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## RETRO ANALYSIS OF THE AVIATION SAFETY SYSTEMS DEVELOPMENT IN UKRAINE

**Volodymyr Grebennikov. Dmytro Bugayko. "Retro analysis of the development of the aviation security system in Ukraine".** Various measures to ensure the safety of civil aviation flights in Ukraine from the time of its inception to the present are considered in a historical aspect at certain stages of activity, mainly organizational, scientific and technical and personal factors regarding the minimization of risks in civil aviation. The article confirms that at all stages of the more than 100-year history of civil aviation of Ukraine, various measures were constantly taken to ensure flight safety and minimize risks in aviation, especially since the second half of the 20th century. Innovative achievements of designers, scientists, engineers and technicians, training of highly qualified aviation specialists at the national and international level have become the achievement of global aviation. The integration of domestic aviation into the European and world community contributed to the strengthening of aviation safety in Ukraine.

**Keywords:** retro analysis, aviation safety, civil aviation of Ukraine, risk management, history

**Володимир Гребенніков. Дмитро Бугайко. «Ретро аналіз розвитку системи безпеки авіації в Україні».** Розглядаються в історичному аспекті різнопланові заходи забезпечення безпеки польотів цивільної авіації в Україні з часу її започаткування до сьогодні за визначеними етапами діяльності, головним чином організаційні, науково-технічні та особисті фактори щодо мінімізації ризиків в цивільній авіації. Стаття підтверджує, що на всіх етапах понад 100-річної історії цивільної авіації України постійно проводилися різнопланові заходи по забезпеченню безпеки польотів, мінімізації ризиків в авіації особливо з другої половини ХХ ст. Інноваційні досягнення конструкторів, науковців, інженерів і техніків, підготовка висококваліфікованих авіаційних фахівців на національному та міжнародному рівні стали здобутком глобальної авіації. Інтеграція вітчизняної авіації до європейської та світової спільноти сприяли посиленню безпеки авіації в Україні.

**Ключові слова:** ретро аналіз, безпека авіації, цивільна авіація України, ризик менеджмент, історія

**Introduction.** Since the emergence of world and domestic aviation, the problem of flight safety has also arisen. The first manned flight of brothers Orville and Wilbur Wright on December 17, 1903 in the "Flyer" airplane is considered the beginning of aviation. It is characteristic that the first aviation accident in history due to an aircraft defect occurred during the test flight of O. Wright on September 17, 1908, who was injured, and the passenger supervisor, Lieutenant of the US Army T. Selfridge, died [1].

The initial process of formation and development of aviation in Ukraine took place on a public basis, on the initiative and material resources of enthusiasts, engineers, scientists who selflessly embarked on the thorny path of conquerors of the sky, risking even their lives during the tests of their experimental aircraft. In Ukraine, in 1908-1911, public aviation organizations were created in Odesa, Kyiv, Kharkiv, Lviv and other cities, which had their own organizational structures, statutes, regulations and programs, and carried out multi-faceted activities for the development of aviation. The authorities reacted to this only by the fact that, after a "comprehensive review by a special interdepartmental commission", the Deputy Minister of Internal Affairs, the commander of the Separate Corps of Gendarmes, issued a secret circular on August 12, 1909, obliging the heads of the provincial gendarme departments and security departments to establish "unrelenting supervision of flights", "aviators and generally persons learning the art of aeronautics", as well as to register the personal composition of all aero clubs and "conduct covert supervision" of their members [2]. The first flights in Kyiv in 1910 by members of the Kyiv Aeronautical Society (hereinafter - KAS) on airplanes designed by KPI professor O. Kudashev in Kyiv on June 5 and aircraft designer I. Sikorskyi on June 16 actually started aviation in Ukraine.

Simultaneously with the emergence of domestic aviation, the problem of flight safety immediately arose, since aviation accidents began to lead to both the loss of human lives and considerable material damage.

**Analysis of recent research and publications.** Flight safety issues were considered in publications on the history of domestic aviation by many authors. Among them are Savin V.S., Trotsenko A.M., Horyashko A.M., Kharuk A.I., Maraev R.V. etc. The research of a number of scientists - V.I. Tokareva, G.Y. Kasperovych, M.V. Karpenko, F.I. Skrypnyk, M.G. Kovtyukha, M.F. Davydenko became a significant achievement from this problem. etc. This topic of the modern period was covered quite fundamentally in the publications of research scientists V.P. Babak, S.O. Dmitrieva, M.S. Kulyk, V.P. Kharchenko, and F.I. Yanovsky. etc. Administrative and legal of civil aviation flights of Ukraine is presented in the works of legal experts Bagan Y.Y., Sobakary A.O., Filippov A.V., Zhukov S.I. etc. However, in the historical aspect, the problem of the safety of civil aviation flights in Ukraine was not specifically and comprehensively investigated. The works of Y. Kharazishvili, D. Bugayko, and V. Lyashenko [15, 39 – 41] are devoted to the strategic management of air transport safety.

**The purpose of the article:** to highlight in historical retrospect, according to the stages of development of domestic aviation, the main measures to ensure flight safety in Ukraine.

**Presentation of the main research material.**

**Until 1917.** At the first stage of the development of Ukrainian aviation (this is the second decade of the 20th century), it was represented by experimental aircraft created by members of the aviation associations of the designers O. Kudashev, I. Sikorskyi, D. Grigorovich, F. Bilinkin, V. Iordan, O. Karpeka,



the Kasyanenko brothers, O. . During the period from 1909 to 1912, about 40 different types of aircraft were created by Kyiv aviators alone, which were registered and belonged to members of the Kyiv Aviation Society (KAS) [3, p.29,49]. By 1914, 13 airplanes were built by aviation enthusiasts in Galicia [4, p.70]. All of them were used sporadically for experimental, test and demonstration flights, including with passengers. The flights, in particular in Kyiv, were carried out with the knowledge and permission of the KAS Sports Committee at low altitudes and short distances. That is, the organizational factor of ensuring flight safety was taken care of by civil aviation associations.

