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Review paper

Bird Collision Prevention Systems in Passenger Aviation

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Abstract. The purpose of this article is to present the results of a preliminary analysis of modern methods for preventing collisions between birds and aircraft. The focus was in particular on methods that enable defining the level of threat in passenger aviation and existing solutions for eliminating these threats. The first section defines the level of the existing threat of collision with birds for civil aviation on the basis of collision statistics based on collision reports submitted by pilots. The second chapter describes normative documents on methods intended to reduce the risk of collisions with birds, such as aviation rules and regulations, passenger aircraft certification, bird detection and deterrence systems, procedures of flight crews and air traffic controllers, and the development of bird detection and deterrence methods. Based on the analysis of existing solutions, the third chapter proposes a block diagram of an on-board system reducing the risk of aircraft collisions with birds by determining the level of collision risk and transmitting information about the risk level to the flight crew in order to reduce the effect of surprise among pilots, improve the accuracy of the statistics and operational safety by carrying out a technical inspection of the aircraft after the collision. The final chapter contains conclusions.
Key words: collision, detection, deterrence, aircraft

1. INTRODUCTION

Collisions with birds pose a significant threat to air traffic safety. This article presents an overview of the statistics, aviation regulations, bird collision prevention systems and procedures of flight crews and air traffic controllers, as well as an analysis of existing solutions. The first chapter contains statistical data related to collisions between birds and civil aircraft. The second chapter describes current collision prevention solutions, i.e., aviation regulations, aircraft certification process, flight crew and air traffic controller procedures, bird detection and deterrence systems. It also takes into account the technological development of bird detection and deterrence methods along with an analysis of existing solutions. The third chapter describes the block diagram of the on-board system, which would determine the level of threat of collision with birds and provide information on the level of threat to the flight crew. The fourth chapter contains the conclusions.

2. STATISTICS OF COLLISIONS WITH BIRDS

The International Civil Aviation Agency (ICAO) imposes a requirement for flight crews to report collisions with birds after each incident [1]. So far, about 47 civil aviation disasters have occurred as a result of collisions with birds, in which a total of 242 people have died [2].

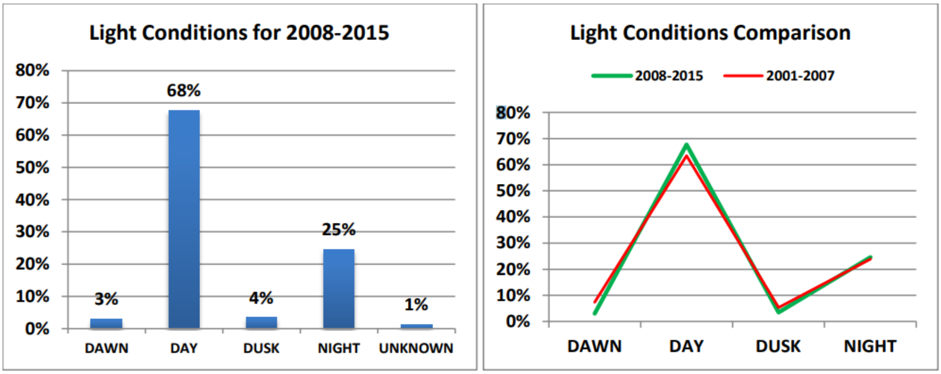


Fig. 1 Light conditions for collisions with birds [7]

In 2017, ICAO issued a bulletin based on pilot reports, presenting bird collision statistics between 2008 and 2015 in all member states [3]. The previous bulletin contained data from 2001 to 2007. A comparison of statistics shows that the number of reports submitted to ICAO concerning collisions with birds increased significantly from 42,508 to 97,751 cases. The number of actual collisions is much higher because the data show that in some member states as many as 75% of cases are not reported [4].

