

Applying non-lethal lasers and other techniques to dissuade birds from hitting and damaging the airborne aircraft

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ABSTRACT

Thousands of incidents of bird strikes with the airborne aircraft are reported every year across the world. Some of these incidents/accidents have caused a huge financial loss because of the damage to the aircraft. A few of such accidents have put the lives of the aircrew and the passengers to danger. In this paper, we have listed the major potential birds present in and around the airports, which are likely to strike the aircraft. Further, we have discussed in this paper: (i) what are the major attractions in and around the airport area for these birds to roost, settle and fly? (ii) What are the most likely timings in the day and the favourable situations which cause these birds to strike the aircraft? (iii) What steps should be taken for the landscape in and around the airports to make them unattractive for the birds? (iv) What should be the non-lethal non-laser as well as laser-based techniques employed to dissuade these birds from hitting the airborne aircraft? The laser-bird interaction studies, analysis and advantages have been discussed in more details in this paper. Finally we have reviewed the strategies to be adopted to tackle this menace of bird-aircraft strike more effectively in order to minimize such incidents.

Keywords: Bird hit, BASH, aircraft, lasers, non-lethal, accidents.

1. Introduction

When birds and aircraft occupy the same airspace at the same time, unpleasant things are likely to happen. In such a situation the 'aluminium birds' (aircraft) and some of the real birds are likely to collide with each other resulting into a 'lose-lose' situation (opposite of 'win-win' situation) for both the birds and the aircraft getting damaged. A bird strike is strictly defined as a collision between a bird and an aircraft which is in flight or on a takeoff or on landing phase. Bird strikes are a significant threat to flight safety, and have caused a number of accidents with human casualties. Most accidents occur when a bird (or birds) collides with the windscreen or is sucked into the engines of mechanical aircraft.

Birds pose a real threat to aircraft, particularly in the area of the airport and in the neighbourhood (from 75% to 95% of bird collisions with civil aircraft occur at the airport or close to it). Especially hazardous are big and heavy species of the birds, such as gulls and geese, and also small gregarious birds, such as starlings and swallows. Birds travel across the flight corridor to and from the roosting/feeding areas in the airport vicinity, causing a high bird-strike potential. Bird strikes may occur during any phase of flight but these are most likely during the take-off, initial climb, approach and landing phases because of the presence of greater number of birds in flight at the lower levels. Birds aggregate at runways, also fly over the airport and through the approaches. Typically, they fly at a height of 10-100 m, rarely 200 m above ground level. During migration they fly up to 500-1500 m high, occasionally even up to 6-8 thousand meters high. The probability of a bird strike is the highest where aircraft fly low and use the same space in the air and on the ground as birds do, thus in the area of the airport and in the nearest neighbourhood. 93% of the collisions occur during takeoff run, in the first phase of ascend, and in the final phase of landing on the airfield [1]. More than 80% of bird strikes occur below 300 m. Since most birds fly mainly during the day, most of the bird strikes occur in daylight hours or in twilight times in early mornings or in the evenings just before it gets dark.

A large number of BASH (Bird Aircraft Strike Hazard) incidents are being reported every year from all the countries causing damage to the aircraft and occasionally leading to the accidents. Modern commercial aircraft such as Boeing and Airbus have quieter engines than older aircraft which make the birds difficult to detect and