At the same time, state control was exercised only over military aviation, which was mainly equipped with foreign aircraft, and the first government regulations regarding aviation were the 1912 decree on prohibited zones and the government decision of June 18, 1914 on the prohibition of flights across the western border. The creation of a system of air law standards has just begun to take shape [5, 26].

Flight safety at the beginning of the 20th century depended mainly on two factors: 1. flight-technical - safe operation of the aircraft, efficiency of all its units and systems; 2. subjective, human (personal) - the ability to control the flight of an aircraft and its high-quality maintenance.

It was the flight-technical factor at the dawn of aviation that was the most difficult, since the creation of aircraft was carried out independently by pioneer designers based on original projects at their own expense, without financial support from the state and without sufficient scientific and technical justification. The construction of safer types of aircraft was facilitated by certain foreign experience, conducting experimental experiments in small aerodynamic laboratories developed by the inventors themselves, in particular I. Sikorskyi, V. Grigoryev, G. Proskura, as well as the organization of exhibitions, reports on aviation issues by members of societies,

acquaintance with special literature, including foreign literature, as was the case in the Kyiv Aeronautical Society. It was here that his supervisor, Professor M.B. Delaunay of KPI, actively worked on the publication of literature on the problems of aviation and aviation. With his participation, the "Collection of Articles on Aeronautics" was published, and from March 1914, the magazine "Automotive Life and Aviation" was published. In Kharkiv, since September 1911, with the participation of the members of the Aeronautical Department of the Kharkiv RTT Department (chairman G. Proskura), the monthly aviation magazine "Heavier than air" was published.

Kyiv designers, working on the thorough development of the first aircraft, promoted their exclusive technical innovations in the latest aircraft models. Thus, O. Kudashev, in the design of another aircraft "Kudashev-2" (1910), installed a heavier engine ("Gnome" at 50 hp) and first stagnated the arc landing gear. This type of chassis was immediately proposed by the French for their airplane "Duperdussin", as it was widely used in flight [6, p.29].

Glorious aircraft designer I. Sikorsky, creating his own flights, consistently recognized the reliability of their design, the safety of airplanes and the comfort of passengers. "The first time I was able to rise was on the 16th of November 1910 on the BIS-2 (S-2) biplane and the advanced structures became more thorough. On the plane - S-5 12 June 1911 r. I. Sikorsky made flight with a passenger on board. He remembered: "I especially thought about the ways of increasing the reliability of flying pilots after the spring of 1911" [7].

All-worldly glory I. Sikorsky was brought the world's first powered giant – "Russian Vitiaz" (b. 1913). After the mechanical failure, 11th June 1913. (having hit the new one with the broken engine of another aircraft flying over it), creating a new gigantic aircraft. This flight under the name "Illya Muromets" with comfortable washrooms for 16 passengers first rose in the air in 1913. It were possible

thanks to structural improvements and new Argus engines of 140 and 125 hp, dated 1914. A whole series of flight records were set in terms of payload, height and flying distance. The following is supported by a fairly safe design of the airframe - when two motors are connected, the airborne motors are connected without losing height [6]. It was produced serially in a variety of modifications, such as a bomber and a hydroplane (B, V, D, E) until 1919. The significance of the particular (human) factor first began to emerge in the early 20th century. foreign fakhivtsi. In 1910 Previously, the German scholar G. Münsterberg formulated and vindicated the concept of "special factor" in scientific literature. In the Russian Empire since 1912. The training began to become a military pilot under the hour of flight, as you can see in the article "Psychophysiological state of aeronauts during flight," which was published in the "Military Collection" (1912, No. 3) [8].

At the dawn of the emergence of aviation in the large organizations of Ukraine, the human factor was given importance to respect, which later became important, especially after the creation of the dismantled air transport system. For example, in the KAS they expanded knowledge of overseas aviators, scientific and technical knowledge, discussed aircraft nutrition, including with the participation of military aviators, including the 7th Air Navigation Company. All flights that were completed by non-military pilots in Kyiv were performed on registered members of the KAS by the Sports Committee and with its permission [4, p.49].

During the First World War, the same military aviators also took care of the power supply for flights and the safe management of air flows. Illustrative in this regard is the activity of the artillery lieutenant P. Nesterov, who was born in 1910. saturated with aviation and in 1912 having given up the title of military pilot. During training flights over Warsaw, he showed his talent as an experimenter: having gained an altitude 1600 m. [9]. In his work "On the interaction of depth and direction rudders at significant roll

angles," P. Nesterov was the first to demonstrate the possibility of making turns with a roll of more than 45 degrees. Having become the commander of the 11th air squadron, he ordered the start of flights with deep turns and landing with the engine running in the designated area behind him. P. Nesterov 27 serpnya (9 vesnya) 1913 r. over the Siretsk military airfield, which became the first "dead loop" in the world and went down in history as the founder of great aeronautics. KAS awarded him a gold medal "For scientific solving the problem of controlling an airplane during vertical rolls and the willingness to sacrifice one's life for science" [4, p.46-47].