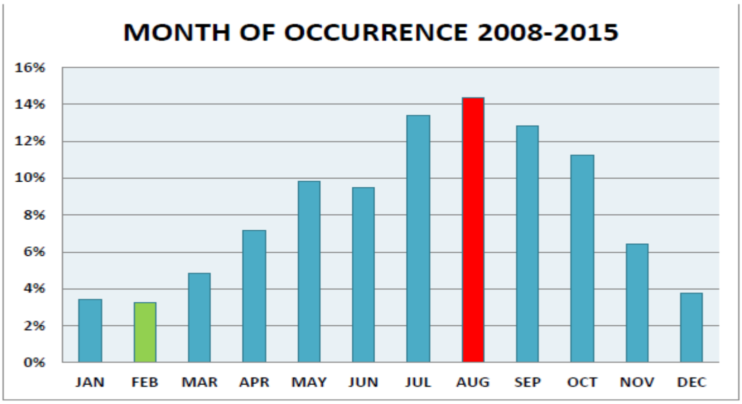


Fig. 2 Reports of collision with birds depending on the month [7]

This bulletin contains a statistical analysis on the basis of reports, the first category of which is the time of the day when the collision occurred. Approximately 68% of cases occurred during the day and 25% at night (Fig. 1). The data analysis also shows that the largest number of incidents occurred between May and October (Fig. 2).

Another category in the analysis is the flight phase during which the collision with the bird occurred. According to statistical data [3], 90% of collisions occurred in the vicinity of the airport, of which 59% during the approach and landing phase, and 31% during the take-off phase (Fig. 3). The last category was the impact of the collision on the flight (Fig. 4).

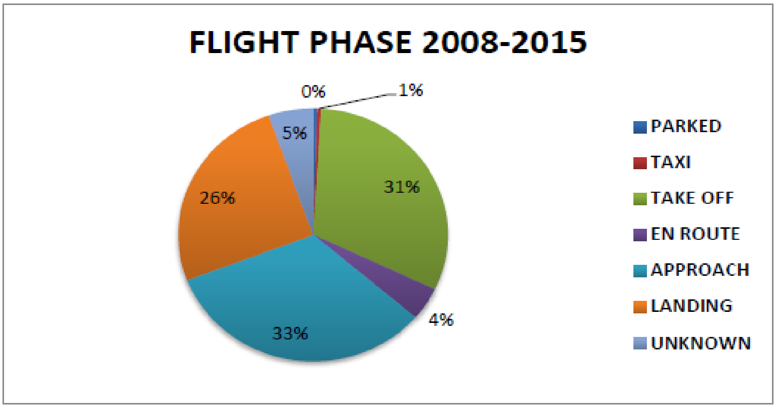


Fig. 3 Collision with birds depending on the flight phase [7]

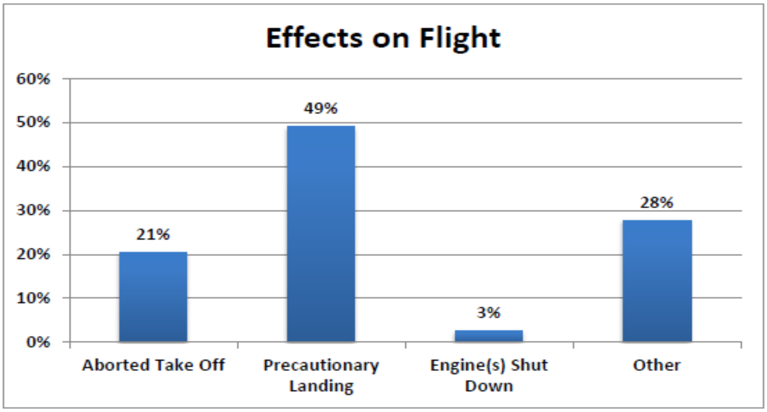


Fig. 4 Impact of collisions on the flight [7]

The most serious consequences are: interrupted take-off (21% of cases), precautionary landing (49% of cases) and engine(s) failure (3% of cases). The above analysis shows that collisions with birds pose a high threat to civil aviation.

