remain one of the safest forms of travel.

The introduction of artificial intelligence not only simplifies operations, but also significantly reduces the risks associated with human error. The involvement of artificial intelligence in aviation is due to the need to solve existing problems, while setting ambitious goals for the future. With the help of innovative artificial intelligence solutions, the aviation industry seeks to increase safety and contribute to climate improvement. AI can optimize flight routes, significantly saving fuel and reducing emissions. AI can offer the most efficient flight routes by analyzing weather conditions and air traffic. The application of AI in civil aviation allows you to optimize flight trajectories. Using machine learning algorithms, airlines can analyze huge amounts of data related to weather conditions and air traffic [26]. This allows you to determine the most efficient routes, reducing fuel consumption and minimizing carbon emissions. Using the capabilities of artificial intelligence in civil aviation results in a safe, efficient, sustainable aviation system.

Artificial intelligence can analyze data on weather conditions, sector configurations, air traffic congestion and other factors, can help optimize flight routes, reduce flight time, fuel consumption. Such optimization allows to increase the efficiency of the air traffic control system, reduce delays and increase the capacity of air transportation. The application of artificial intelligence and machine learning can also help air traffic controllers make more informed decisions and faster when they are faced with a conflict situation.

In the future, AI could help develop and deploy clean aviation fuels by analyzing data on biofuel production, performance, and environmental impact. Flight path optimization is one example of how AI can help reduce carbon emissions from flying. Assessing the environmental impact of aviation, such as noise around airports or engine emissions during flight, is a data- and computation-intensive activity. AI can improve its ability to process such data.

It is important to analyze how modern technologies can help to reduce the negative impact on

airspace caused by contrails, the thin white lines that follow aircraft. The clouds created by contrails are responsible for approximately 35% of aviation's global warming impact, accounting for more than half of the global impact of aviation fuel. Unlike typical greenhouse gas emissions, the formation of contrails depends on specific atmospheric conditions, namely humidity and temperature.Weather forecasts influence the choice of flight altitude, and humidity measurements are not available. It is AI that can synthesize signals from multiple data sources. By combining weather, satellite, and flight data, AI can predict when and where contrails are likely to form, so that aircraft avoid areas with high humidity and low temperatures. This data can be used to adjust flight altitudes. AI has unique capabilities to accelerate contrail avoidance, which can mitigate the impact of aviation on airspace, and flights can minimize their climate impact without significantly increasing fuel consumption.

Artificial intelligence will always play an important role in all areas of aviation. Innovative technologies for implementing artificial intelligence provide assistance to aviation professionals and optimize almost all safety processes, which was previously impossible. Scientists draw attention to the fact that new technologies have risks and challenges, for example, the complexity of machine learning systems, ethical implications and cybersecurity of AI systems. Through their recommendations for the development of artificial intelligence, international and European civil aviation organizations, in particular EASA, seek to ensure that the aviation industry uses the potential of integrating artificial intelligence while maintaining the highest safety standards.

One of the biggest advantages of AI is its ability to process huge amounts of data. For example, to identify patterns, develop forecasts and predict risks, it can positively impact various areas of aviation. AI can provide crews with task advice to improve operational efficiency of flights, predict problems such as turbulence and icing conditions, and assist pilots in making decisions in the event of a conflict situation. With the increase in digitalization, the amount of data is increasing, and the reliance on AI capabilities to process this data is increasing. AI can help optimize maintenance schedules, predict the remaining life of parts and thus prevent failures.

AI can help reduce carbon emissions during flights by influencing the optimization of flight paths. Noise around airports or engine emissions during flight are tasks that require a lot of data and calculations. AI can improve its ability to process such data.

Artificial intelligence can help with such an important issue as the detection of foreign objects, debris on the airport runway, which are potentially dangerous. The presence of debris on the runway poses a significant safety problem, as the debris can damage other aircraft or disrupt their operation. Rapid response by ground crews reduces the risk by ensuring prompt clearance of the runway. Experts have estimated that damage caused by foreign objects (FOD) on airport runways costs the global aviation industry approximately 12 billion US dollars. Objects as small as a bolt can cause serious damage to aircraft and pose a safety threat [27].