At the dawn of the emergence of aviation, there was a serious problem with the entry of the aircraft into a spin, which ended in disaster. This problem solved in 1916. commander of the military division at the Kacza military school of aviation K.K Artseulov, who has extensive theoretical knowledge of aerodynamics. The situation became even worse when in this section of 8 aircraft for flights, 6 broke in a short time due to a corkscrew. In October 1916 r. K.K Artseulov on the Newport-21 flyer ascended to an altitude of 2000 m, turning off the engine and flying into an overhead spin, and at an altitude of 600 m flying from a dive to a distance, successfully repeating the same maneuver. The impossibility of recovering from a spin was introduced into the aviation school program [3, p.74].

During the First World War, volunteer pilots transferred to military service, restored the army's crews for aircraft parts, which had already spent 3-4 months of the war on a large number of pilots were lost. [4, p.70-71,74].

***In the period from 1917 to 1920,*** all governments created in Ukraine at that time formed aviation units, but in fact aviation was used episodically and not effectively enough. Wear and tear of equipment led to numerous accidents. Only in 1918-1920, there were 420 disasters in which more pilots died than in air battles and from ground fire [10, c.85]. Flight safety issues have become relevant for all aviation countries of the world. Taking this

into account, in 1919 the non-governmental International Air Traffic Association was created in The Hague, which over the years was transformed into the International Air Transport Association (IATA). On the International Air Traffic Association first assembly in Paris developed the minimum requirements for an international standard aimed at ensuring flight safety. However, the draft convention prepared in 1925 was never signed.

The flight safety system at each new stage of the development of national aviation had its own characteristics. They were related to various types of aircraft, the level of their scientific and technical support, the qualifications of pilots and technical workers, controllers, airport equipment, the intensity of flights, the number of passenger and cargo transportations, etc.

**The 1920s and 1940s** became a new period in the activity of civil aviation in Ukraine. In the 20s, it was actually formed as a branch of the economy. The instruction of the Civil Air Fleet Inspectorate regarding the implementation of flights was developed from September 20, 1923 [5, p. 28-39].

The use of aviation gradually improved and expanded, especially in the 1930s, not only for the transportation of mail, cargo and passengers on domestic and international airlines, but also for use in medicine, rural, forestry and other areas of the economy, in sanitary and epidemiological, rescue measures, etc. A significant event in the history of domestic civil aviation was May 1, 1921, when the first regular mail-passenger airline was opened from Kharkiv, which was served by 5 Ilya Muromets aircraft.

Aircraft designers in Ukraine created new, safer aircraft. As a result of the increase in the production of aircraft of national design, primarily by designers K. Kalinin, V. Khioni, Y. Neman, V. Tairov and others, the process of ousting foreign airplanes took place. By the mid-1930s, their purchase was stopped. This was significantly facilitated by K. Kalinin's aircraft created from 1925 to 1938, from the K-1 to the K-23. Already in his first plane, the K-

1, he proposed the concept and main schemes of its design, which at that time were significantly different from traditional ones. As the design of the plane, a winged plane with an original elliptical wing was chosen, this gave a number of advantages. The smallest losses on vortex formation, increased lateral stability, reduced engine energy, which ensured higher speed and longer flight range. It was a breakthrough in aircraft construction. The effectiveness of this form was theoretically substantiated by the famous German hydro-aerodynamicist L. Prandtl. K. Kalinin's priority in the development of the design of such a wing was confirmed by a patent in 1923. He used chain-mail aluminium as the main structural material for the first time. K. Kalinin began to implement the idea of unifying his own designs, which made it possible to reduce development costs, increase its reliability and manufacturability, and make it easier for pilots to master new equipment. At the first air show for Soviet aircraft manufacturers in Berlin (October 1928), the Kalinin "K-4" won the main prize - the Gold Medal. The reliability of the K-4 aircraft was proven by the event when, in August 1929, during an ultra-long flight on the Kharkiv-Moscow-Irkutsk-Moscow-Kharkiv route (it was in the air for 73 hours and covered 10,400 km), the engine failed on its final stage, but the plane in covered 100 km in gliding mode and successfully landed at the Kharkiv airfield [11]. A special place among K. Kalinin's planes belongs to the K-5 plane (1929), which became the flagship of passenger aviation and operated until 1940. His giant K-7 plane, work on which began as early as 1929, was one giant wing (area 454 square meters), but although he was not happy, he was several decades ahead of his time in terms of his technical solutions. On November 21, 1933, during one of the flights, one of the tail beams broke and the plane fell to the ground from a height of about 100 m and caught fire. There were 20 people on board, 15 of them died. The established state commission did not find errors in calculations and construction [6, 113].

In Ukraine in the 1930s, civil aviation also used aircraft of other designs - PS-9 (ANT-9), P-5, ANT-35, Li-2, "Stal-2", "Stal-3" , U-2, amphibian Sh-2, etc. The network of Ukrainian airlines, which in 1940 reached 27.5 thousand km, was constantly growing. In 1936–1940 alone, more than 109,000 passengers were transported by planes of the Ukrainian Civil Aviation Administration [6, p.96-97]. Training of aviation specialists was carried out in the newly established aviation institutions, in particular the Kharkiv (1930) and Kyiv (1933).

With the appearance of new types of aircraft in the 1930s, the requirements for airfields increased. The increase in the weight of aircraft required, for safety reasons, to limit the height of obstacles in the airfield areas during take-off and landing. Therefore, the requirements for the approach angle were increased from 1/15-1/25 to 1/70-1/80 [4, p.173].

In 1923, the Society of Aviation and Aeronautics of Ukraine and Crimea - was established, with G. Petrovskyi as the chairman of the Council. [3, p. 111].