3. SOLUTIONS TO PREVENT COLLISIONS BETWEEN BIRDS AND AIRCRAFT

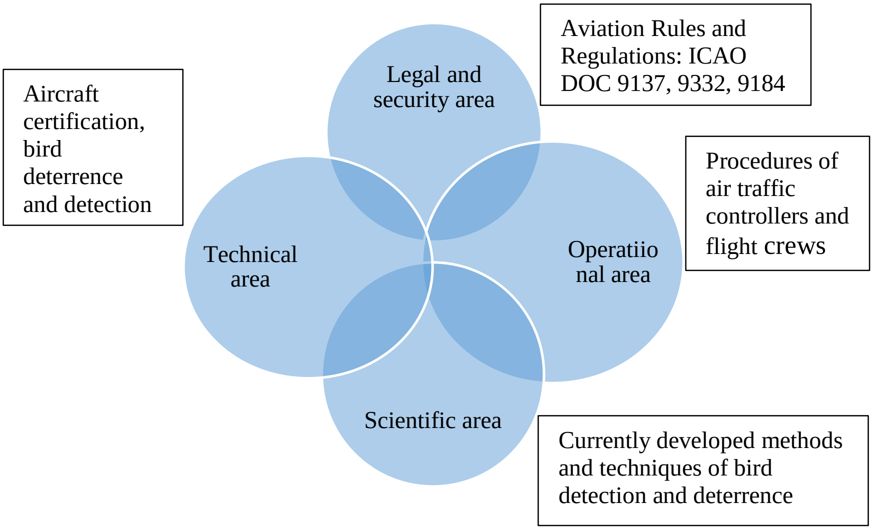


Fig 5 Division of solutions for bird collision prevention

There are many solutions that reduce the risk of collisions with birds. These solutions cover four primary areas (Fig. 5):

- legal and security area, including the most important provisions and regulations on the procedures of airport operators and the requirement to submit a report after a collision,
- technical area that includes aircraft certification and methods of bird detection and deterrence commonly used at airports,
- operational area that describes the safety procedures used by air traffic controllers and procedures used by flight crews in the event of a threat,
- scientific area that includes the current methods and techniques that have not yet been implemented and regulated by law.

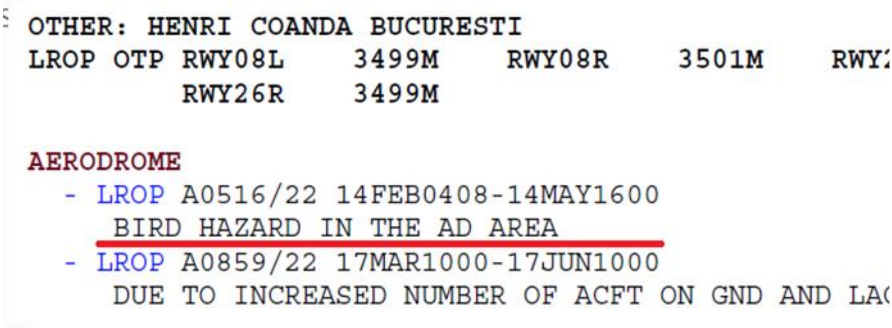
The article reviews the existing solutions and considers the effectiveness of their application. It also presents the concept of an on-board system for the detection of birds and determining the level of threat to increase the safety of passenger aircraft.

3.1. Legal and security area

In the authors' opinion there are three essential documents related to reducing the risk of collision with birds issued by ICAO. These are:

- Doc 9137 – “Airport Service Manual” [5], Part 3 – “Wildlife Control and Reduction”,
- Doc 9332 – “Manual on the ICAO Bird Strike Information System (IBIS)” [1],
- Doc 9184 – “Airport Planning Manual” [6].

The first of these documents by ICAO, Doc 9137, provides information for airport operators needed to develop and implement an effective control group of wild animals at the airport. The manual contains information on factors that determine the presence of animals at airports and presents the structure and composition of the national bird strike committee. In addition, the document contains modifications that can be made to airports to remove elements that can be attractive to animals. Through numerous records in the document, the airport operator is required to provide information about threats to the flight crew. Information about the threat from animals is transmitted by general aeronautical information, such as AIP ("Aeronautical Information Publication" [4]), NOTAM messages (Fig. 6), ATIS ("Automatic Terminal Information Service") radio messages [4] and directly by the air traffic controller [7].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AERODROME
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BIRD HAZARD IN THE AD AREA
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Fig. 6 Example of NOTAM with information about birds in the airport area

The information contained in AIP, NOTAM and ATIS is imprecise (no precise information about the location of birds at the airport) and short period of the usefulness of such information. Information about the threat from animals provided by an air traffic controller contains the latest data on the threat, but it is usually transmitted after a collision occurs at the airport. Before starting the landing approach, the crew obtains operational data and meteorological conditions at the airport using an ATIS radio message. Operating data includes information about the direction of the landing strip, the type of landing approach and threats, including threats caused by wildlife.

