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A CHARACTERIZA ION OF THE BIRDSTRIKE RISK TO THE SPACE HUTTLE ORBITER AT ITS PRIMAR LANDI SITES

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Major effrey J. Sho t, USA

Crew otection Branch
Vehic Subsystems Division

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A R FO E WRI AERONAUTICA LABORATORIES
WRIGHT- ATTERS AIR FORCE ASE, OHIO 45433-6553

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This technical report has been reviewed and is approved for publication.

Jeffrey J. Short

JEFFREY J. SHORT, Maj, USAFR
Bird Hazards Analyst

Robert E. McCarty

ROBERT E. MCCARTY, Group Leader
Aircrew Protection Branch

FOR THE COMMANDER

[illegible]

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A risk assessment of the birdstrike hazards to the Space Shuttle Orbiter was conducted to support a National Aeronautics and Space Administration study on the windshield design. The birdstrike risks were evaluated for three Shuttle landing sites: Kennedy Space Center, FL; Edwards AFB, CA; and, Vandenberg AFB, CA. The US Air Force Bird Avoidance Model (BAM) was used to determine the relative level of birdstrike risk along the Shuttle approach routes. In this application, the proportionate risk from discrete size classes of birds was multiplied by the BAM estimates to examine the relative risk from different weights of birds. The bird population data was collected from the Merritt Island National Wildlife Refuge which is adjacent to the Kennedy Space Center landing site. The cumulative distribution frequency of bird weights approximated a Weibull distribution. This analysis showed that the Fall and early Winter is the worst time to attempt a landing at KSC and that at least one out of every 100 Shuttle approaches might involve a 3-pound bird. The chance of encountering a 4-pound bird, probably raptor, is greatest in the Summer at KSC.

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22a. NAME OF RESPONSIBLE INDIVIDUAL: Jeffrey J. Short

22b. TELEPHONE (Include Area Code): 904-283-2942

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Discrete bird population data was unavailable for the California sites so a simple comparison was made between the sites using the BAM estimates. The birdstrike risk is highest at KSC and Edwards AFB especially at night during the Fall migratory period. Raptors comprise the highest birdstrike hazard at Vandenberg AFB in the summer months.

More complete bird population data from the California sites would allow a size class breakdown of the birdstrike hazards.

EXECUTIVE SUMMARY

The National Aeronautics and Space Adminstration requested an evaluation of the Space Shuttle Orbiter windshield system with regards to the possibility of birdstrikes. To support their damage assessment analysis, the Air Force Wright Aeronautical Laboratories Aircraft Windshield System Programs Office directed a characterization of the bird populations at the three primary Shuttle landing sites: Kennedy Space Center, Florida; Edwards AFB and Vandenberg AFB, California. The objective of this effort was to determine the risk of birdstrike to the Shuttle during the approach/landing phase.

The USAF Bird Avoidance Model (BAM), developed for the Bird-Aircraft Strike Hazard Team by the University of Dayton Research Institute, is used to examine bird hazards on high-speed, low-level flight routes in the continental United States. The BAM calculates the birdstrike risk on a route by estimating the number of birds in the route airspace at a particular time. The BAM was used to determine the relative birdstrike risk to the Shuttle by defining the segments of a typical approach at each of the landing sites.

The BAM estimates for Kennedy Space Center (KSC) were multiplied by the proportion of the local bird population segregated into discrete weight categories. This yielded the probability of a birdstrike involving a bird of a particular weight. The bird population data was collected from the Merritt Island National Wildlife Refuge adjacent to KSC. This analysis indicated that the chance of the Shuttle hitting a 2-pound bird is close to 4 per 100 approaches during the fall each year. One out of every 100 landings would involve a 3-pound bird during the fall and early winter. The predominant risk comes from waterfowl at KSC with the chance of encountering larger (over 4-pound) raptors greater during the summer.

No discrete bird population data was available from the California sites so only the BAM estimates were used for comparison of birdstrike risk. The analysis showed that the birdstrike risk to the Shuttle is highest in the fall at all sites. Based on the BAM, the birdstrike risk ranges from over 1 per 100 approaches at KSC and Edwards AFB to nearly 3 per 1000 flights at Vandenberg AFB. Waterfowl create the majority of the birdstrike hazards during from fall through early spring while raptors comprise the major hazard during the summer. Night landings would present the most risk to the Shuttle, especially during the fall and spring migrations.