prevent bird strike. The first powered flight by the Wright Brothers occurred in December 1903, and the wildlife strike problem began shortly thereafter. On 7th September 1905, the first reported bird strike, as recorded by Oliver Wright in his diary, occurred when his aircraft hit a bird (probably a red-winged blackbird) as he flew over a cornfield near Dayton Ohio [2]. The earliest fatal airplane crash attributed to a bird strike took place seven years later, on April 3, 1912 [3]. Calbraith (Cal) Perry Rodgers, piloting a Wright Flyer over Long Beach, California, ran into a flock of seagulls, crashed the biplane into the surf, and was killed. Stuart Frost, a retired Pratt and Whitney engineer, narrated the account of an engine bird strike he experienced while traveling on a flight from Dublin to London on December 7, 1985 [3]. He was sitting near the front, with a good view of the Pratt and Whitney JT8D-9A left engine. After liftoff from Dublin Airport, the aircraft, with 117 passengers, encountered a flock of 20 to 30 black-headed gulls (weighing about 0.5 kilograms each) near the end of the runway. Several bangs were heard and the Boeing 737 aircraft yawed and buffeted. Frost heard a loud explosive noise from the left engine, as gulls were ingested. As the engine's fan blades broke, the engine almost immediately stopped, which forced two of the three engine mounts to fail. The now thrustless engine hung from the wing by one remaining mount and two thrust reverser hydraulic lines. However, with remaining thrust from the right engine (which had also ingested gulls), the pilot and copilot managed to make an emergency landing on an adjacent runway, with the left engine barely hanging from the wing. On 26th September 2017, an Air Asia Flight from Medan, Indonesia to Penang was forced to return to Medan after a bird was sucked into one of its engines. The airliner was carrying 150 passengers [4]. In 2009, minutes after takeoff from New York's La Guardia airport, US Airways Flight 1549 flew into a flock of Canada geese, and birds sucked into the two engines caused a complete loss of power. Captain brought the Airbus A320 down safely on the Hudson River, earning acclaim for saving the lives of the 155 people on board [5].

Although most collisions with birds do not end in a catastrophe, they pose a real threat to the life of people, and the financial losses they cause (when equipment is damaged or the course of flight is disturbed) are severe. On a world-wide basis, direct and indirect costs to the civil aviation industry owing to bird strikes exceed \$ 1.2 billion annually [6]. The nature of aircraft damage from bird strikes, which is significant enough to create a high risk to continued safe flight, differs according to the size of aircraft. Small, propeller-driven aircraft are most likely to experience the hazardous effects of strikes as structural damage, such as the penetration of flight deck windscreens or damage to control surfaces or the empennage. Larger jet-engined aircraft are most likely to experience the hazardous effects of strikes as the consequences of engine ingestion. Partial or complete loss of control may be the secondary result of either small aircraft structural impact or large aircraft jet engine ingestion. Many aircraft engines have decreased from four to two turbine engines, reducing aircraft noise levels and thus reducing the distances birds can hear planes approaching. Turbine engines are also more likely to ingest birds than piston engines, commonly used on older planes. These airplane modifications increase the possibility of bird strikes because birds mainly rely on sight and hearing to avoid colliding with airplanes [7]. Bird strikes occur at various wing and fuselage locations but they usually inflict most damage to the jet engines, composed as they are of intricate high-speed rotating parts.

Airplane damage and the effect on flight from bird strikes are closely correlated with kinetic energy derived from the mass (of the bird species) and the velocity squared. The military aircraft operations have a much bigger problem with damaging bird strikes than is experienced with civil transport aircraft operations. This is usually attributed to a greater proportion of flight conducted at low levels. Higher-speed jet propulsion itself has greatly increased the seriousness of bird strike damage, giving birds less time to avoid an approaching aircraft, with the resulting higher-speed impact causing much greater damage to both the aircraft and the birds.

Lasers have been used with success to disperse several species of birds. However, lasers are species-specific as certain species will only react to certain wavelengths. Lasers become more effective as ambient light levels decrease, thereby limiting effectiveness during daylight hours. Lasers are the most cost-effective, safe, and animal friendly (drawback: Weather/light dependent) to disperse a flock (average size of 20). In conjunction with Bird control vehicle, bird dispersal with almost close to 95% has reportedly been achieved. However, if not handled carefully, lasers can be hazardous to the pilot, crew and passengers in the aircraft.

2. Common Types of Birds Hitting and Damaging the Aircraft

Knowing the exact species of potentially hazardous birds provides guidance regarding the size, behaviour, and ecology of the bird in question. It is the key to tracking species trends as well as focusing on the preventive

measures. Species identifications provide the baseline data needed to plan their habitat management on airfields (that is, to make them less attractive as feeding and nesting areas) and to build avoidance programmes. These have also been used to assist engineers in designing jet engines that are more resilient to bird-strike events.