In parallel with the Council of Civil Aviation, the Civil Air Fleet Inspection under the Chief Air Fleet operated, and in March 1923, the joint-stock company "Ukrpovitroshlyah" (UPSh) was established, which became the first civil aviation company of Ukraine (1923-1930). The first Kharkiv–Moscow, Kharkiv–Kyiv, Kharkiv–Simferopol, Kharkiv–Odesa airlines began to operate on the planes purchased abroad from the Dornier company. The first international air route in Ukraine was opened in February 1928 along the Kharkiv–Baku–Enzeli–Tehran route.

The adoption of two air codes in 1932 and 1935 was of great importance for aviation activity and ensuring flight safety. In addition to the adoption of the codes, this stage is marked by significant rule-making in terms of regulating the main issues of civil aviation. Among the adopted documents are the Temporary Disciplinary Statute of the Civil Air Fleet (1939), the orders: "On the categorical prohibition of overflight of the sanitary norm of flight hours by pilots of the civil air fleet"

(1938), "On measures to combat accidents of the civil air fleet" ( 1940) and others. [5. with. 20].

In order to ensure the safety of civil aviation during this period, fairly high criteria were introduced for industry workers. In the first years of the formation of civil aviation in the Soviet republics, the main source of replenishment of its ranks with specialists of various specialties was military aviation, and the procedure for staffing was determined by a special instruction dated October 25, 1923. It provided for the selection of educated "military pilots" at the age from 21 till 40 years old for the position of civil aviation pilot, who are in good health, have flown on airplanes for at least 300 hours, have excellent knowledge of aviation technology, etc. [12, p. 44].

In the 1930s, the first pneumatic-hydraulic autopilots of the first generation of the AVP series were created (autopilot AVP1 in 1932), which were significantly improved over time.

In the 1920s and 1930s, it was difficult to ensure the safety of flights and prevent disasters. This was due to the fact that the flights took place in rather difficult conditions, there were imperfect means of navigation and communication, the lack of meteorological support for flights, etc. Therefore, it can be stated that, for example, on May 19, 1926, a passenger plane crashed in Kharkiv, which collided with a wooden building during descent. 2 passengers died, the pilot, mechanic and 2 passengers were seriously injured [13].

**1939 - 1945.** From the beginning of the Second World War until the attack of Nazi Germany, the civil air fleet of Ukraine as part of Aeroflot continued to carry out its peaceful work, carried out the transportation of passengers, mail and cargo, improved its infrastructure, developed medical aviation, cultivated agricultural land, carried out the fight against forest pests, locusts, aerial photography, etc. After Western Ukraine joined the Ukrainian SSR in 1939, routes were laid from Kyiv to Lviv, Ternopil, Stanislav (Ivano-Frankivsk), Rivne, and Lutsk. In

September 1939, the board of the main administration of the civil air fleet approved the "method of high-altitude flights" (from 3.5 to 6 thousand m)), which, as it noted, was "a great contribution to the struggle for safety, regularity, high speed and economy of flights..." [12, p.93]. In connection with the threat of military aggression were trained 10,000 pilots for the Air Force [14, p.4].

During the years Ukrainian civil aviation acted heroically from the first days of the war. During the war, the front-line units of the Civil Air Fleet, along with victories, suffered significant losses - more than 1,000 aviators and more than 1,500 aircraft [4, p.253].

Since many aircraft were damaged during the war, in 1942 a Scientific and Experimental Base was created for the repair of material parts of the Air Force. At the same time, the repair and technological department of the research institute of the civil air fleet began to investigate the causes of aircraft accidents, which contributed to a certain extent to the increase of flight safety.

In 1944, the International Civil Aviation Organization (ICAO) was established, which established international standards for ensuring the safety, reliability and efficiency of air transport.

Already the first standards and recommendations of ICAO on the investigation of air incidents were adopted by the ICAO Council in April 1951 in Appendix 13 "Investigation of aviation accidents" to the Chicago Convention. [1].

**The period from 1946 till 1990s** is considered the prime time of domestic aviation, when the aviation industry was re-equipped, it began to occupy key positions at the republican, all-Union and international levels, and significant measures were taken to ensure flight safety. Airplanes with turboprop and turbojet engines appeared on the air routes of Ukraine - a line of OKB Antonov aircraft - from An-2 to An-124 "Ruslan" and An-225 "Mriya", airliners Tu-104, Tu-134, Tu-154, Yak-40, Yak-42, Il-18, Il-62, etc. Mi-2, Mi-6, Mi-8, Ka-26, etc. helicopters began to be operated intensively. Already in the 1960s,

Ukrainian civil aviation took the first place in Aeroflot in terms of the number and length of air lines, the transportation of passengers, mail and cargo.

An important event for Ukraine was the accession of the USSR to the International Civil Aviation Organization (1970), which issued the first edition of the "Guidelines for the Prevention of Aviation Accidents" in 1984. In it, for the first time, the interaction of three groups of accident factors was considered: man, machine and the surrounding environment, and the "human factor" was recognized as a priority in the field of ensuring flight safety [8].

The improvement of the legal framework of flight safety is primarily associated with the adoption of the Air Codes of 1961 and 1983. They embodied all the main norms of air law, and most importantly, they increased the requirements for air transport and, first of all, in the matter of ensuring the safety and regularity of flights.

Ensuring the safety of civil aircraft flights is a complex problem that is solved by the joint efforts of all structures of the aviation and transport system. The first post-war decades were marked by a high level of accidents, when, according to ICAO, almost every thousandth flight in world aviation had serious safety problems, and among the main causes of events, the first place was occupied by the failure of aviation equipment [15, p.168].

