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When I spoke to the third Bird Control Seminar in 1966 on "Ecological Control of Bird Hazards to Aircraft", I reviewed what we had accomplished up to that time. I spoke about the extent of the problem, the bird species involved and the methods we used to make the airports less attractive to birds that created hazards to aircraft.

I wish to discuss today our accomplishments since 1966. I have presented a number of papers on the topic including one with Dr. W. W. H. Gunn, in 1967 at a meeting in the United Kingdom, and others in the United States (1968 and 1970) and at the World Conference on Bird Hazards to Aircraft in Canada in 1969. There is no longer any question about the consequences of collision between birds and aircraft. Aircraft have not become less vulnerable either. Engines on the Boeing 747 have been changed as a result of damage caused by ingested birds.

Two of our most serious recent incidents involved Boeing 737 and Douglas DC. 8-63 aircraft. The Boeing 737 was approaching Winnipeg Airport on May 12, 1969 at a time when very large numbers of blue and lesser snow geese were migrating northward almost at right angles to the trans-continental air routes. The aircraft struck six or seven geese and had several components and systems damaged. Both engine cowlings were damaged but fortunately no material was ingested into either engine and power remained normal. If the aircraft had been inclined as much as five degrees, both engines would have ingested geese with subsequent serious damage. The aircraft was able to land with its 82 passengers but repairs took several weeks.

Damage on the DC. 8-63 was different. Fully loaded for Tokyo, the aircraft took off from Vancouver and went through a dense flock of small sandpipers (dunlin) just as it left the ground. Dunlin occur in large flocks on Vancouver airport during the winter. In January, when that incident occurred, there were flocks of up to 8,000 birds moving about on the field. Efforts had been made to drive them away from runways, but their activities are unpredictable and they are difficult to keep away from the runways. As the aircraft passed through the dense flock, instrument readings remained normal and gave no indication to the flight crew of any problem. Ground staff, called to the area immediately, found several hundred dead birds. That information was immediately given to the airline's engineering section and to the aircraft captain. After consultation, the captain and

the chief engineer decided that the aircraft should come back to base for examination. After dumping 6,000 gallons of fuel to reach landing weight, the aircraft returned and landed without difficulty. Examination showed damage to 15 fan blades in two engines and less important damage to the others. The engineers believed that operation of the engines for several hours on the trans-Pacific flight could have resulted in breakage of the damaged fan blades and catastrophic failure of two engines, somewhere over the Pacific-not a happy thought. Careful action prevented a serious incident. The cost was less than $50,000 including engine changes and repairs. We have since studied dunlin behaviour and find they are most active on Vancouver airport once a month at times of extreme high tide. Since we can forecast tides, we now know when to arrange for special patrols to drive dunlins off runways.

Figures crossing my desk daily show that while we are reducing the number of serious incidents and cutting down repair costs, we will continue to have bird strikes. Modification of the airport environment (Solman, 1966) has gone on continuously since 1963. The Department of Transport of Canada has spent more than 10 million dollars modifying major Canadian airports to reduce their attractiveness to birds. Modifications are still going on and will continue until bird attraction has been reduced to a minimum.

To show what airport environmental change can do, I would like to quote some figures from Air Canada's records. Before airport modification began, Air Canada's average cost of replacement parts for aircraft damaged by bird strikes was $238,000 a year during the 1959-1963 period. The annual cost of hardware replacement dropped to about $125,000 during the 1964-1968 period after we had begun to modify airports. The 1969 cost was less than $50,000 of which about $35,000 was for an incident which occurred outside Canada.

At our National Defense bases overseas we modify habitat to control birds on airports. Our German colleagues have been equally successful using the same method. Dr. Werner Keil of Frankfurt, whom some of you know, works on German civil airports. He told me recently that using our techniques, he had been able to reduce the bird strike rate at one airport from about 250 strikes a year to 15 in 1969. Ecological control of bird hazards is very effective when well carried out.

Even though we reduce birds on airfields, they are still encountered in flight at altitudes up to 21,000 feet. We have looked closely at the problem of mass migrations of large birds across east-west trans-continental airways in Canada. The numbers of birds involved are large. The fall flight this year will involve more than 100,000 ducks, 5,000,000 geese, 350,000 sandhill cranes, 100,000 swans and a very large number of smaller birds.

Our concern was aroused in 1962 by a Viscount aircraft which crashed in Maryland after collision at 6,000 feet with one or two whistling swans. Since swans still migrate on the same routes, we needed to know more about them. In 1969, we put radio transmitters on a number of swans in a co-operation program with Dr. William Sladen of the John Hopkins University and several others. We tracked individual swans by radio following them with ground vehicles and light aircraft. We found that northward migration took them through a series of points at each of which they spent several days feeding and resting before moving on. The flight route from Baltimore passed through Lake Erie, Lake Michigan, North Dakota, Manitoba and Saskatchewan to the Northwest Territories. They stopped at the

west end of Lake Erie for up to a week; on northern Lake Michigan for a few days; and in North Dakota for as long as two weeks. They also stopped off in the prairie provinces before going to the nesting grounds in the Northwest Territories. We kept track of one radio-equipped bird for more than 2,500 miles and got interesting data on rate of climb and flight speed, duration, time and altitude of migration, and length of time on the ground at various points. Migration took from mid-March to mid-May with flights of 500 to 900 miles on six or seven *nights* at altitudes up to at least 10,000 feet. Dr. Gunn is preparing a report which relates the swan migration to the weather at the time. Briefly the swans moved northwestward when winds were favorable and fed and rested at stop-over points when they were unfavorable.