There is no airport free from the threats due to the presence of birds. For example, of the many resident bird species at the airport, black vultures have been found to pose the biggest risk to aircraft and passenger safety because of their large numbers, large size, and tendency to circle in groups on thermal columns above the airports [7]. All birds occurring near the runways and on the approaches to the airport can constitute a threat to flight safety. Even a small flock of starlings (*Sturnus vulgaris*) taking off the grass, a pair of kestrels (*Falco tinnunculus*) hunting every day for rodents near a runway, or several gulls flying a permanent route to foraging areas can damage an aircraft or threaten human life [2]. Especially hazardous are large and heavy species characterized by a high degree of inertia, such as birds of prey. Also small birds living in large flocks, such as starlings and swallows, belong to the same category. Obviously, the most dangerous are big birds occurring in large flocks, such as geese, ducks and herring gulls. Also body density is important. For example, the body of starlings is very dense; hence they are called “feathered bullets”. In many countries they cause the biggest problems at the airports. In Europe these are mainly herring gulls (*Larus argentatus*), great black-backed gull (*L. marinus*), lesser black-backed gulls (*L. fuscus*), common gulls (*L. canus*), and black-headed gulls. These birds easily adapt to man-made or man-transformed environments. They are indiscriminate foragers, and rapidly learn to use novel sources of food such as dumping grounds and crop fields. For the last 20-30 years, a significant increase in the number of some gull species has been observed on a regional scale. Gulls prefer vast open areas of airports, and treat them as a safe place where they can rest after foraging, bathe, or gather in large flocks before flying to roosting sites at night. They form large flocks on runways or in the adjoining expanses of grass. Gulls cause the greatest number of collisions with aircraft. In Britain, lapwings account for 11-12% of the collisions with aircraft. Generally, it is assumed that the flocks of gulls or lapwings occurring at the airport or close to it can cause a collision at any time. The next group is represented by waterbirds. It includes swans (*Cygnus* sp.), geese (*Anser* sp., *Branta* sp.), ducks, herons (e.g. grey heron, *Ardea cinerea*), and cormorants (*Phalacrocorax carbo*) – the heaviest birds. They like to visit bodies of water at airports (for example, storm water and fire control basins), drainage ditches, wet areas, and even larger puddles after thawing or heavy rains.

Some of the birds found in and around the airports in India are [8]: Black Kite, Black-winged Kite, Shikra, Buzzard sp, White-rumped Vulture, Booted Hawk Eagle, White-throated Kingfisher, Red-Wattled Lapwing, Yellow-Wattled Lapwing, Blue Rock Pigeon, Indian Roller, Crow, Indian silverbill, Little Cormorant, Myna, Ibis etc.

3. Attractions for the presence of Birds in and around the Airports

All birds need food, cover (including shelter, safety, places to nest, rest and roost) and water to survive. Design and management of the airport habitat are being done in such a way that these elements are eliminated or minimized, and thus it will reduce the local population of birds. Following are mentioned some of the attractions in and around the airports for the birds to be present and be the cause of their strike with the aircraft.

(i) Birds are attracted to airports because they view the vast airport area as a safe place for resting, gathering in flocks, or hiding from predators. Vast, open and flat area of an airport is very attractive to such birds as gulls, lapwings, starlings, corvids, and geese. Besides safety, birds can find food and water for drinking and bathing at the airport. The occurrence of birds at the airport also depends on the attractiveness of the neighbouring habitats.

(ii) Food of birds at airports mainly consists of scraps of unwanted food thrown into garbage bins, improperly stored food waste at fast-foods, restaurants, catering services, and grocery stores located at the airside zone or close to the airport. Especially, corvid birds take advantage of such places. Of great importance is additional food provided for birds by people at the airport.

(iii) Airfield grass spaces are inhabited by a variety of animals such as rodents, insects, earthworms, and other invertebrates. There are also different plants producing fruits and seeds, such as grasses and other

herbaceous plants, decorative trees and shrubs planted in groups or forming hedgerows surrounding the airport area [8].

(iv) There are also bodies of water such as basins for storm waters or for fire-extinguishing, drainage ditches, marshes, and water pools in or around the airports.

(v) Areas near the airports are often used by people for disposal sites of wastes, sewage treatment plants, industrial works, cremation grounds, throwing dead animals, and even meat-and-fish processing plants. Many of these objects can attract many birds including gulls and corvids.