In particular, the plane crash of the Il-18B passenger plane that occurred on August 17, 1960 in the Kyiv region (34 people died) was caused by a violation of the tightness of the fuel nozzle in engine No. 4, which resulted in a burnout of the combustion chamber and oil cavity casing, which led to a fire. According to the results of the investigation, the fire partitions of AI-20 turboprop engines were replaced with titanium ones, and the material of the pipelines was replaced from duralumin to steel, and the industry began to produce aircraft with the specified changes [16]. In the process of operation, the AI-20 engine of the designer O.I. Ivchenko reached an aircraft

engine resource unmatched by anyone anywhere in the world - 8,000 hours between repairs and 22,000 (!) hours in total [17].

In the 1950s and 1990s, the activities of workers in the aviation industry to modernize aviation equipment and ensure flight safety, minimize risks in aviation, because in this field it is still relevant to achieve a zero option for the elimination of aviation accidents. Innovative achievements of designers, scientists, engineers, and experts made it possible to reduce the probability of accidents in world aviation to one per 100,000 flights by the 1970s [15, p.169].

A significant role in ensuring flight safety was played by test pilots who "examined" new flying machines in various conditions and modes. Among the representatives of this dangerous profession, a special place belongs to the Hero of the Soviet Union Yu.V. Kurlin, Hero of Ukraine with Order No. 1 "Golden Star" O.V. Galunenko, his son test pilot E.O. Galunenko and others. In particular, Yu.V. Kurlin took part in the creation and testing of world-famous aircraft of the "An" family - An-2, An-8, An-10, An-12, An-14, , An-24, An-26, An -28, An-30 An-32, An-72, An-74, An-22 "Antey", An-124 "Ruslan", An-225 "Mriya". He made experimental landings with both engines stopped on An-24 and An-26; An-32 flights from high-altitude airfields in India; An-74 landings on frozen and wet runways; flights to study the behavior of the An-124 "Ruslan" in the wake of another aircraft and airdropping of heavy cargo; extinguishing fires on the An-32P in difficult conditions in Spain and Portugal, etc. [6, p. 203-204].

Test hero O.V. Galunenko set 263 world aviation records, including on giant aircraft An-124 "Ruslan" and An-225 "Mriya". His name is entered in the "Guinness Book of Records", and his activity was marked by the orders "For Merit", "Badge of Honor", "For Love and Faith to the Fatherland", "Equal-Apostolic Prince Volodymyr" [6, p. 308-309].

The flight practice of E.O. Galunenko includes mastering 20 types of aircraft. He, in addition to test flights, including in the conditions of the Far North, completed state

test programs for obtaining the Certificate of Suitability of An-74 TK-200, An-38-100, An-140, An-148 aircraft, making dangerous flights at large "angles of attack" and system failures in flight, etc. [6, pp. 310, 312].

Scientists, engineers and technicians of the Kyiv Institute of Civil Aviation Engineers, the Kharkiv Aviation Institute, employees of the Central Research Institute of Central Asia, as well as military aviation specialists worked quite actively and fruitfully on the issues of ensuring flight safety. In the 1970s, 23 industry research laboratories operated only in Kyiv Institute of Civil Aviation (KIICA) [18, p.163].

During this period, the main scientific directions were formed at the Kharkiv Aviation Institute. On the basis of theoretical research, innovative structural and technological solutions for aircraft were developed by DKB Antonov O.K., Tupoleva A.M., Mikoyan A.I. The very concept of "constructive-technological solution", which reflects the essence of the development of parts and aggregates from composite materials, was first formulated in the works of the KHA school and subsequently became generally accepted [19, c.99].

The mass use of gas turbine engines in civil aviation exacerbated the problem of ensuring the reliability and durability of aircraft engines. In this regard, a group of KIICA scientists under the leadership of Professor L.P. Lozytsky in the early 1960s created mathematical models of the operational behavior of structural elements, which became the basis for practical calculations of durability assessment, operational resources of a wide range of parts and programs equivalent to cyclic tests of engines. This prompted the leadership of the Ministry of Civil Aviation in the mid-70s to create a branch research laboratory at the institute for the further development of methods for diagnosing and managing the technical condition of aircraft engines [20, p.11].

Since 1955, professor T.M. Bashta began to deal with the fundamental problems of

industrial hydraulics and pneumatics at KIICA Tower. Many innovative developments developed in the scientific laboratory created by him were put into practice. In particular, recommendations were developed for the transition to operation of the hydraulic equipment of the Tu-134A, Tu-154B, Yak-40, Yak-42 aircraft, and the developed tactical and technical requirements for hydraulic systems of supersonic aircraft were used in the creation of the Tu-144 supersonic aircraft [21, p.25]. Proposed and created for the first time in the world by T.Bashta, the system of automatic spin-up of the wheels of the landing gear in the air before the revolutions of the start of landing made it possible to avoid hydraulic shocks and yuzu of aircraft [Founder of Ukrainian hydraulics// Government courier.-2019, February 9]. 5 chief designers of aviation equipment and many scientists and specialists graduated from the scientific school of M. T. Bashta [20, p.25].

Research by a group of scientists of the problems of theoretical and applied aerodynamics (the founder of the direction is professor A.M. Mkhitaryan), in particular in the field of the theory of laminar and turbulent intermediate layers, semi-confined and immersed jets, was aimed at improving the take-off and landing characteristics and lightning protection of aircraft, increasing flight safety and environmental cleanliness. Their scientific achievements were taken into account in the practical activities of the aviation and other branches of the country. [20, p.19].

In order to increase the safety of aircraft flights in the 1970s, under the leadership of Professor V.O. Kasyanov, research on flight dynamics, flight simulation, and identification of flight models began. Representatives of other countries took part in the research alongside KIICA scientists [21, p.7].

