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A BIRD-WARNING SYSTEM FOR AIRCRAFT IN FLIGHT

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The theme of this paper is that radar can readily detect flights of birds and that this information can be used effectively in flight planning and in air traffic control to reduce significantly the number of bird strikes.

Since military aircraft are expected to carry out training flights and missions at all seasons and all times of the day or night, it has been argued that losses of aircraft and even crew owing to bird-strikes should be accepted as one of many operational hazards. It has been argued that the vast complex of national and international air traffic control is an operation requiring split-second timing and having no leeway in terms of either space or time for diversionary tactics to by-pass birds. It has also been argued that the problems of air traffic control are mounting so rapidly because of other factors that birds are becoming a relatively minor problem scarcely worth consideration. If these viewpoints are valid, then we're wasting our time and yours, but we don't think they <u>are</u> valid.

Let's look at the commercial operation first. While the chance of an unforeseeable, random bird-strike in flight will always exist, it is nevertheless possible to define the high-risk conditions within fairly narrow limits. In the first place, we know that most commercial aircraft cruise at altitudes far higher than those used by the vast majority of birds, so that the danger of a strike in the cruise phase is very slight, and comes close to being negligible above, say, twelve thousand feet. Secondly, the multi-engines of commercial aircraft mean that loss of power through damage to one engine may be expensive but not catastrophic. Thirdly, experience has shown that at present-day cruising speeds wind screens and the rest of the airframe will withstand the impact from one or even a few <u>small</u> birds without serious damage. The high-risk conditions are therefore narrowed down to those in which a multiple strike may damage more than one engine and/or those in which the bird struck is large enough to do serious damage to such vital parts of the airframe as the wind screens and stabilizer. Moreover, as the risk in cruise is small, we can concentrate largely on other phases of flight: take-off and climb-out, and approach and landing. The type of risk differs to some extent with the particular flight regime. In take-off and climb-out, the time elapsed is relatively brief, but it is also the time when most power is required; engine damage is therefore the most critical risk here. In the approach phase, the time period is considerably longer and the speed still high, but power is relatively less important, so here we are probably more concerned with structural damage to the airframe. Finally, at landing, the speed is relatively low and the time is quite short, so the risk of a serious strike is consequently less and probably inconsequential unless the birds are of gull-size or larger.

In sum, then, for commercial operators, we are concerned mainly with the take-off, climb out, approach and landing regimes, and with small birds in dense flocks, medium-sized birds (e.g. gulls) in relatively dense flocks, or large birds (geese, swans, cranes, or vultures, for example) flying individually or in flocks. Moreover, since the risk in the cruise regime is relatively low (above 12,000 feet), we are concerned primarily with airport surroundings outward to a radius of 50-75 miles.

Assume now, for the sake of argument, that we had precise and specific information at hand about bird movements of the type mentioned. What alterations to normal operational routine would federal regulatory bodies or commercial aircraft operators be prepared to make to reduce the bird strike hazard? The first reaction to this is likely to be "very little or none". But suppose we consider the problem on the basis of what is being done today in terms of another aspect of air safety. An example we like to use in Canada is the thunderstorm. Thunderstorms are seasonal in their frequency, local and short-lived in their occurrence, difficult to track with precision, and harder still to predict with accuracy. Yet the high degree of turbulence lurking in their centres may represent a very real hazard to aircraft. Pilots in training are warned to treat them with respect, and not to fly casually though them. Meteorological services go to considerable trouble to provide pre-flight and in-flight advisory information about their occurrence. Air traffic controllers in airport towers and radar centres may change runways or approach routes or altitudes to help aircraft avoid nearby thunderstorms. When there are severe thunderstorm conditions in the immediate vicinity of an airport, pilots may delay their take-off briefly and landings may be delayed or even diverted until conditions become less hazardous. If all this can be done for thunderstorms, it can also be done as readily for flights of birds following patterns known to be hazardous - provided that the warnings are at least as accurate and precise as they are for thunderstorms. This, I think, is a fair enough challenge, and all the flexibility of operational procedure that need be asked for to reduce bird-strike hazards. But is the comparison of hazard between thunderstorms and bird-strikes a valid one? Squadron Leader G.W. Ovans, of the Directorate of Flight Safety, Canadian Forces Headquarters, says: "We have an elaborate warning system that allows us to take appropriate precautionary measures when dealing with thunderstorms. At least in part because of these precautions, we very seldom lose planes or have them seriously damaged by thunderstorms. Yet we do lose planes and have many others extensively damaged by bird-strikes. So far, we have not developed any functional warning system against bird-strikes, but if it can be done successfully for the one, it should be possible and worthwhile to do it for the other."