(vi) Fish ponds are a very unfortunate investment near the airports. Food provided for fish attracts large numbers of ducks, and fishes themselves are staple food of cormorants, herons, ospreys, and white-tailed eagles.

(vii) The airports located in agricultural landscape are surrounded by different crops and plantations, including cereals and sunflowers that are very attractive to many small passerine birds. Some vegetables attract birds, for instance, cucumbers can attract gulls.

(viii) Crop fields during their ploughing, harrowing, sowing, and harvesting are abundantly visited by gulls and corvids. Orchards and plantations of berries, in turn, attract starlings, corvids, gulls, and numerous small passerines moving around.

(ix) Many airports are located on cheap grounds near wet areas, bodies of water, or sea coasts. These habitat types are preferred by water birds, waders, and their avian predators during the breeding season, local movements, and migrations.

(x) Off-airport sites in close proximity to airports have landfills, abattoirs, piggeries etc. This results in the increased number of birds in and around airports thereby increasing the probability of a strike.

(xi) Birds need shelters for breeding, resting, roosting at night, protecting against predators, forming flocks before migration, or for exchanging information and maintaining social bonds. Examples of good shelters are hangers in the airports, clumps of trees, groups of shrubs, dense shrubberies, reed beds, islets on rivers or lakes in the vicinity of airports etc.

4. Steps to Prevent the Birds perching and flying in and around the Airport Area

As it is essential that the 'aluminium birds' (aircraft) and the real birds are kept strictly separated, bird controllers take a wide range of measures to chase birds away and discourage them from roosting on the airport grounds.

The bird control program should be preceded by a study of ecology and behaviour of problem birds at the local and regional level. The first step towards effective bird control is answering the question why the birds are attracted to the airport. The answer will be provided by identifying to what extent the environment offers food, cover and water.

Following questions that should be answered before the strategy for the bird control is decided [9]:

- (i) Which bird species are causing the most damage to the aircraft?
- (ii) What is the legal status of the problem birds? Are these national birds or protected species etc?
- (iii) What are the daily movement patterns of the birds between their feeding, loafing and roosting areas?
- (iv) When are they most vulnerable in their movement cycles?
- (v) What effective and legal control methods are available?

- (vi) How selective are these control methods? The object is to control only the target birds, not all the birds in the area.
- (vii) How much will it cost to apply the selected control methods (also in relation to the costs of the damage)?

Following are some of the suggested **steps to prevent the birds** perching and flying in and around the airport Area:

- (i) Every airport administration should plant the surrounding area with special varieties of grass, bushes and trees that are unattractive to birds.
- (ii) The grass between the runways at the airport should be longer in height than we would normally see in a park or garden, kept approximately 12 to 20 cm high in the airfield. The airport administration should apply a special method to mow its grass to ensure that it is kept at the desired height. Birds don't like tall grass, as it makes it more difficult for them to find food and spot natural enemies, such as birds of prey.
- (iii) Study the trash problem in the communities surrounding the airport to find a solution that benefits residents of the communities surrounding the airport and the airport. Trash cleanup in the surrounding neighborhoods may be an effective and low cost solution to bird strikes because it will reduce the presence of vultures on and near the airport property. People living in the surrounding areas should be made aware of this menace of bird strikes and motivated to keep their area clean so that it does not attract any hazardous birds.
- (iv) The runway area should be kept dry by a special drainage system that prevents puddles from forming after rainfall since puddles also attract birds.
- (v) Closing of holes in buildings can solve many bird problems in a very simple manner.
- (vi) A promising technology for airports near wetlands is the use of overhead grid line systems. These grids of wires, suspended at least 1.5 meters above the ground, can cover lengths up to 675 meters. The wires deter waterfowl from landing and feeding in wetland areas near airports, without seriously damaging the surrounding environment.

Lastly, it should be noted that the bird deterrents are only a temporary bird strike prevention method because birds become acclimated to them.