An example of information contained in ATIS about the threat from birds: “birds in the vicinity of the airport” or “flocking birds on airfield”. However, this information may also be outdated because an ATIS message is updated once every 30 or 60 minutes.

The second document, Doc 9184, describes the requirements for selecting the location and operation of the airport, taking into account environmental restrictions and threats (e.g., bird habitats). According to this document, the choice of location, size and configuration of the airport must be coordinated with residential, industrial, commercial, agricultural and other land use patterns, taking into consideration the impact of the airport on humans, flora, fauna, atmosphere, watercourses, air quality, soil pollution, rural areas and other environmental aspects. However, the choice of location does not provide full protection against threats [8]. Airports are usually located on the outskirts of large urban centres, surrounded by large areas of unused and undeveloped land. This acts as a noise and safety buffer for humans, but for birds it is often the only usable nesting space within many kilometres. Paradoxically, for some bird species, airport noise makes it an attractive location. The constant presence of humans and the intensity of sound deter large predators that threaten smaller species [9].

The third document by ICAO is Doc 9332, which describes the structure of the bird collision report and requires flight crews to submit a report after an incident. Despite the requirement to submit a report after a collision, statistical data show that only 25% of cases are reported by flight crews.

3.2. Technical area

Federal Aviation Administration (FAA) and European Union Aviation Safety Agency (EASA) issue regulations imposing aircraft certification requirements regarding collisions with birds [10]. Certification is carried out through ground tests using dead birds with a specific weight and quantity at representative impact velocities. Aircraft certification can be divided into two parts, i.e., engine certification and airframe certification.

3.2.1. Engine certification

Current standards for multiple and single bird strikes into a single engine in monoplane aircraft exist in equivalent form in FAA14 CFR Part 33-77 [11] and in EASA CS-E 800 Airworthiness Code "Bird Strike and Ingestion" [12]. It should be emphasised that there are currently no standards that would cover bird strikes into more than one engine of a multi-engine aircraft due to the very low risk (most passenger aircraft flights take place at a high altitude). However, the emergency landing of US Airways Flight 1549 on 15 January 2009, commonly referred to as "the Miracle on the Hudson" [2] showed that it was possible for a flock of birds to be sucked simultaneously into both engines of a passenger plane and resulted in a loss of thrust in both engines. Based on these experiences, the basic requirements for bird strikes into an engine were revised to take into account both the increased weight and number of birds, and the problems associated with the development of engines with a very large inlet and a high double-flow ratio.

Despite the revised certification procedure for passenger aircraft engines, there is still a risk of loss of thrust in both engines. An example of loss of thrust at low altitude caused by bird collision after the revision of the regulations is Ural Airlines Flight U6-178, Airbus A321-200 [1]. On 15 August 2019, the crew of flight U6-178 suffered a collision with birds shortly after take-off at 340 m. The aircraft lost power in both engines, which forced the crew to stop the aircraft climbing and land in a corn field 5 km away from the end of the runway, with the landing gear retracted.

3.2.2. Airframe certification

Current standards for single bird strikes into passenger aircraft are included in the provisions of 14 CFR Part 25-571 [11] as well as EASA CS-25.631 [12]. This means the aircraft must be able to continue its safe flight and landing after being struck by a 1.8 kg bird in the event of:

- collision at cruising speed, V_c (which is not exactly defined in the regulations, because each aircraft has a different cruising speed, usually defined in the flight manual),
- collision at a speed of 85% V_c at an altitude of 2400 m (8000 ft).
- collision with the windows directly in front of the pilots; the windows should withstand the collision without puncture by a bird weighing 1.8 kg moving at a cruising speed at mean sea level,
- collision with the pitot tube; the regulations require pitot tubes to be placed far enough apart to prevent damage to both sensors caused by a single bird strike.

In addition to the general requirements for collision with a 1.8 kg bird, there are no special certification requirements for fuel tanks and this issue requires improvement, as in many cases fuel tanks have been found to be punctured by birds [13]. The regulations do not specify the exact requirements for deterrence methods to be used at airports. There is no single solution or set of procedures that would be best for all situations. Each species of wild animal reacts differently to different deterrence methods [5]. Deterrence methods can be divided into sound, visual and chemical repellents.