This was the first application of the BAM on other than military aircraft. Though the BAM is certainly an imperfect model, it provides a method of quickly estimating the relative birdstrike risk from waterfowl and raptor populations in the continental United States. More bird population data is needed for other bird species (gulls, blackbirds) known to present hazards to flight to improve the BAM's predictive ability.

Reliable bird population data from the region around the landing site, combined with the BAM estimates, can provide design engineers with a good idea of the bird hazards that the Shuttle will encounter during a certain time period. If some aspect of the design is inadequate to provide an acceptable level of birdstrike resistance, the flight hazards can be minimized by scheduling Shuttle landings at a particular site to a time when the birdstrike risk is lowest. If rescheduling is not feasible, then measures to reduce the birds along the Shuttle approach could be implemented.

PREFACE

The United States Air Force (USAF) Wright Aeronautical Laboratories (AFWAL), at Wright-Patterson AFB, Ohio, has been requested by the National Aeronautics and Space Administration (NASA) to assess the birdstrike risk(s) to the Space Shuttle orbiter. This study, conducted by AFWAL/FIVR, will focus on the capabilities of the windshield design to withstand a birdstrike during the approach and landing phase of a Shuttle mission.

In anticipation of this project, AFWAL/FIVR needed information on the type of bird that the Shuttle would most likely encounter during its operations. I was asked to prepare this report characterizing the birdstrike hazard at the primary Shuttle operational landing sites: Kennedy Space Center, Florida; Edwards AFB and Vandenberg AFB, California. This bird risk assessment was conducted during the period 5-16 January 1987.

This report covers work performed by the author during his support of AFWAL during his Air Force Reserve assignment to the Aeronautical Systems Division, Wright-Patterson AFB, Ohio. I wish to express my appreciation to the following individuals for their support in this effort:

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1Lt Steve Hargis	AFWAL/FIVR
2Lt Paul Kolodziejski	AFWAL/FIVR

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SECTION I

INTRODUCTION

NASA has long been concerned with the possibility of birdstrike damage to the Shuttle. Beginning in 1974 (Reference 1), the Air Force's Bird-Aircraft Strike Hazard (BASH) Team has recommended measures to reduce the risk of birdstrikes at the Kennedy Space Center (KSC) Shuttle Landing Facility (SLF) and other operational landing sites. BASH Team assistance was provided to NASA several times in the last 8 years regarding the SLF. Over the past 10 years, the BASH Team has conducted surveys of the bird hazards at the other primary Shuttle landing sites, Edwards AFB and Vandenberg AFB, California. Once implemented, those recommendations made by the BASH Team effectively decreased the overall attractiveness of the airdrome to birds, considerably reducing bird hazards to both the Shuttle and other aircraft.

The BASH Team data base shows that Edwards AFB has reported 54 birdstrikes over the last 11 years for a total cost of almost $57,000. Almost half of these birdstrikes occurred during airdrome operations (takeoff or landing/approach). During the last 5 years, Vandenberg AFB has experienced 7 birdstrikes--all to Navy aircraft. Patrick AFB, Florida, which is close to the SLF, has had 82 birdstrikes in the last decade for a cost of $133,023. This information suggests that the birdstrike hazard at the SLF may be of more concern to safe Shuttle operations than the California sites. One birdstrike is known to have occurred during a Shuttle landing at the SLF (Mission 1042A, 11 Feb 85 at 1215 hours GMT).

Generally, the expected birdstrike risk near an airfield increases proportionally with the number of birds transiting the aircraft flight paths. The SLF is located next to the Merritt Island National Wildlife Refuge (MI NWR) which hosts hundreds of thousands of waterfowl (mostly ducks and coots) and tens of thousands of waders, shorebirds, raptors and songbirds. The movement of these birds in and around the MI NWR constitutes a significant hazard to the Shuttle (or other aircraft) landing at the SLF.

Determining the weight distribution of birds requires knowledge about the predominant bird species of a population and their associated body weights. Bird weights vary with sex, age, subspecies and season. Combining this information with behavioral information on the chronology, geographic and vertical distribution of their movements provides the basic biological inputs into a hazard assessment model; i.e., how many birds of a known hazard potential might interfere with the Shuttle's approach.