5. Non-Laser Methods to scare away the Birds from hitting the Aircraft

Some of the proposed strategies to minimize bird strikes outside of the immediate airport environment include development of onboard systems that could make aircraft more visible to birds (thus, enhancing the probability of avoidance behaviours), such as modifications to lighting or paint schemes. If birds are alerted to the approach of an aircraft at a greater distance, avoidance maneuvers similar to those in response to aerial predators might be initiated sooner, thus reducing the risk of a bird strike [6]. Following are some of the non-laser methods to dissuade the birds from striking the aircraft.

(i) Audio Repellents: Birds are repelled or chased away by sounds producing equipment. The biological basis for the birds to leave is the startling reaction to sound, and the fear of potential predator. Most commonly used sound deterrents are pyrotechnics (cartridges, flares, electronic alarms), propane gas cannons or bioacoustics (pre-recorded distress calls).

(ii) Audible Microwaves: This approach involves active deterrence of bird activity from the aircraft flight path, using special sounds and "audible" radar to help birds notice aircraft sooner and (hopefully) get out of the way. Laboratory tests have determined that modulations can be incorporated into the radar signal that will

allow birds to perceive (“hear”) the radar, and these tests have identified the types of sounds that get the desired bird reaction of “searching” to locate the sound source [10].

(iii) Flash and Noise: The flash, bang kind of stuff immediately gets the attention of the birds and pushes them away. The flares and noise blanks come in various types, including a number of ‘whizzers’. The flare used depends on the bird species and the number of birds the controller wants to scare away. Some species respond better to a loud bang and others to a screeching noise.

(iv) Strobe Lights: Flashing, rotating, strobe and searchlights are novel stimulus to birds, which encourage an avoidance response [11]. Although stationary lights are known to attract birds at night; bright, flashing, revolving lights cause a blinding effect even in the day time, which causes confusion among birds. Light systems are designed for deterring birds from roosting and feeding in specific areas and are most effective between dusk and dawn. Studies conducted on light systems [11] have shown that high intensity strobe lights caused birds to take evasive action and move away from the airfields. In the same study it was found that a randomised selection of two strobe frequencies increased the effectiveness over a range of species and that the strobes stopped all bird habitation.

(v) Visual Deterrents: Visual deterrents are human and animal-friendly (non-lethal) methods to repel birds mostly in daylight. Traditional methods include placing Scarecrows or Hawk kites and balloons which birds perceive as fear for potential predation, and avoidance of unfamiliar objects.

(vi) Lights on aircraft: Lights on aircraft could be used to increase their visibility to birds. The idea is to manipulate the characteristics of the light by varying the pulse rates and wavelengths in the electromagnetic spectrum and tune these changes to specific bird species. The lights would provide an earlier warning so the birds can detect and avoid the aircraft.

(vii) Changing the Indicator Light Colour of the Aircraft: Studies have indicated more birds collide with communication towers equipped with red warning lights than with towers equipped with lights of shorter wavelengths [12]. If a similar relationship exists for turbine-powered jet aircraft with 2 underwing or fuselage-mounted engines and bird strikes. In the comparison, more strikes were reported for engine #1 as compared to engine #2 during day, night, and dawn/dusk flights. These findings suggest that modifying red navigation lights to include shorter wavelengths and the use of supplemental lights specifically designed for avian vision could enhance detection and reduce bird strikes.

(viii) Chemical Repellents: Chemical methods are very effective short term deterrents. Examples: Tactile agitation, Grass poisoning, Water, Reta, Polybutene, Methyl anthranilate, and other toxic repellents are sprinkled on the surface or near the roosting places of birds [13]. Methyl Anthranilate is the primary component of synthetic grape flavour. When it is spread through use of an airborne fogging device over an area that birds congregate and feed in, such as an airport, it acts as an irritant to their eyes and nasal passages [7]. Not only does this irritant deter birds that are present at the time of fogging, it also deters birds from landing on that area in the future to feed on the grass.

(ix) Predators (Falcony): In the past, airports have tried introducing natural predators to scare off flocks of smaller birds. Falconry, the hunting of wild quarry by a trained bird of prey, is one such way airports introduce predators to their property. Trained raptors, such as gyrfalcons, eagles, and peregrine falcons are released by falconers to scare away resident birds [7].