Any FOD can be detected using special innovations. For example, American Airlines Flight AA1175 encountered a mechanical problem during takeoff from San Francisco International Airport (SFO). Debris, including the left engine thrust reverser shroud, was left on Runway 01R. The aircraft emitted a "cloud of smoke" from the left engine, but the crew continued the flight to Dallas-Fort Worth, where the debris was later identified [28]. The damage can be severe and devastating. For example, FOD was involved in the loss of a Concorde taking off from Paris/Charles de Gaulle Airport in July 2000. A small piece of metal on the runway killed 109 people on the Concorde and four on the ground [29].

The presence of debris on the runway is a major safety concern for civil aviation, as the debris can damage other aircraft or disrupt their operations. Airports and airlines around the world are investing in innovative detection technologies and maintenance methods to minimize such risks, reinforcing their safety commitments. Aerodrome operators must stay abreast of the latest technologies and ensure proper civil aviation safety.

Artificial intelligence can help create more effective and reliable systems to prevent cyberattacks. It can be used to automatically detect and fix system vulnerabilities, as well as to identify threats based on behavior.

Innovative AI technologies can help identify new risks, classify the risks of events, and prioritize security issues.

In 2020, EASA published its first “Artificial Intelligence Roadmap” [30], which set out the Agency’s initial vision for the safety and ethical aspects of developing AI tools in the aviation sector. The EASA Artificial Intelligence Roadmap is a document that is constantly updated and improved through the exchange of views and practical work on AI development.EASA has also published concept papers on artificial intelligence, which support the adaptation of existing aviation regulations to AI and the identification of new requirements and means of compliance, setting the pace for the development of concept recommendations and expected rulemaking activities. In addition, research is ongoing under the project “Approval of Machine Learning Applications” [31], which concerns the investigation of machine learning technology for systems designed to ensure safety in all areas of EASA’s competence.

Innovation in civil aviation to ensure safety will always be a top priority. Future advances are likely to include further developments in artificial intelligence, autonomous flight systems, and advanced materials that will make aircraft even safer.

Legal regulation aims to create a high-quality regulatory framework that ensures the effective functioning of the public safety protection system at civil aviation facilities, with state control over the activities of its subjects, as well as knowledge of the latest achievements of innovative technologies. The practical solution to the problem of orderliness of public relations in the field of aviation safety largely depends on the improvement of the legislation regulating these relations, on the completeness and quality of the regulation of various aspects of this area by legal norms. Innovations play a key role in improving aviation safety, protection, efficiency, environmental sustainability and simplification of formalities. They strengthen safety, the benefits of civil aviation for society and business.

5. Conclusions

So, innovative technologies need to be implemented while strengthening the existing infrastructure. The growing role of innovation in ensuring the safety of international civil aviation worldwide is taken into account by the ICAO Council, which regularly updates the Annexes to the Convention on International Civil Aviation, including new standards in the fields of communications, navigation, airport operations, and aeronautical meteorological services.

The relevance of new technologies for civil aviation is particularly important given the need to help pilots navigate more accurately, especially in conditions where traditional navigation aids are limited. Importantly, these standards better support the implementation of navigation so that pilots can choose flight routes that minimize flight time, cost and CO2 emissions. New standards for aeronautical meteorological services will contribute to the safety and efficiency of aircraft flights by helping to plan flights and avoid adverse weather conditions in real time. They include improved capabilities for volcanic ash monitoring and weather forecasting, and the introduction of new protocols for the enhanced exchange of meteorological information in digital format.

Member State governments share a common strategic goal to protect international civil aviation, and are constantly introducing new ideas through innovative technologies to address challenges through international partnerships. States should now regularly assess the impact of ground handling on flight safety, which will help reduce the number of events and incidents.

All modern innovative technologies will directly contribute to ensuring the safety of international civil aviation through their implementation in national legal systems. + Governments of ICAO member states support innovations and implement them in national regulatory acts, while taking into account any problems and risks through appropriate policies and proportionate rules. In particular, the update occurs through the implementation of international and European civil aviation standards in the legal system of Ukraine. Thus, the inclusion of Ukraine in global efforts to develop innovative technologies to improve standards allows to increase the level of aviation safety.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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