3.2.3. Sound repellents

Pyrotechnic and bioacoustic solutions can be used at airports. Pyrotechnic materials are an effective method of repelling birds; however, they pose a potential fire hazard and must be used carefully in dry conditions [14]. Propane explosions are capable of producing sounds with an amplitude of approx. 130 dB. They can be programmed to fire at designated intervals and be remotely controlled or activated by motion; however, due to their stationary and predictable nature, wild animals quickly become accustomed to them [15].

Bioacoustic solutions are commonly used for bird deterrence by recreating the sound of birds warning about a threat. Most bird species respond to one particular sound and can still quickly adapt to it.

3.2.4. Visual repellents

Visual repellents (for example birds of prey, lasers, etc.) are commonly used by airport operators. Specially selected bird species [5] are used with high efficiency at airports. Airport operators must take into account the risk of knowingly releasing birds to the airport premises (birds should be released when there are no scheduled flights).

Lasers are successfully used to scatter several species of birds. Some species respond only to specific wavelengths [16], which translates into the effectiveness of the applied measures. Laser bird deterrence becomes more effective as light levels decrease. Improper use of lasers may pose a real threat to flight crews (e.g., blinding), and therefore, the potential risk should be considered before deciding on the location of laser deployment at the airport. An example is Southampton Airport, where laser equipment [17] are switched off beyond the altitude above which the laser poses a threat to the flight crew and the air traffic control tower.

3.2.5. Chemical repellents

Non-lethal chemical repellents work by affecting the senses of the animal, causing an aversion to the smell or taste. These repellents can be sprayed at nesting sites, food sources or other places where animals gather. Some chemical repellents (e.g., predator urine) may in fact attract other dangerous wildlife, and airports should be aware of the effects when using these repellents. In many cases, experiments with chemicals to deter birds have often failed [18]. The use of potentially toxic chemicals may also have legal (and ethical) complications. Therefore, it is not recommended to test and use chemicals to deter birds.

3.2.6. Detection methods

The airport operator is responsible for assigning staff to observe and report the presence of animals at the airport [5]. The main detection method used at airports is optical observation using mainly equipment such as telescopes and night vision equipment [19]. Alternative methods may be monitoring systems using cameras and radar [20].

3.3. Operating area

Preventing the risk of bird collisions and minimising damage is based on close cooperation with air traffic controllers and flight crews. Both the controller and the crew have appropriate procedures to provide information about the threat and post-collision procedures to prevent aircraft accidents.

3.3.1. Air traffic controller procedures

The direct authority responsible for preventing the risk of collision with birds at the airport is the air traffic controller appointed by the airport operator [5]. The task of the air traffic controller is to provide crews with information about the presence of birds at the airport via radio and ATIS messages. The controller should perform a periodic scan for the presence of birds at the airport using patrols or previously mentioned detection methods. The controller should also inform the airport operator about the presence of birds and, if necessary, introduce measures to deter birds before the aircraft takes off or lands [21]. In the event of a collision, the tasks of the air traffic controller are to separate the aircraft from other traffic, give priority to landing or exclude the runway from use if there is a collision on the ground, and inform the airport rescue services.

3.3.2. Flight crew procedures

The flight crew is directly responsible for flight safety. In the event of collision with a bird, depending on the technical condition of the aircraft (e.g., engine failure) and flight phase, the crew should interrupt the take-off, perform a precautionary or emergency landing and inform the airport services about the threat [5]. In the case of information about the presence of birds at the airport, the crew should consider delaying the take-off (if there is sufficient fuel for the flight) or take off from another runway [22]. In the case of a collision during take-off, the decision to abort or continue the take-off depends on the aircraft speed during the incident [23]. In the case of a collision below the speed of 80 knots, the take-off should be aborted, and in the case of collisions above 80 knots (if there are no direct indications of engine failure), the take-off should continue. In the case of collisions during landing approach, continuing the approach is the preferred solution [22].

3.4. Scientific area

In addition to the solutions presented in the technical area, there are still developing technologies that can be used to detect and deter birds and provide information on them to reduce the risk of collisions with birds.

The following methods and technologies are in the research phase and are not currently regulated by civil aviation organizations.