The scientific researches of other leading scientists of KIICA - professors V.O.Ignatov, V.S.Novykov, A.O.Komarov, L.P.Lozytskyi, Zh.S.Chernenko, F.K.Hermanchuk and others contributed to ensuring aviation safety. They

created new methods and optimal strategies for maintenance of aviation equipment "as is" on controlled An-24, Il-18, Yak-40 aircraft. In 1963, the first textbook for students "Technical operation of airplanes, helicopters and aircraft engines" was published (authors V.M. Suharnikov, F.K. Hermanchuk, G.N. Heletukha, M.F. Davidenko [20, p.9]

The problem of the failure of aircraft braking devices, which led to a significant number of aviation accidents, was solved by the participants of the scientific school for researching the state of friction materials and developing optimal methods of maintenance of aviation braking devices (founder F.K. Hermanchuk). The work of the scientists was implemented in the production of braking devices of all types of civil aviation aircraft and used during the development of the Buran program [21, p.7].

To increase the efficiency of operation of aviation radio-electronic equipment in the early 1960s, a branch research laboratory was created, in which, under the leadership of Professor L.Ya. Ilnytskyi and Associate Professor V.V. Kazimirchak developed a method of experimental operation of radio beacons of the short-range navigation system. Theoretical and experimental research, a significant part of which was carried out by Professor V.S. Novikov, encouraged the creation of a new progressive schedule-calendar system of operation. One of the important results of the scientists' research was the adoption in 1986 of the main regulatory and technological document "Guidelines for the technical exploitation of the means of radio-technical support of flights and telecommunications in civil aviation" using the new ICAO requirements [21, p.7,19].

In order to solve the problems of structural and parametric synthesis of radioelectronic systems, including of aircraft landing systems, professor V.P. Kharchenko proposed theoretical principles related to the functional description of dynamic systems. The properties of the ergative system "dispatcher-pilot-radiolocator" were

experimentally studied. The results of the research were widely used in the implementation of research and development works in the country [21, p.19].

Taking into account the statistics about a significant number of lightning strikes on planes in non-thunder clouds, the team of the department of aeronautical systems. In the 1980s, V.P. Kharchenko investigated the possibilities of finding zones of increased electrical activity in clouds that could not be considered as thunderstorms, and developed a complex active-passive method for remote detection of the electrical structure of cloud cover from an airplane [21, p.19].

The transition in civil aviation to the operation of multi-seater aircraft, a significant increase in their altitude and flight distance, the regularity of flights, flights in different climatic zones led to the actualization of the third group of emergency factors - the environment, which involved taking into account the impact of various adverse weather conditions on aircraft (icing, thunderstorms, torrential rainfall, wind shear, etc.). Considering this, professors V.O. Kasyanov, V.S. Maksimov, E.P. Udartsev and other KIICA scientists, thanks to experiments on the TAD-2, the largest direct-flow wind tunnel in Ukraine, began to study such risks for aviation, solved the problems of safe flight in conditions of wind shear and the influence of other external factors, optimal piloting, etc. [20, p.19; 21, p.14].

An important factor in increasing the regularity and safety of flights was the equipping of the main airports in the late 1960s with new SP-50 "Materik" landing guidance systems and the equipping of airfields with modern radio-technical means of navigation and landing [4, p.351,353].

The scientific group under the leadership of the head of the branch scientific research laboratory V.M. Sukharnikov for the first time considered the problem of the human factor in the maintenance of aircraft [21, p.6].

This problem appeared especially in the 1960s, when the "contribution" of human errors to aviation accidents was estimated at

approximately 20%, and in the 1990s, this figure increased 4 times to 80% [8].

Despite carrying out significant work to ensure flight safety, flight accidents with serious consequences occurred in a number of units due to the fault of personnel. To overcome this, in 1971, the new "Instructions for Flight Performance in Civil Aviation", "Regulations on Assigning Classes and Issuing Certificates to Flight Crew of Civil Aviation" and others were put into effect. Measures aimed at increasing the efficiency of the use of aviation simulators were carried out. Work on the creation and improvement of flight simulators and simulators was started back in 1957 at the Kyiv Aviation Institute by Academician O.I. Kukhtenko, continued in the following decades [21, c.26].

In practice, emergency events did not stop, and in the early 1970s there was even an outbreak of them. After the crash of the An-10 passenger plane, the operation of this type of aircraft was stopped (except for transporters) [21]. The investigation of the flight events showed that the main reasons for the accident were insufficient preparation of crews for flights in difficult conditions, violation of flight rules, indiscipline of crew members and other aviation specialists, "fatigue" of metal, etc. It also became clear that the aviation equipment had begun to be inferior to foreign models in terms of its level and was often of low quality. Ten bulletins for their modifications followed the new aircraft leaving the industry (in 1973, there were 239 bulletins for the Tu-134, 174 for the Yak-40, and 629 for the An-24). During the same year, 75.2% of the prerequisites for flight accidents and incidents were registered in the Ukrainian administration for technical reasons, 290 engines were removed ahead of schedule [4, p.366]. The issues of flight safety were presented at all levels - from the Management Board to the air squadrons, and the proposals of the airlines became the basis of the developed measures to ensure flight safety at each flight squadron. Also in 1973, the State Commission for the Safety of Civil Aviation Flights and the State Aviation Register - the



State Aviation Registrar were created under this commission. These bodies were entrusted with the supervision of ensuring the safety of civilian aircraft flights, the compliance of ships, airports, air routes and their regulatory actions with the norms, etc. [4, p.366].