The objective of this study was to quantify the birdstrike hazard to the Shuttle at its three primary landing sites in the United States. Sufficient bird population data exist for the Florida site but the information needed for an in-depth study of the California sites is incomplete. Therefore, this report will concentrate on the bird hazards at the SLF. I will include a cursory assessment of the birdstike hazard at Edwards AFB and Vandenberg AFB, CA and will evaluate the bird weight distribution data for the California sites when it becomes available.

SECTION II

DATA COLLECTION AND ANALYSIS

Monthly waterfowl censuses (1978-84), performed by U.S. Fish and Wildlife Service (USFWS) and quarterly surveys of raptors, waders and shorebirds (Reference 2) were analyzed to characterize the bird population at MI NWR. Monthly waterfowl censuses were consolidated into quarters for consistency with the survey data. Appendix A provides a species breakdown for each period. Similar data are being sought for the California sites.

Body weights were assigned to each species according to the highest mean weight published in "Body Weights of 686 Species of North American Birds" (Reference 3). No consideration was given to the sample size, whether the birds were male or female, their breeding condition, or the season they were collected. Where sample range (geographic distribution) was identified, the mean weights for the easterly occurring subspecies were used. All weights were converted to pounds.

Census data show that most waterfowl leave the MI NWR by May of each year and return in October (Appendix A). Large raptors are present year-round but comprise a large part of the bird population from April through September. Many raptors follow the Florida coastline during fall migration. The bird population data was separated into three groups to compare the weight distribution of the waterfowl, raptor and wader/shorebird populations (Table 1). Table 2 shows the consolidated distribution of weights for the three groups. The large numbers of waterfowl (311,900) eclipsed both raptor (3,387) and

TABLE 1. Quarterly Distribution of Bird Weights at MI NWR.

WATERFOWL POPULATION N=311,900

Weight Class(Lbs)	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Annual
1.0	0.0836	0.1277	0.5547	0.0621	0.08104
2.0	0.7408	0.6915	0.1434	0.7481	0.73486
3.0	0.1753	0.1808	0.3015	0.1896	0.18383
4.0	0.0003	0.0000	0.0004	0.0001	0.00023
6.0	0.0000	0.0000	0.0000	0.0000	0.00000
>6.0	0.0000	0.0000	0.0000	0.0001	0.00003

RAPTOR POPULATION N= 3,387

Weight Class(Lbs)	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Annual
1.0	0.4741	0.1842	0.0710	0.4060	0.34928
2.0	0.1034	0.0614	0.0772	0.0855	0.08562
3.0	0.0233	0.1023	0.1235	0.0744	0.06761
4.0	0.2888	0.5048	0.4537	0.3248	0.36374
6.0	0.1034	0.1364	0.2469	0.1026	0.12400
>6.0	0.0069	0.0109	0.0278	0.0068	0.00974

WADER/SHOREBIRD POPULATION N= 96,285

Weight Class(Lbs)	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Annual
1.0	0.6405	0.6804	0.7126	0.6301	0.66345
2.0	0.0636	0.0274	0.0313	0.0587	0.04648
3.0	0.1529	0.1279	0.1341	0.1528	0.14281
4.0	0.0794	0.0365	0.0670	0.0745	0.06543
6.0	0.0199	0.0434	0.0257	0.0205	0.02674
>6.0	0.0437	0.0845	0.0293	0.0634	0.05510

TABLE 2. Cumulative Weight Distributions for MI NWR Birds.

Weight Class(Lbs)	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Annual
1.0	0.16287	0.54988	0.67950	0.15244	0.21950
2.0	0.64331	0.16987	0.04990	0.63682	0.56848
3.0	0.17127	0.13849	0.16092	0.18310	0.17328
4.0	0.01307	0.04067	0.06093	0.01386	0.01848
6.0	0.00[illegible]40	0.03650	0.02421	0.00387	0.00728
>6.0	0.00608	0.06459	0.02454	0.00991	0.01299

wader/shorebird (96,285) proportions of the total population at MI NWR.

The cumulative distribution frequency (CDF) of the weights of the bird populations at MI NWR were calculated from the annual proportion of each weight class for a bird group (see Table 1). Weights for the population samples involved in birdstrikes characteristically fit a Weibull curve (References 4 and 5). The CDF (Figure 1) for the MI NWR waterfowl population approximates a Weibull distribution but the raptor and wader/shorebird curves are flatter, indicating a higher percentage of heavy birds in the population; e.g., Black Vulture (4.7 pounds) and Wood Stork (6.0 pounds), respectively.