3.4.1. Telemetry and satellite imagery

It is possible to monitor the area around the airport using satellite images [24]. Satellite images allow airport operators to track changes around the airport that are favourable to wildlife habitats (e.g., expansion of wetlands and landfills). Satellite telemetry helps monitor animals from habitats that can enter the airport area. An example of the use of satellite telemetry is the analysis of Canadian geese movements from habitats around Midway Airport [25]. Based on recorded bird movements, it was determined that more than 60% of geese crossed the airport area from the monitored habitats. Satellite telemetry can help effectively reduce the risk of bird collisions by identifying the time, climate factors and locations leading to the disruption of flight operations.

3.4.2. Geographic information system

An alternative solution used by airport operators is the geographic information system used to manage and analyse airspace [26]. Much of the data collected from bird collision reports has a spatial reference (e.g., altitude at which the collision occurred). The use of geographic information system (GIS) for data analysis allows airport managers to assess patterns of wildlife sightings and control activities in relation to flight operations [27]. Collisions with animals can be linked to specific points, such as on landing approach, runways and airport areas, and then mapped using GIS to show the hotspots where collisions occur [28].

3.4.3. Radar systems

A bird warning system based on two radar equipment (one operating in the X band and the other in the S band) is presented in [29]. Further examples of the use of radar technology include such solutions as: Merlin produced in the USA, Accipiter in Canada and Robin in the Netherlands [30]. In 2010, the FAA conducted research to test the effectiveness of radars at airports [31]. These studies show that large single birds seen by observers on the ground at a distance of 4 km from the radar were tracked by the radar about 30 percent of the time [32]. Flocks of large birds, including those that were located several nautical miles away, were tracked by the radar 40 to 80 percent of the time. The results of these and other studies [33] suggest that radar may be a useful tool for monitoring the activity of bird flocks at airports, but to a lesser extent when monitoring large single birds.

3.4.4. Monitoring systems

Cameras monitoring the airport area may include thermal imaging cameras [5]. Data obtained from cameras is processed using appropriate software for image analysing and processing. Commonly used object detection algorithms are based on convolutional neural networks [34]. Bird detection also determines the position and species of the bird [35]. Information about these objects can be used in combination with other warning systems, including radar [36]. Frankfurt Airport is one of the airports where a camera-based bird detection system is used [37].

3.4.5. Unmanned aerial vehicles

Unmanned aerial vehicles (UAVs) are used as means for detecting and deterring birds. As equipment with cameras installed, UAVs can autonomously patrol specific areas of the airport [38]. UAVs are used to monitor hard-to-reach areas (e.g., roofs of buildings at the airport) [39].

3.4.6. Pulsating light on the airport and aircraft

Another method of deterring birds is the use of pulsating lights on aircraft and airports at a specific pulsation frequency. Birds can respond to a specific frequency of light pulsation and specific colours [40]. In 2010, tests [41] were carried out to check whether pulsating light would cause a faster response in birds compared to birds exposed to non-pulsating light. Of the species tested, only the brown-headed hawk [41] showed a faster response to pulsating light.

3.4.7. On-board detection and deterrence systems

The developed detection method is the use of on-board radar to detect birds in front of the aircraft [42]. One of the on-board deterrence systems is an ultrasonic bird deterrent system [43]. The on-board system involves the generation of ultrasonic waves in the direction of the aircraft approach to landing and take-off in order to repel birds [43].

4. SUMMARY AND PROPOSED SOLUTION

The statistics of collisions between birds and passenger aircraft presented in the first chapter show that the number of collisions is increasing. Despite the commonly used solutions described in chapter two, birds have been posing an increasing threat to air traffic. The section presenting the legal area and safety refers to regulations aimed at reducing the number of incidents.

Despite numerous requirements, the solutions in Document 9137 do not fully protect against collisions. Document 9137 requires flight crews to provide information about the threat through NOTAM or ATIS messages. However, the information contained in the messages is imprecise because it does not specify the exact location of the birds at the airport and have a short validity period. The solutions contained in Document 9184 do not have a major contribution to improving safety. Despite numerous indications in this document, such as where the airport should be located, animals quickly adapt to the prevailing conditions, such as noise, which translates into the safety of flight operations. Document 9332 imposes an obligation on crews to report collisions with birds; however, flight crews are not always aware of such incidents or intentionally do not report collisions, which has an impact on the statistics.

The technical area concerns the certification requirements for airframe and engines as well as common detection and deterrence methods. The disadvantage of this certification is the lack of defined requirements for fuel tanks, which are exposed to damage and failures, such as tank puncture leading to fuel leakage. The aircraft is tested in the event of failure of only one of the engines, while history shows that two engines may be damaged, indicating that this is another aspect that should be subject to certification.