Especially few measures to help flight crews have been established at airports developed by scientists for automatic landing of aircraft according to ICAO categories, since the biggest accident occurred during take-off and landing, when the time needed to make a decision was very small. The measures taken, including the adoption the new Disciplinary Statute of aviation employees, gave a certain positive result - in the mid-70s, the number of aviation accidents decreased by 1.5 times [4, p.377].

Thus, in the 1950s and 1990s, during the unfolding of the global scientific and technological revolution, the civil aviation of Ukraine, having a powerful material and technical base, an appropriate regulatory and legal basis and highly qualified specialists, achieved significant success in its development, did a lot to ensure safety flights.

***The modern stage of ensuring the safety of Ukrainian civil aviation flights*** begins on August 24, 1991, when the Act on the State Independence of Ukraine was adopted and which initiated a new, independent period in the development of domestic civil aviation. On September 9, 1992, Ukraine became the 172nd member state of the International Civil Aviation Organization (ICAO), then a member of the European Civil Aviation Conference (EECA), the European Organization for the Safety of Air Navigation (Eurocontrol), the World Federation of Unmanned Aviation (UAV), etc. The key direction was the global integration of civil aviation of Ukraine into the international aviation community, entry into the Common Aviation Area (CAA) with the European Union (EU). In sovereign Ukraine, the national system of state management of civil aviation, its infrastructure, the regulatory and legal system, etc., were consistently created. Thus, in 1992, the State

Administration of Air Transport of Ukraine was created as part of the Ministry of Transport of Ukraine, in 1993 the Air Code of Ukraine was adopted, and in 2011 its new edition (with changes in 2012-2023), in 2009 the Concept was adopted The State Targeted Flight Safety Program for the period until 2015, a new version of the Law of Ukraine "On the State Program for Civil Aviation Safety" (2017), the Aviation Transport Strategy of Ukraine for the period until 2030 (approved in 2018), the State flight safety program (2021), which took into account ICAO, European Union, ECAC, Eurocontrol standards, as well as changes in the norms of Ukrainian legislation, etc. In the mentioned Law, it was noted that the main task of the Program is the distribution of responsibilities, establishing rules for the implementation and implementation of measures to ensure the aviation safety of passengers, aviation personnel and personnel involved in aviation activities, aircraft, property transported by aircraft, objects of aviation activity subjects regardless of the form of ownership and subordination. Since 2013, the activity of the National Bureau for the Investigation of Aviation Events and Incidents with Civil Aircraft (NBICA) has been introduced, which prepares conclusions and recommendations, summarizes data related to flight safety, etc. The Air Code of Ukraine states that flight safety is one of the components of the aviation safety system and gives an interpretation of the concept of "flight safety": it is "a state in which the risk of damage or injury is limited to an acceptable level." In addition, it stipulates that subjects of aviation activity, regardless of the form of ownership and subordination, must form aviation safety services [23, Art. 1.21, 85.6].

According to the Regulation on the State Aviation Service (2014), among its main tasks is the implementation of comprehensive measures to ensure flight safety, aviation, environmental, economic and information security. It also emphasizes that "the basis of flight safety management is a systematic approach to identifying and eliminating

sources of danger and implementing risk control to ensure flight safety in order to minimize human losses, material, financial, environmental and social losses" [24].

In the first years of Ukraine's independence, as a result of demonopolization of industry-wide and interregional structures, a significant number of small airlines emerged in the country (in 2001, there were about 100), whose fleet of aircraft sometimes did not exceed two or three machines. In the pursuit of profit, new air carriers often violated operational restrictions and deteriorated the quality of aircraft maintenance. All this led to a decrease in the level of flight safety and awareness of the need for appropriate reforms.

Solving the issue of updating the flight fleet, Ukraine continued to develop and create new aircraft - An-32P, An-38, An-70, An-140, An-148, An-158, An-178, An-132D, modifications of the An-74TK-200, An-74TK-300, which met international requirements for the safety of aircraft operation, and also began to operate foreign liners of well-known airlines. In addition, the domestic aviation industry began to take part in cooperation with foreign partners to a greater extent. With the adoption in December 1996 of the Concept of Development of Civil Aviation of Ukraine, the second stage of development and formation of the aviation industry of Ukraine actually began. It is characterized by reforming and improving the system of state management of civil aviation, increasing measures to ensure flight safety, creating new national aviation legislation in accordance with international legal norms and rules.

After the establishment of the regional European Regional Center for Aviation Safety at NAU in 1996 by the decision of the ICAO Council, in 2002 the second such ICAO center was opened - for the training of state inspectors for flight safety and airworthiness of aircraft. The following year, in order to ensure the coordination of training and retraining of security specialists, the ICAO Institute was created at NAU. In modern conditions, the international aviation

community (ICAO, IATA, Eurocontrol and other organizations) pays special attention to the "flight safety culture", the most influential components of which are organizational, professional and national cultures. ). The "safety culture" is understood as the professional and psychological training of aviation personnel, the main purpose of which is the internal need to fulfill the established norms of aviation safety, which guarantees awareness of personal responsibility and self-control during work that affects flight safety]. In the ICAO Aviation Safety Management Manual (DOC 9859 AN-474), it is noted that the "human factor" is directly influenced by the working environment (right working environment) and a positive culture of flight safety [25].

In this regard, the Corporate Culture Procedure in the State Aviation Service of Ukraine was developed and approved (February 14, 2022 No. 1-560-22), as well as the Manual on the procedure for the adaptation of newly appointed employees of the State Aviation Service was approved (August 2, 2022 No. 1-1068-22).