FIGURE 1.

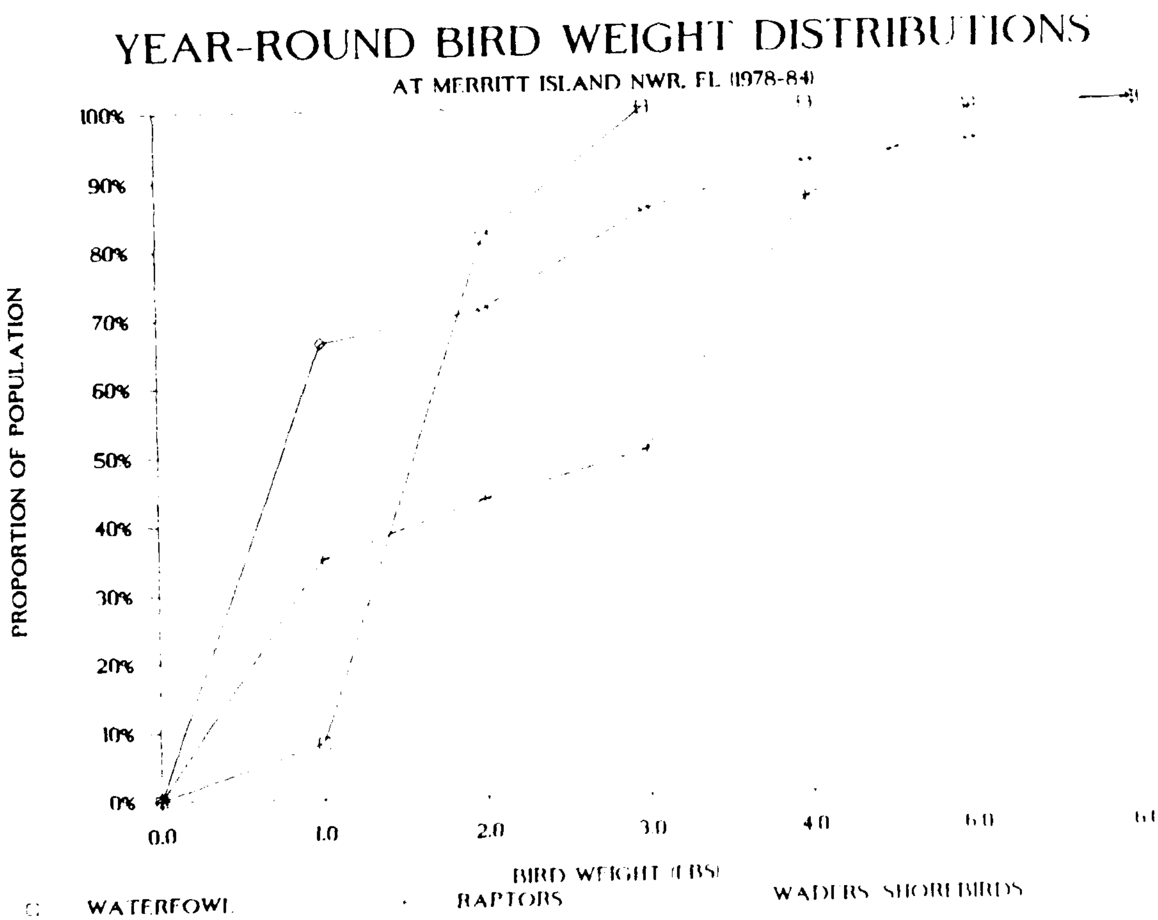
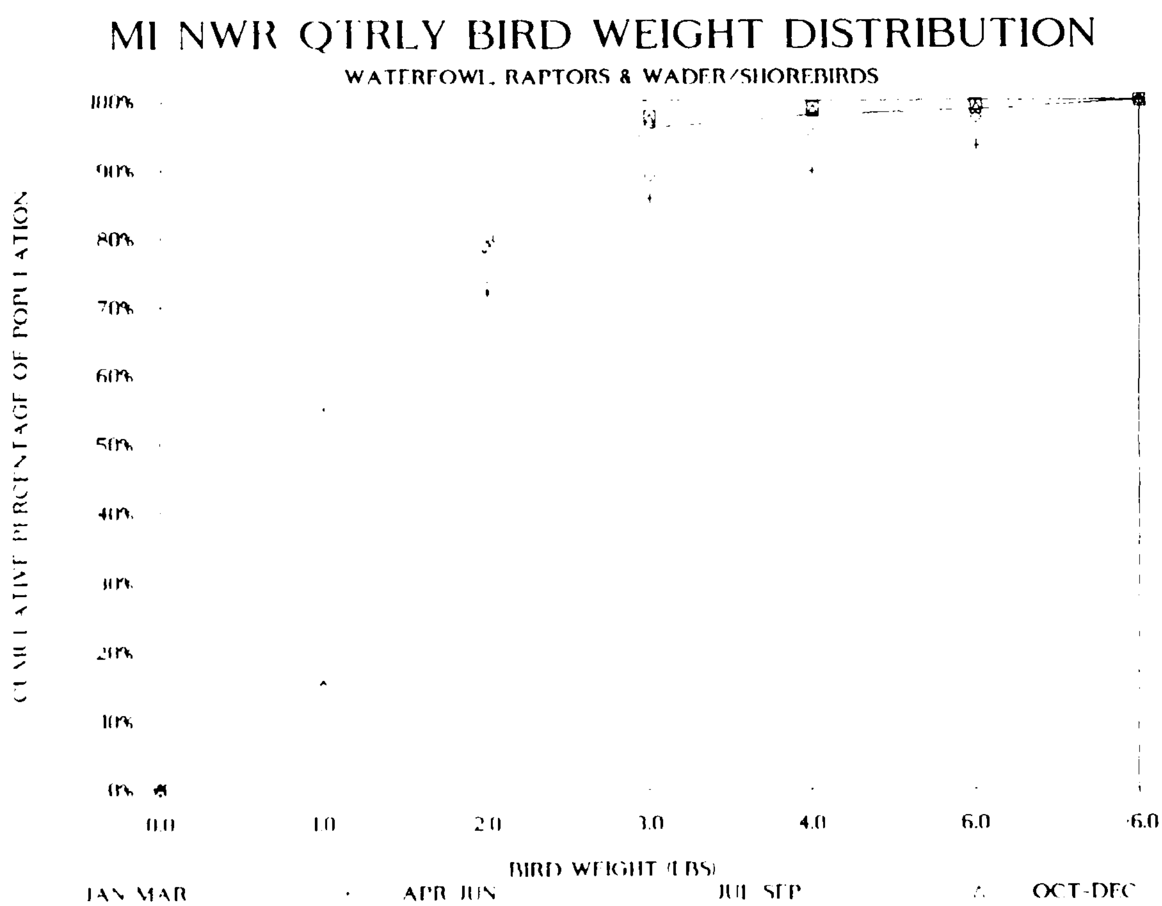