We have known for a long time that birds move most easily with a tail wind. We have reviewed a couple of hundred miles of time-lapse movies of plan position indicator radar presentations of bird movement and compared the movement with weather data for the same period. From that comparison we have worked out correlations between parameters and bird migration.

These correlations were used on an experimental basis to forecast southward movement of large birds in the autumn for Canadian Armed Forces flying training (Gunn and Solman, 1967). These forecasts were important to flying training on high speed military jet aircraft in western Canada. We have since gained experience in forecasting intensity of bird migration both in spring and autumn. We have also simplified the method of handling data and making forecasts. We have used bird migration intensity forecasts operationally with the Canadian Armed Forces for the past year. During the spring of 1970, we also provided forecasts for the United States Air Force B52 practice flights across the Canadian Prairies.

Our forecasts of migration intensity of bird movement relate well to that observed on radar, provided they are based on weather forecasts. Seventy-five percent of our bird migration forecasts are correct. The accuracy increases to 90 percent if we compare what the birds did with what the weather *did*, rather than what the weather was forecast to do. More accurate bird migration forecasting requires more accurate weather forecasts. The present weather forecasts allow us to help the operations people decide when certain flying training exercises should be carried out. Our Armed Forces and the U. S. Air Force group operating in Canada, cancelled flights when we forecast high intensity of migration during the spring of 1970. Both expressed satisfaction at being able to avoid the most hazardous flying conditions using our forecasts.

I mentioned earlier the unfortunate experience of a Boeing 737 which hit a number of geese at Winnipeg during spring migration in 1969. To avoid a recurrence of that incident, some of our most experienced staff worked with the air traffic controllers at Winnipeg during the corresponding period in 1970. An additional console was attached to the air traffic control radar so our staff could record bird observations by time lapse movies for later study. The goose migration and aircraft traffic (a major airline was on strike during the 1969 migration) were heavier than in 1969. By forecasting the periods of heavy bird traffic and by using the air traffic control and precision approach radars to study the birds in real time the operators were able to give the pilots up-to-date information and help them thread their way through several hundred thousand geese without any collisions. On approach to the airport, the experienced pilots put their landing lights on at 10,000

feet as they came in through the night migrants. That apparently helped the birds see the danger and move out of the way. One large flock of geese was seen on the precision approach radar presentation to turn aside twice as aircraft approached along the glide path and crossed the airway only when no aircraft was approaching. We recommend the use of landing lights in such situations.

We recommended a reduction of speed of airline aircraft below 10,000 feet to reduce the damage of a bird strike. Many major airlines now fly at less than 250 knots when they are below that height. Pilots are well aware that a 4-pound bird hit at 300 miles per hour exerts a 15-ton force on a saucer-sized Impact area. Most of them have seen what that does to aircraft structure in actual strikes or in the National Research Council simulator. They also know that at 600 miles per hour the force increases to 60 tons on the same area.

Our French colleagues are also using radar to provide information about bird movement to pilots. They operate a training program for air traffic control officers to familiarize them with bird movement characteristics as seen on radar. As a result of the spring, 1970, migration experience at Winnipeg, we are developing a training program for Canadian Air Traffic Control operators so that they can do an even better job next year. Needless to say, the Canadian Airline Pilots Association, which is represented on the Associate Committee on Bird Hazards to Aircraft, is a strong supporter of more use of radar to keep birds and aircraft apart. We still need information on the height at which the birds are moving. The precision approach radar gives data only for birds crossing the approach route. We can get some information from plan position radar by knowing the slope of the base of the radar beam and noting at what distance birds first appear on the screen. We also get some information from pilots but not much at night when we need it the most. We are now studying new equipment and hope that better radar height finding equipment will soon be in use at airports to help the operators keep track of light aircraft as well as birds. Both are important though the last mid-air collision between an airliner and a light aircraft damaged the airliner less than the collision with the geese in May 1969.

Because of incidents involving Canadian airlines and military aircraft outside Canada, we decided to begin international work several years ago. That work has brought us a great deal of information which we could not have obtained at home and has helped strengthen our good working relations with biologists and other specialists in a number of countries. We first worked with the French air traffic control officials and helped them to set up motion picture recording of their P. P. I. radar presentations. They were soon doing such a good job of studying bird movement by radar that they brought to our attention the importance of local bird movements in connection with certain of their air bases. We then looked at local bird movements near some of our Canadian airports and realized that in our earlier work, we had overlooked some bird problems which the French work drew to our attention.