Chemical repellents (described in chapter two) are under legal restrictions due to wildlife protection and are usually characterised by low repelling effectiveness. Visual repellents used on most airports are mainly based on the release of trained birds of prey over the port area, but the disadvantage of such a solution is the obligation to constantly care for the animal and control its activity. A less common method is the use of bird-deterrent lasers. Lasers are effective in deterring several species; however, their effectiveness decreases during the day, when bird activity is at the highest level.

A very dangerous aspect of laser use is the risk of blinding the crew, which directly affects flight safety. The most popular sound repellent is the use of equipment based on bioacoustic technology. The sounds are selected for a specific species, but birds have a high ability to adapt, so that method becomes less effective.

The primary and most common method of bird detection at airports is observation with the use of optical equipment. The operational area defines the procedures used by air traffic controllers and flight crews to prevent the threat. A collision between an aircraft and a bird leads to the application of specific procedures by the air traffic controller, such as excluding a runaway from use or giving priority to landing, which results in reduced safety for other participants in the air traffic. In the event of an incident, then all flight crews decide on what their further actions should be. Depending on the location of the incident and the aircraft speed, they interrupt or continue a given phase of the flight.

The section on the scientific area describes the development of technology in the field of bird detection and deterrence methods. The above-mentioned methods include radar systems, monitoring systems, satellite methods and telemetry. Radar systems are being tested at several airports. The research carried out in 2010 showed the low effectiveness of radar systems. Camera-based bird detection is now used at Frankfurt Airport, with insufficient data available to determine the system effectiveness. Satellite images and a geographic information system can be used to observe wildlife, analyse bird migration and predict collision sites. Data from telemetry equipment mounted on birds together with analysis of satellite images of the area around Midway Airport have expanded our knowledge about bird habitats in the vicinity of airports. Unmanned aerial vehicles can be used both to detect birds and to repel them, but this method is currently not utilised at airports. The technology that is currently being developed is a method for detecting birds using weather radar. Like the ultrasonic deterrent system, it has not yet been introduced to passenger aircraft. Both methods require further testing to determine their effectiveness.

Another method for deterring birds is the use of pulsating lights. These are installed at airports and on aircraft to emit a signal (light) at a specific frequency. The research carried out in 2010 showed an impact on only one bird species. These methods, such as telemetry and satellite imagery, geographic information systems, radar systems, monitoring systems, unmanned aerial vehicles, pulsating light at the airport and aircraft, and on-board detection and deterrence systems are not widely used. Therefore, they do not have an impact on air safety on a global scale. The statistics quoted clearly confirm that the highest number of incidents occur during the landing approach, at an altitude where all kinds of detection and deterrence systems are ineffective. Collisions with birds at critical flight moments at low altitude are very often unnoticed by flight crews. Lack of knowledge about the collision results in a failure to submit a report and the failure to perform a technical inspection, which may directly translate into the safety of subsequent flights. If the crew notices a collision with a bird, the "surprise effect" can drastically reduce the psychomotor skills and directly affect safety. With regard to the above analysis, a solution to improve the flight safety is the on-board system for monitoring the area in front of the aircraft during critical flight phases. The primary task of the system would be to detect birds, assess the risk of collision and provide the flight crew with information about the threat. System operation (Fig. 7) can be divided into stages:

1. Bird recording and detection

   The first stage includes recording the space in front of the plane and bird detection. The threat area is determined by the maximum distance from the aircraft and angles in vertical and horizontal planes in relation to the aircraft axis. The sensor should be able to record fast-moving objects in all lighting conditions throughout the designated area. The preferred sensor is a digital camera.

The camera should have digital stabilization, high viewing angle (64° - 84°) and high resolution (1920 × 1080 pixels or higher). Taking into account the flight speed of birds [45] (approx. 9-18 m/s) and the aircraft flight speed (about 60-80 m/s), the number of recorded frames per second should be between 30 and 60 fps [46]. The camera signal is transmitted to a computer (e.g., Raspberry Pi) to detect the object in real time image [47]. An effective solution for detecting objects in an image (including the determination of their position) is the use of algorithms based on convolutional neural networks [48]. Important factors that need to be taken into account during tests of the presented system are disturbances, such as vibrations and sudden changes in the aircraft position.