Figure 2 shows the CDF for weight when combining all MI NWR bird groups (from Table 2) throughout the year. Again, the weight distribution for all bird groups combined resembles a Weibull Curve. The occurrence of birds greater than 3 pounds from April through September flattens the distribution, indicating that heavy birds make up a higher percentage of the total population. Most of the duck population has left by early spring leaving the heavier raptors to dominate more of the population.

FIGURE 2.



Bird Avoidance Model

In 1981, the University of Dayton Research Institute (UDRI), under contract from the BASH Team, developed and implemented the Bird Avoidance Model (BAM). BAM quantifies birdstrike risk as a function of mission profile, route-of-flight, date, time of day, and aircraft frontal area (References 6 and 7). The original purpose of the BAM was to compare low-level flight routes on the basis of bird risk to allow flight scheduling to avoid the worst hazards. It would also enable route planners to redesign flight segments to minimize the risk of birdstrikes. This study is the first application of the model to characterize bird weight distributions.

Birdstrike risk is defined by BAM as the number of birds that will be encountered along a flight route during a particular mission. BAM uses latitude, longitude, and segment altitude to calculate birdstrike risk on each segment. The risks are summed over all segments to give the total birdstrike risk for the entire route. BAM allows the user to compare routes/route segments based on an expected number of birdstrikes for each mission or per mile.

The BAM results are shown as the number of expected birdstrikes per flight for each week and for each daily period. Mid-day corresponds to the hours between 1000 to 1500 each day; morning/evening refers to the periods between dawn and 1000 hours and after 1500 hours until dusk; night covers the period between dusk and dawn. Week one begins on 1 January of each year. BAM output also offers the option of a segment-by-segment summary and a breakdown of the effect of local and migratory movements of waterfowl or raptors.