6. Laser-Bird Interaction Studies

Electrophysiological studies of the avian retina suggest that birds can distinguish colours ranging from the ultraviolet (350 nm) to the red (750 nm), spanning the visual range of humans (400-700 nm). In an experiment [14], it indicated that low-to-moderate power; long-wavelength lasers (630-650 nm) provide an effective means of dispersing some problem-bird species under low-light conditions.

In another experiment [2], cage tests were conducted to quantify the effectiveness of a 10-mW, continuous wave, 633-nm laser as a visual repellent (treating a perch) against brown-headed cowbirds (*Molothrus ater*) and European starlings (*Sturnus vulgaris*); and a 68-mW, continuous wave, 650-nm laser in dispersing (by targeting birds with the laser) starlings and rock doves (*Columba livia*) from perches and Canada geese (*Branta canadensis*) and mallards (*Anas platyrhynchos*) from grass plots. All experiments were conducted under low ambient light conditions. In experiments with stationary and moving laser beams treating a randomly selected perch, brown-headed cowbirds were not repelled. Similarly, a moving beam did not repel European starlings from treated perches, nor were they dispersed when targeted. Rock doves exhibited avoidance behaviour only during the first 5 minutes of the six 80-minute dispersal periods. Notably, six groups of geese (4 birds/group) exhibited marked avoidance of the beam during 20-minute periods, with a mean 96% of birds dispersed from laser-treated plots. Six groups of mallards were also dispersed from treated plots during 20-minute periods, but habituated to the beam after approximately 20 minutes.

Experiments were also conducted [15] to study the effect of various lasers on the captive birds. Radiant energy from laser (454-514 nm, ≥ 500 mW) exceeding maximal permissible exposure (MPE) levels for animals and humans. The results varied for species (gulls [Laridae], mallards [*Anas platyrhynchos*], and European starlings [*Sturnus vulgaris*]) as well as for the laser beam intensity. It was suggested that birds with higher concentrations of rhodopsin, (rod) pigment were sensitive to light intensity rather than the hue. High rhodopsin concentration (indicating scotopic versus photopic vision) is characteristic of most avian species that forage or migrate at night (for example owls, waterfowl, and wading etc.). Further, it exhibited a higher degree of avoidance of the intense (1–3W) laser beam. However, irritation due to beam intensity produced avoidance behaviour in all species tested. Yet, while the use of intense laser beams to deter bird use of the airport environment is impractical both from a safety and an ethical standpoint, this work demonstrated the potential for the use of lasers as a visual avian repellent.

Precautions in using lasers for scaring away birds:

Just as you should not point a laser beam at any person's eyes or face, you should also not point a laser beam at an animal's eyes or face. The beam could cause eye injury. This is especially important if you have a handheld laser with a power that may be over the limit for laser pointers. This limit is 1 mW/cm² in most countries.

A specially designed lens system broadens the laser beam, taking away the risk of blinding, yet increasing the bird-repelling effectiveness. This results in products which are 'eye-safe'.

Following are some of the precautions when using lasers to scare away the birds:

- (i) When using a laser to disburse birds, use a zig-zag movement along the ground or along a ledge towards the birds.
- (ii) If given an option, use a wide beam rather than a pinhead version.
- (iii) Use the laser in short bursts rather than a continuous stream.
- (iv) When using a laser to move birds off a landfill site, check that other objects are not in the line of site of a laser.

Preferably, we should ensure that at all the distances ($=z$), a constant power density ($=K$, say), which is equal to 80% (say) of the MPE (maximum permissible exposure) of the particular cw laser beam falls on the particular species of the bird. So,

$$K = \text{constant} = 80\% \text{ of MPE} \quad (1)$$

By simple derivation [16], it can be shown that K can be given by the following equation:

$$K = \frac{4 P_0}{\pi \emptyset^2 z^2} e^{-\mu z} \quad (2)$$

where P_0 is power of the cw laser beam transmitter; \emptyset is the beam divergence, and μ is the attenuation coefficient of the laser beam in the atmosphere.

So, from Eqn. (2), what we require is, to change the value of \emptyset for each z . This can be achieved by suitably designing the beam expander, which contains two lenses separated by a variable distance, d . The lens nearer to the transmitter is a convex lens and the lens farther away from it is the concave lens. \emptyset can be changed by changing the distance between the lenses, which is automatically programmed after sensing the distance z of the target bird. The design of such a system was proposed by us [16] for a laser dissuader system for self-defence of the laser-torch bearer against the possibly hostile person approaching the victim in a lonely or unprotected area of low light or dark.