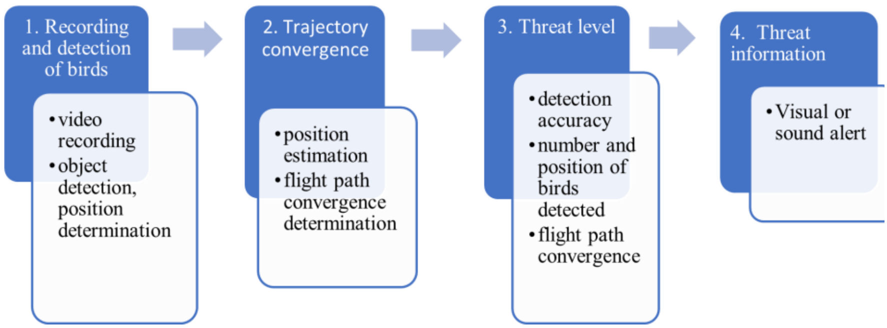

Fig. 7 Block diagram of the on-board system

2. Flight trajectory reconstruction

   The second stage is the synthesis of an algorithm (or exploration of existing solutions) capable of positioning the detected objects. The algorithm should be developed according to the assumed models of bird and aircraft movement. The position of the object relative to the aircraft will be used to determine whether the predicted trajectory of the bird is on a collision course with the planned flight path of the aircraft.

3. Threat level

   The information obtained in 1st and 2nd stages will be used to determine the threat level. The determination of the threat should depend on the number of detected birds, the accuracy of detection, the position of objects relative to the aircraft and the convergence of flight paths. The scale for determining the degree of threat must be defined.

4. Threat information

   The last stage is to provide information about the threat level to the flight crew in the form of a light or sound signal. Information about the threat together with recorded data should be saved on the equipment to verify the correctness of operation and possibly to modify the algorithm.

5. CONCLUSIONS

The statistics of collisions between birds and passenger aircraft show a growing trend. The current solutions do not contribute to a significant improvement in safety, and therefore the article proposes a concept for an on-board system, whose task is to inform the crew about the level of the threat of a collision with birds. Information generated by the system will contribute to reducing the surprise effect, which in turn will allow pilots to make better decisions earlier and increase the safety of flight operations. An additional advantage of the proposed system is the proposal to implement a technical inspection after the system detects the assumed level of threat, which will eliminate cases of overlooked damage when pilots are not aware of a collision.

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Systemy przeciwdziałające kolizji z ptakami w lotnictwie pasażerskim

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Streszczenie. Celem niniejszego artykułu jest przedstawienie wyników wstępnej analizy współczesnych metod przeciwdziałania kolizji statku powietrznego z ptakami. W szczególności skoncentrowano się na metodach, które umożliwiają zdefiniowanie poziomu zagrożenia w lotnictwie pasażerskim oraz istniejących rozwiązaniach eliminacji tych zagrożeń. W pierwszej części zdefiniowano poziom istniejącego zagrożenia kolizji z ptakami dla lotnictwa cywilnego na podstawie statystyk kolizji określonych na podstawie raportów składanych przez pilotów o zaistniałej kolizji. W drugim rozdziale opisano dokumenty normatywne traktujące o metodach umożliwiających ograniczenie ryzyka kolizji z ptakami takie jak zasady i przepisy lotnicze, certyfikacja samolotu pasażerskiego, systemy detekcji i odstraszania ptaków, procedury załóg i kontrolerów lotniczych oraz rozwój metod detekcji i odstraszania ptaków. W trzecim rozdziale na podstawie przeprowadzonej analizy istniejących rozwiązań zaproponowano schemat blokowy systemu pokładowego redukującego zagrożenie kolizji statku powietrznego z ptakami poprzez określenie poziomu zagrożenia kolizji oraz przekazanie informacji o stopniu zagrożenia do załogi lotniczej, w celu zredukowania efektu zaskoczenia u pilotów, poprawienia dokładności statystyk oraz bezpieczeństwa operacji poprzez wykonanie przeglądu technicznego samolotu po kolizji. Ostatni rozdział zawiera wnioski.
Słowa kluczowe: kolizja, detekcja, odstraszanie, samolot