Turning to the military side of the bird-strike problem, we can assume first of all that military transport aircraft encounter roughly the same types of hazards as comparable commercial aircraft. In Canada, we do not as yet have large pure jet transports in military service, and this reduces the size of our bird problems. What we do have, however, is the F104 or Starfighter aircraft, used by our squadrons serving with NATO, and in Canada chiefly at the training centre at Cold Lake, Alberta. As you know, this is a single-engined jet aircraft which is flown at very low levels and very high speeds. From our point of view, this is a particularly bad combination, since they cruise at altitudes where birds are frequently very numerous (250-500 feet), and at speeds which usually preclude either the pilot or birds from taking avoidance action if collision seems imminent. The wind screens seem able to withstand bird impacts at high speed, and the remainder of the air frame is practically invulnerable to serious damage from bird strikes, but not so the engine. The ingestion of even a small bird can result in serious damage which may lead to loss of power, which in turn means almost inevitably that the aircraft will crash. Fortunately, the Canadian design of ejection seat is extremely efficient, and as a result no pilots have been lost owing to known bird strikes, but there have been seven definite and two possible losses of 104 aircraft from bird-strikes.

At roughly one and one-half million dollars per aircraft, each loss might be considered inconsequential among the great powers, but in Canada it is not, and we have felt it worthwhile to do a considerable amount of research on the problem.

With the Canadian military forces, then, the problem lies largely with engine ingestion of birds in a particular type of aircraft, the 104, where a strike by even a small bird may be catastrophic. A strike is more likely to occur in cruise than during the other phases of the flight regime because most of the flying time is spent in cruise at low altitudes. By comparison with commercial operations, the problem is more specific with regard to aircraft, but considerably less so with regard to the types of bird involved and distance from the airport.

In military flying, the margin for change in flight plans can be extremely small when, for example, operational exercises are taking place. On the other hand, flexibility may be considerably greater than with commercial operations for much of the time, particularly as far as training programs are concerned. In planning training programs over a two-or three-year period, for example, it may be possible to arrange schedules so that the peaks in flying periods do not coincide with seasonal peaks in bird migration. Even during seasonal peaks of bird activity, it may still be possible to minimize flying time during hours of the day or night when bird activity is greatest. If there is some leeway in the number of days to be flown per month, an efficient bird forecast and warning system should be able to select days and nighte within a given period when the bird hazard is relatively high or low, and it should also be able to advise altitudes and flight routes with the lowest degree of hazard. It would then be up to the operations group to set a threshold for the degree of hazard which would require the altering or postponing of scheduled training flights. The threshold could be adjusted up or down according to the urgency or type of flight programmed.

It was in fact with something like this technique in mind that we in Canada made our first efforts to operate a bird-activity forecasting program that might be used for operational purposes. This was done at the Canadian Forces Base at Cold Lake, Alberta, from May 1 to June 15 and again from August 21 to October 31, in 1966. We were at that time already taking time-lapse motion pictures of a Plan-Position radar display at Cold Lake for long-term analysis of the relationship between bird movements and weather conditions. For the above periods, we extended our photographic coverage to include a series of still photographs of a similar PPI display. One photograph was taken each hour around the clock. Each film was exposed for 10 minutes, followed by a two minute pause, then re-exposed for a final minute. The result was a streak of light representing each substantial bird echo (probably indicating a flock of birds). The interruption in exposure caused a break in the track at one end to indicate the direction of movement. Both Polaroid and ordinary negative film were used in about equal quantities. The Polaroid film was quicker and easier to handle but lacked depth. The ordinary negative film, with a two speed emulsion, provided better contrast and detail, and therefore seemed better for making careful assessments of bird activity, especially in high density situations. The two kinds of film were often used alternately for one-hour periods.

The hourly series of photographs was delivered to the duty forecaster at about 9 a.m. and 4 p.m. These were rated according to an arbitrary 8-point scale set up from a selection of photographs covering the whole range of migratory intensities and provided evidence of bird movements up to one or two hours before forecast time, which was regularly at 10 a.m. and less regularly at 4 p.m. The forecaster endeavoured to forecast the probable density of bird movement for each hour of the next 24-hour period, basing his decisions on:

(a) the hourly intensity pattern for the previous 24 hours;

(b) the hourly patterns for the past several days, giving an indication of the seasonal trend;

(c) the weather forecast for the next 24-hour period; and

(d) a rudimentary idea of what effect this weather might have on bird movements.

During the spring of 1966, the project was carried out purely as a "dry run", with no influence on operations; in the autumn of 1966, some limited operational use was made of the forecasts.