7. Using Non-lethal lasers to dissuade birds from hitting and damaging the Aircraft

The non-laser deterrent methods described above do not eliminate all birds from the zone of airport operations, and should be supplemented with a range of dispersal methods. No one technique is 100% effective; hence many techniques should be used in combination. Repelling potentially dangerous birds with the help of lasers has been found to be very effective in conjunction with non-laser methods. Lasers offer a major improvement over pyrotechnic devices when noise must be kept at a minimum and non-target species may be adversely affected by pyrotechnic controls.

In an experiment [2] hand-held laser devices were used that project a 1-inch diameter red beam to disperse birds such as Canada geese, double-crested cormorants, and crows from nighttime roosting areas in reservoirs and trees. Advances in technology have made available compact, low power, lasers capable of producing beams across the light spectrum. Laser “rifles” are being employed to project a narrow, spot of light that apparently “scares” the birds enough to leave these sites. Collectively, tens of thousands of Double-crested Cormorants (*Phalacrocorax auritus*) could be dispersed from their night roosts in response to a tight, 10-mW, He-Ne 632.8-nm laser “rifle” and to the more diffuse Laser Dissuader system [10]. Completely moving a roost usually requires three episodes (at dusk) of moving the laser light-spot across the birds from a 200-300 yards distance. There are other laser systems that show promise against birds in the wild as well as in hangers or on other structures. A beam from a hand-held, class II, eye-safe laser, battery powered, ~60-mW, 650-nm, diode laser focused to a 0.15-m spot at 35 m, was successful at moving groups of Canada Geese at night [10].

It should be noted that the types of potentially hazardous birds will vary from airport to airport. Therefore more controlled studies are needed to evaluate the species-specific and physical limits of lasers as avian repellents. Understanding the range of wavelengths to which a particular species may be visually cognitive is an important aid in designing future experiments. For each bird, the MPE limit should be studied experimentally for the chosen laser beam. The aim is to ensure that the laser beam does not harm or kill the birds, the beam is ensured to be non-lethal so that it simply dissuades the birds from striking the aircraft. Further, though these data are not readily available for all species, spectral sensitivity may be inferred to some degree from the electrophysiological work, or species of similar ecology.

8. Discussion and Conclusion

In this paper we have discussed various non-laser as well as laser-based technologies for dissuading the birds from striking and damaging the aircraft. These techniques not only help preventing the financial loss due to damage of the aircraft, they save the lives of crew members and passengers too. But in this process, it should not be forgotten that we have got the right and privilege to harm and kill the birds in order to save human lives. Not at all. Therefore, it should be ensured that each of these techniques (non-laser or laser-based) should be non-lethal. The sole purpose is to dissuade the birds from striking the aircraft and not to harm the birds.

Further, it is observed that the laser beams (because they are in the visible region of the spectrum) work best during the low-light conditions. Therefore it is recommended that a combination of multiple techniques should be used throughout 24 hours of the day, with lasers to be used in the early mornings (before the sunrise), and after the sunset.

As far as laser-based technologies are concerned, it has been mentioned in this paper that different birds respond differently to different lasers. Therefore it is recommended that: (i) a systemic survey should be conducted for each airport to identify various potentially hazardous birds involved in the aircraft strike; (ii) a systematic experimental study should be conducted to see the effect of different laser beams, their changed

power levels on different birds and designate one type of suitable laser per each or more birds; (iii) it should be ensured that MPE limit is not crossed at any stage and no bird is harmed/killed in this process. Each of these lasers has to be non-lethal.

It has further been observed that the birds develop some sort of immunity to these dissuading strategies over a period of time. In the initial phase of application, these birds leave the airport area but they return after some time. In such a case, we have to change the dissuading techniques, their combinations and their dosage while still maintaining their non-lethal levels.

Lastly it should be mentioned that the techniques mentioned in this paper will help in minimizing the bird strikes to the aircraft but the number of incidents can never be zero.

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