The decrease in the number of aviation accidents was not so fast, and their fate as a result of human error was increasing. If in 1996 it was 70-75%, then according to ICAO documents, 85% of air accidents are the result of the human factor [27, p.197].

However, increasing attention to safety in aviation gave positive results. In 2017, the world had the lowest number of plane crashes with victims, and in Ukraine, if in 2017 there were 5 crashes, 3 accidents, and 4 incidents, then in 2021, respectively: 2, 1, 2 [28].

In 2022, according to the information received by the NBICA from the subjects of aviation activity until February 24, 2022, there were 3 aviation incidents with Ukrainian-registered aircraft - two of which were in Ukraine and one incident outside its borders. All events occurred for different reasons, but, according to the authors of this analysis, the categories associated with the occurrence of aviation events remain unchanged over the years. These are aircraft rolling off the runway,

collision with obstacles during low altitude flight and failure or failure of power plant systems/components [29]. Among the important achievements of 2022 in the field of air transport of Ukraine was the adoption of the Law of February 17, 2022 No. 2067-IX, by which Ukraine ratified the Agreement with the European Union and its member states on the Common Aviation Area (CAA). In light of international incidents, such as the disappearance of Malaysia Airlines Flight MH370 Boeing 777-200ER on March 8, 2014, en route from Kuala Lumpur (Malaysia) to Beijing (China) over the South China Sea, ICAO implemented a new a standard requiring all commercial aircraft to report their location every 15 minutes to air traffic controllers regardless of origin. The regulation, introduced by the ICAO in 2016, initially did not extend to the installation of any new aviation equipment. The standard is part of the long-term plan of the Global Aviation Distress and Safety System (GADSS), which requires new aircraft to be equipped with data transmission systems that are in constant contact with air traffic controllers [30]. Even after the annexation of Crimea, Ukraine took measures to ensure the safety of flights over the Black Sea (the airspace over the Autonomous Republic of Crimea and its territorial waters was closed to aircraft flights). Thus, the European Aviation Safety Agency (EASA) published in 2020 the updated Flight Safety Information Bulletin EASA SIB 2015-16R3 (Safety Information Bulletin) regarding the safe use of 6 routes that do not affect the territory of the ARC (L851, M856, M860, M854, M435, M861) and which EASA recommended to airspace users to use for flight planning over the Black Sea, where responsibility for air traffic maintenance is delegated to Ukraine [31].

In Ukraine, work on scientific and technical support of flight safety continued, even with a decrease in funding for the aviation industry. For example, it turned out to be the second country in the world (the first was the USA), whose designers created a aircraft collision avoidance system SPZ-2000.

This idea was implemented in 2003 by the Kyiv Research Institute "Buran", which develops avionics for civil and military transport aircraft. Without such equipment, starting from 2003, all aircraft flights were completely prohibited by ICAO decision [32].

The events of February 24, 2022 fundamentally changed Ukraine's aviation development strategy and caused the closure of airspace for civilian purposes for an indefinite period. Some air carriers managed to evacuate their fleet of aircraft abroad, while the fleet of other airlines was forcibly "landed", is in conservation according to the regulations in closed Ukrainian airports and is waiting for the resumption of flights. The state of war in Ukraine caused a change in the determining priorities and long-term plans for the development of aviation, the provisions of which were regulated by the Aviation Transport Strategy until 2030. In particular, a new classification of airports was formed according to the level of damage caused [35].

Ukrainian airports actively cooperate with the EU, studying the needs and expectations of carriers. According to the Aviation Committee of the Chamber of Commerce and Industry of Ukraine, there is a great demand from foreign airlines, which is confirmed by the fact that only 9 out of 63 airlines left BSP Ukraine. The activity of our airports at international events stimulates air carriers to plan their return to Ukraine [36]. In modern conditions, while a full-scale war is going on, civil aviation of Ukraine, as noted by the Deputy Prime Minister O. Kubrakov, is focused on three priorities: the preservation of highly qualified aviation personnel, maintenance of aviation infrastructure in proper condition and deregulation of the industry within the framework of the previously initiated reform [37].

The head of the State Aviation Service of Ukraine, O. Bilchuk, said that in order to ensure the protection of civil aviation, the territory of Ukraine and the airspace above it are classified as conflict zones with a high degree of risk to aviation safety by order of the State Aviation Service dated 04.07.2023 No.

438. This is due to the presence on the territory of Ukraine of real threats to aircraft and personnel of civilian airports/airfields caused by the full-scale military invasion on the territory of Ukraine ( shelling of populated areas, destruction of civilian objects and critical infrastructure objects, etc.) [ 38]. A significant event for civil aviation was the adoption of the Law of Ukraine dated March 21, 2023 (No. 3007-IX) "On Amendments to Certain Legislative Acts of Ukraine for the Purpose of Development of General Purpose Aviation, Adaptation of Ukrainian Legislation to European Union Legislation in the Field of Civil Aviation, establishment of additional mechanisms for effective control over ensuring aviation safety and deregulation of economic activity in the field of civil aviation". The changes provided for in it are aimed at simplifying access to the markets of air transportation and ground handling services

by adapting the legislation of Ukraine to the legislation of the European Union in this area, as well as enshrining at the legislative level additional measures to increase the level safety of aviation.

**Conclusions.** Thus, at all stages of the more than 100-year history of civil aviation of Ukraine, various measures were constantly taken to ensure aviation safety&security and minimize risks in aviation, especially since the second half of the 20th century. Innovative achievements of designers, scientists, engineers and technicians, training of highly qualified aviation specialists at the national and international level have become the achievement of global aviation. The integration of domestic aviation into the European and world community contributed to the strengthening of aviation safety&security in Ukraine.

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