An over-all assessment of forecast accuracy was made from verification of 2068 hourly forecasts. Taking errors of plus or minus one in the rating scale as being not significant, it can be said in summary that 77 per cent of the forecasts were accurate, 11 per cent underrated, and 12 per cent overrated - on the face of it a very acceptable rate of forecast for a first attempt. However, further examination showed that much of the accuracy was obtained by forecasting a continuation of the prevailing state. The level of accuracy was much lower if only those hours of greatest bird-flight intensity are considered. Of the 119 hours when the intensity was rated at 5, 6, 7, or 8, only 50 per cent of these were correctly forecast in spring and 35 per cent in autumn. It is incidentally worth noting that these presumably high-risk situations amount to only 6 per cent of the total number of hours forecast, so that if this relatively small number could be forecast accurately, the practical value of the forecast system would be greatly enhanced.

A review of the results of the project brought forward three main points. First, the arrangement of a 24-hour forecast with a 12-hour updating provided much more lead time than was normally required. A six-hour forecast with a three-hour updating, the standard procedure for meteorological forecasts, would have provided sufficient lead time and allowed greater accuracy in forecasting. Second, there were inherent difficulties in the quality of the radar information. The radar was being operated for purposes other than bird detection, and frequent changes in settings of gain, polarization, beam elevation, MTI, and range led to difficulty in standardizing measurements of intensity of bird movement. Third, and most important, the input of ornithological data was far too inadequate and vague to enable the forecaster to interpret with any confidence the probable intensity of bird activity in relation to the weather forecast. Not only was very little precise information supplied about the bird/weather relationship, but there was also a lack of precise information as to the kinds and numbers of birds represented by the echoes on the radar scope. The general working hypothesis for the weather was that headwinds from the presumed direction of migration would be unfavourable for intensive bird migration and that opposing winds would be favourable. If followed that, in autumn, the east side of a high-pressure system (following the passage of a cold front) was considered favourable for migration activity and, similarly, in spring, the west side of a high-pressure system or a warm sector following the passage of a warm front was considered favourable. It was also assumed that the primary direction of migration was northward in spring and southward in autumn. Subsequent study of the time-lapse motion-picture films has shown this to be an inaccurate assumption, as the primary direction has proved to be northwest in spring and southeast in autumn - a change that would make quite a difference in the assessment of the influence of the forecast weather on bird migration.

The bird intensity forecasting project at Cold Lake functioned very well at the mechanical level but showed serious deficiencies in input at the theoretical level. In the past six months, we have begun a program to make good these deficiencies by learning more about the bird/weather relationship at Cold Lake and about the relationship between the echoes displayed on radar and the numbers and kinds of birds they represent. As this paper is being written, we are about to run a computer program which will make a multivariate analysis of bird movement data assessed from Cold Lake radar film over a period of 17 months in relation to weather data for the same station and period of time. Since in this operation we will be dealing with bird data and meteorological data from one geographical point only, we do not expect to arrive at any conclusive correlations, but we hope to obtain leads that will help in the next step - an analysis of similar bird and meteorological data for the same period from six locations in Alberta and Saskatchewan. This should have illuminating results if we don't become swamped by computer output along the way.

Our second step was to establish an experienced biologist at Cold Lake this autumn with instructions to obtain quantitative information about radar echoes by relating them to visually verified numbers and species. He will also attempt to quantify our 8-point scale of density and will investigate local movements of birds that show up repetitively on the radar display. Many of you have already met this biologist, I expect. He is Mr. Hans Blokpoel, formerly of the Royal Netherlands Air Force, and we are pleased to have him working with us. As our ornithological knowledge of the region is extended, we plan to assemble a manual for the guidance of biologists and others at Cold Lake participating in the bird warning forecast scheme.