The BAM contains exhaustive data on waterfowl refuges, migration, breeding grounds, and raptor concentrations in the contiguous 48 states. Originally, because a paucity of data on other birds, BAM was based solely on waterfowl populations and their migrations. Quantifiable data on raptor populations and movements and breeding populations of waterfowl were input to enhance the BAM.

The BAM assumes a uniform distgribution of birds within a standard radius of known congregation points such as breeding grounds or wildlife refuges. For example, the model uses a maximum population of 155,000 waterfowl at MI NWR to calculate birdstrike risk. However, monthly censuses conducted by USFWS personnel there show an annual average waterfowl population of over twice that amount (311,000). This contradiction is due to the fact that almost half the MI NWR population consists of coots. BAM uses only duck, goose and swan data to estimate waterfowl hazards. Coots were included in the waterfowl analysis since they are often associated with ducks and have similar habits--but may present less of a daytime flight hazard than ducks.

Shuttle Operations

To assess the birdstrike risk to Shuttle operations, it is necessary to know the distribution of birds along the flight path. The Shuttle uses the same approach window (airspeeds and procedures) for each landing. However, the bird populations and their habits are quite different at each operational site.

The estimate of birdstrike risk is a function of the number of birds within a volume defined by the frontal area swept along the length of the flight route. The frontal area is the square footage of a component/aircraft as it approaches head-on. For the Shuttle, the frontal area varies from 768.7 to 944.1 square feet corresponding to 3 to 8 degrees nose-high attitude. For this analysis, the nominal 5 degrees (818 square feet) was used. This corresponds to the area subtended by the wings, nose and fuselage of the Shuttle.

The BAM calculates the number of birds expected for any segment -as defined by geographic coordinates and base altitude- of a standard or user-defined flight route. In this analysis, a typical Shuttle approach was constructed for the SLF with information provided by a 1974 BASH study (Reference 1) and Ms. Karen Edelstein (NASA). The Shuttle intercepts a 19-degree glide angle at 12,600 feet AGL approximately 6 miles from the runway and flies to a point 1700 feet AGL and 8,000 feet from the runway where it intercepts a 1.5- degree glide slope until touchdown. The final approach was broken into a series of segments (Appendix B) based on nominal altitudes at the end of segment. The geographic coordinates for each segment were estimated from a 1:2,000,000 map.

Hardware and Software

The BAM was "run" for Shuttle approaches into the SLF at KSC FL, Edwards AFB, and Vandenberg AFB CA. The model was hosted in Fortran 77 on the CDC 6700 by Mr. Don Skinn of UDRI. The output was written to 5.25-inch floppy diskettes and edited as a data file. The output provided the birdstrike risk for each route, for all time periods (weekly and daily periods) and by bird group (waterfowl and raptor). Data manipulations were performed on personal computers using LOTUS 1-2-3 software.

SECTION III

BAM RESULTS

The total birdstrike risks calculated for the SLF by BAM for each period are summarized in Appendix C. These estimates include the effects of both waterfowl and raptors but not wader/shorebird populations. It would be inappropriate to combine wader/shorebird population data with either bird category because their habits are so different. However, an estimate based only on bird population levels at MI NWR throughout the year would indicate that wader/shorebird hazards would be intermediate between the other two groups and would vary between 1 to 3 hazards per 1000 Shuttle approaches.

Separate BAM estimates were obtained for waterfowl and raptors to better show the size distribution effects attributable to each population. Waterfowl risks at KSC were multiplied by two to correspond with the increased waterfowl populations reported in the MI NWR censuses. Each risk was multiplied by the proportion of the MI NWR population of a particular size class (see Table 2) during a certain quarter. For example, the risk of hitting a raptor in week 14 was multiplied by the probability that the raptor would weigh 3 to 4 pounds (from Table 1) for that period (week 14 is in the Apr to Jun quarter).