We have now studied bird problems in relation to aircraft in ten countries. We are co-operating in programs to develop bird migration forecasts under a N.A.T.O. grant in seven European countries. I am a member of the Associate Committee on Bird Hazards to Aircraft of the National Research Council of Canada which co-ordinates the work about which I have been talking and maintains communication with representatives of forty countries. To provide a world forum, the

Committee convened a World Conference on Bird Hazards to Aircraft at Kingston, Ontario, in September 1969. Representatives from 22 countries presented more than fifty papers. The Russians pointed out that the bird problems of their major airline were similar to those of Air Canada. The strike rates they reported were comparable to those experienced by Air Canada before we began to modify airport use by birds.

I understand the United States federal authorities are more actively studying bird hazards to aircraft and I look forward to development of an international program in North America. Since bird movement is roughly north-south, and aircraft movement is east-west, a continental program could deal very effectively with the migratory bird hazard.

With the dense traffic of birds in the air, it is a wonder we have not had incidents more serious than those recorded. We will be satisfied only when collisions between birds and aircraft are reduced to the lowest possible level.

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DISCUSSION: for Ed Ladd and Vic Solman

J. STECKEL: I flew in with a man from Canada. He was talking about the flock turning back twice on final. This flock is flying pretty low, I take it. What's the altitude?

V. SOLMAN: About three thousand

feet. J. STECKEL: Is this final?

V. SOLMAN: Well, no. The aircraft was coming in fairly steep; it was a 737. You know how fast they settle in. They were back several miles from the touch down point.

J. STECKEL: Is this about where the birds fly, at three thousand feet, or is it predictable?

V. SOLMAN: Yes, it is predictable. We have two staging areas that both lead birds through Winnipeg. One is close in, and the birds go through between three and six thousand feet. One is farther back and they go through between six and ten thousand feet. So we actually have two sets of geese to track through there at that time. This was the low level traffic from the near in roost.

J. STECKEL: How slow can you get the aircraft at that point?

V. SOLMAN: Somewhere under 250 knots. In the old days they used to come barreling right on in at about 350 knots, but they have decided that's not so good.

T. STOCKDALE: I may be pretty naive, but it sounds to me like Dr. Solman has talked about experiences and now a manual; and, not to be critical of our friend from the Northeast, but it sounds like those of us here in the States are eight years or so behind the Canadian people. Why haven't we gotten together on this a long time ago? Why aren't we using their manual today? And why aren't we cooperating on this radar location and predicting of bird flocks?

R. SMITH: Anyone here from FAA?

V. SOLMAN: We have been in full touch with Fish and Wildlife and FAA ever since the beginning. We don't have any secrets.

R. SMITH: I would assume it is FAA, to tell you the truth. The Fish and Wildlife Service has no authority to regulate or suggest. I don't know for sure, but I don't think there is anybody here other than perhaps you, Vic, that can answer this question.

V. SOLMAN: I don't think I can answer it. All I can say is that our cooperation in Europe at the moment is at a higher level than it is here.

D. SCHNEIDER: As an illustration of this lack of cooperation, I was going to address a question to Ed. Some three months ago CBS news had an interview on their night time news which described the clash between the expansionists who want to build an eight-mile-long runway at Kennedy across Jamaica Bay, and the conservationists who want to preserve it. You don't build runways across marshes without

completely destroying the marsh and you are not going to get cooperation from the birds on a marsh like that.

R. SMITH: I can say that our agency is reviewing the placements of new airports and being asked for recommendations for the effects on wildlife. But as far as the recommendations go or how much weight they carry, I can't say.

B. REED: I would like to ask both gentlemen what chemical control, if any, are you using? Do you use baits, contact poisons, or anything either in Canada or the Northeast.

E. LADD: Unless, it is entirely necessary and strictly on an emergency basis, we do not use any toxicants to control birds. The use of a toxicant is a temporary measure. If you knock down a group of birds, there is nothing to prevent more birds from moving right in to fill the vacancy. It is much safer and more logical to kill the cause of the problem.

V. SOLMAN: We feel exactly the same way, that really what you are talking about is habitat modification. You have to make the place as nearly a biological desert as you can. Even when you have done that, of course, some birds will come in just because it is a big open undisturbed area with no domestic animals around. For those birds you have to apply emergency procedures with fire arms or whatever you like to get them out in a hurry. But on a long term basis, ecological manipulation is the only answer.

F. OBERST: In conjunction with the airports we did try some work down at Kennedy, and it didn't work out to the satisfaction of everybody involved because we couldn't go at it extensively enough. The work over at Logan that has been done there to modify that airport has done a very fine job. I am out there quite often. I see very few ducks. They have filled some of these ponds and so on. We spoke of this problem about 1961 or 1962, and they did have plans for all of these things, but so many times with changes in airport management, commissions, and so on, these plans change. But there they did get the money together and they did do a very fine job.

E. LADD: That's right. This is one of the areas where as I said ten years ago it was not unusual to see five or six thousand ducks, and several thousand sea gulls feeding in the flats out around the edges of the airport. It was one of the most beautiful bird refuges I have ever seen in my life. But the numbers of birds have gone down. They have modified this area so that the chance of a major bird strike has been greatly reduced