Meanwhile, in the past year, a good deal of progress has been made in some parts of Europe towards a workable bird-warning system. In the Netherlands, the R.N.A.F. has set up a bird-warning system based on time-exposure still photography of a radar scope at Den Helder. When bird flight intensities rise above a certain level on an 8-point scale, nearby military airports are warned by telephone and a graduated scale of precautions is put into effect. This system is simple, since it is a direct warning based on the latest photograph and avoids the uncertainties of a forecast, but it has the drawback that it has no lead time at all and a serious time-lag may develop if there is any delay in the transmission of information to operations control. In West Germany, special efforts were made to monitor and issue warnings about the spring and autumn migrations of cranes across the country, since these are high-risk birds that cross many airport approaches. The program has worked out well, with enthusiastic support from many field observers, and I leave it to Dr. Keil to elaborate on this project. In France, radar films taken at Aix-en-Provence last spring showed dramatically that local movements of birds may be an even greater hazard than migratory flights. Each morning and evening, gulls made flights between a major food source at a garbage dump northwest of Marseilles and a roosting area at the edge of a lake. The flight traverses the northern approach to the main runway at the military base at Istres, at a critical height, some five miles north of the field. This runway, the longest in Europe, is used in the testing of late-model jet aircraft. No one who has seen the films is surprised that serious and expensive strikes have been occurring there. It is worth noting that while the motion-picture films pinpoint with clarity and precision this daily local movement, still pictures fail to do the job because of intermittent coverage and lack of motion. Still pictures are very effective in portraying bird migration taking place on a broad front over a matter of hours, but they are usually ineffective in showing up short-term local movements occurring in only a small portion of the display. The experience at Aix points up the need to give more attention to local bird movements detected by radar, since they may well involve birds in the high-risk category, and quite specific warnings can be made as to when and where they present a danger. We learned our lesson in this regard one day last October at Cold Lake, when we lost a 104 after an encounter with some snow geese. The bird movement intensity forecast for that particular hour of that day called for a low intensity of bird activity. From a quantitative viewpoint this was quite correct. What the forecaster failed to say and did not know was that although the number of birds in flight would be low, a fair proportion of them would be geese that had recently arrived from the Arctic Coast a thousand miles to the north, and were moving about during the day to visit local feeding areas.

I should like to close now by outlining what might be a workable basis for an effective bird warning system based in large part on radar-derived information. It should work as well or better in Europe as in North America because of the closer grouping of airfields and the greater number of weather (and bird) reporting stations.

The bird movement forecast would be prepared every six hours to cover the next six hours. In migration periods it would be updated every three hours, and every hour at times of high risk. It would be issued for a given region covering a number of airfields and would be as specific as possible. Preparation of the forecast would be the responsibility of a roster of biologists, organized in the same manner as duty meteorological forecasters, but covering a much larger area, so that the total number of biologists required would not be impossibly large. The duty biologist would be closely dependent on the current meteorological forecast and would have to be familiar with the synoptic situation on which it is based. It would be his responsibility to interpret the weather forecast in terms of how it was likely to affect bird movements. He will need to have support: the experience gained from detailed studies of radar films and comparable weather data; information on known seasonal trends in bird movements in the region; reports of visual observations made in support of the operation; visual verification made of local movements that appear repeatedly on radar; and a backlog of general information drawn from the literature on the migratory behaviour of birds. This last must be weighed carefully since it may be based largely on visual observations that, by themselves, can often give a very misleading idea of what is actually happening.

The forecasts should be handled in the same general manner as local or special weather advisories. They should be made available with the shortest possible delay to the pilot briefing room for reference and possible action by pilots. On the same basis they should reach airfield controllers in towers and air traffic controllers in radar centres. It might be feasible or desirable to issue bird movement forecasts only when a designated degree of hazard is reached or predicated.

Forecasts for military airports should be prepared on a somewhat modified basis, in line with the differing requirements for military flights, as indicated earlier in this paper.

The outlined scheme needs to be strong enough to do the job but not so complex to become burdensome. Since it would probably take several years to set up such a scheme on a broad scale, it is appropriate to ask whether new generations of aircraft will continue to be vulnerable to bird-strikes, or whether aircraft design can overcome the problem. It seems evident that in the immediate future aircraft are likely to become more rather than less vulnerable to severe damage from bird-strikes. Larger engine intakes will accommodate larger birds. Larger aircraft carrying many more passengers will make plane loss more catastrophic. Increased speeds, such as are forecast for the take-off and climb-out of the supersonic transports, will greatly intensify the force of impact and give birds even less opportunity to evade. There is a possibility that an effective guard or bird disposal unit can be designed to protect future jet engines. The United States has begun research on this aspect of air safety. They may well come up with an effective design that would greatly reduce the over-all bird hazard. However, such a device would not prevent strikes on the airframe from large birds. It is our belief that the bird-strike problem will not dwindle to an acceptable risk until vertical take-off and landing aircraft are in common use. Meanwhile, in our opinion, any airport that operates without a proper bird-warning system extending outward 50 miles or so just isn't trying hard enough for air safety.

Film clips to be shown:

(1) Whistling swans in migration over southern Ontario, Spring, 1967.

(2) Geese in migration southward over Fort William, Ontario, Fall, 1965.

(3) A typical fall migration sequence from Cold Lake.

Still Pictures:

(1) Cold Lake intensity scale.

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