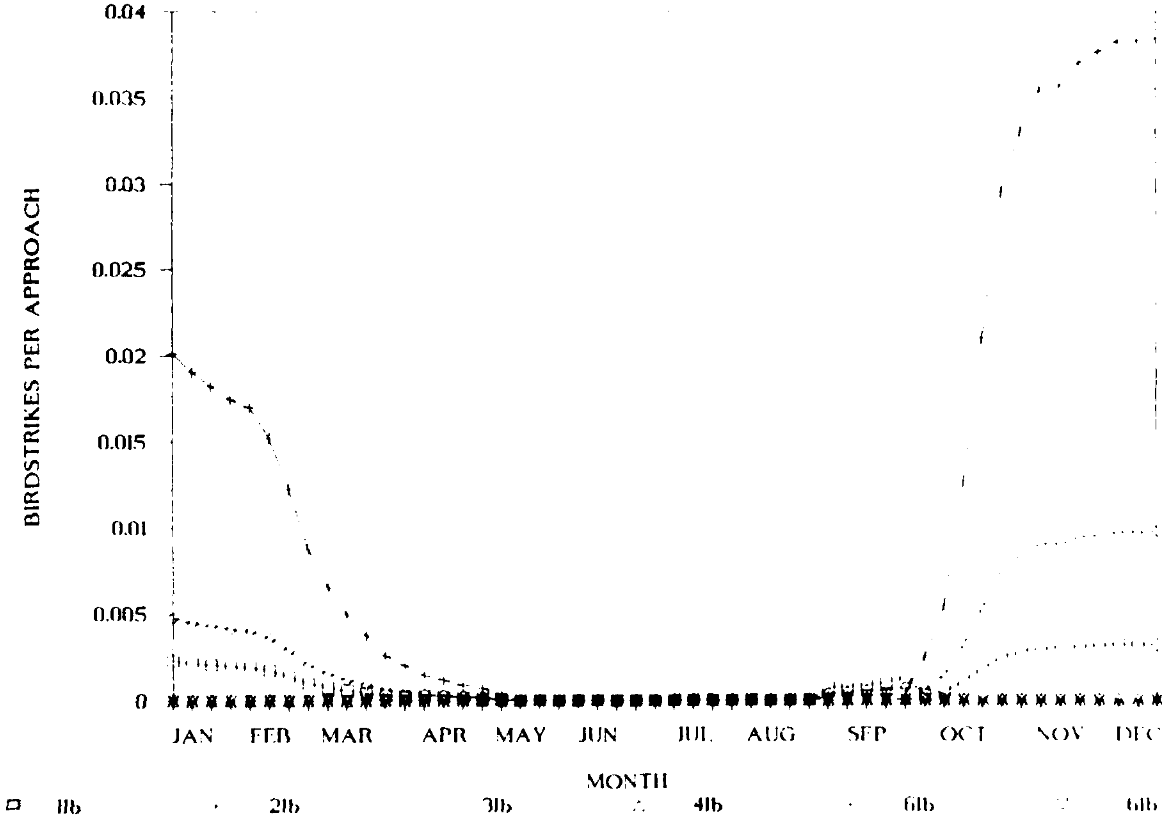
The relative birdstrike risk between the landing sites is not the simple sum of the risks from each daily period (a.m./p.m., midday, night) because of the changing amount of daylight at different latitudes/elevations for each weekly period. Birds respond to the actual illumination of their surroundings for feeding, migration and other behaviors. Since the BAM does not consider this aspect in its calculations of bird movements, the risk estimates must be standardized to the proportion of daylight at each location. The combined weekly birdstrike risks for the landing sites were calculated by multiplying waterfowl and raptor risks for each daily period at each site by the proportional number of hours of daylight each week at that location. The average weekly daylight estimates were obtained from the civil twilight tables which are published for each airfield by the U.S. Naval Observatory. This procedure enabled comparison of the birdstrike risks associated with different periods of the day.

The highest level of risk occurs in the first and last quarter of each calendar year. When plotted (Figure 3), the resultant risk estimates show levels of bird activity and the size relationships of expected birdstrikes. This graph indicates that the most serious birdstrike hazards at the SLF occur in the last quarter of the year when almost 4 of every 100 shuttle flights will impact a bird weighing 1 to 2 pounds and 1 of every 100 will weigh 2 to 3 pounds.

Figures 4 and 5 depict the individual risks from waterfowl and raptors, respectively. These figures show that the waterfowl hazard is more predictable than the raptor hazard. Note that Figure 4 is virtually identical to the total birdstrike risk at the SLF (see Figure 3) suggesting that the annual effects of raptors on the total risk is negligible. Two- and 3-pound waterfowl present the most risk to Shuttle operations for the cooler months at the SLF at levels almost three orders of magnitude higher than raptors. However, during the summer months, 1-pound raptors are replaced by 4-pound ones which creates more potential for structural damage to aircraft.

FIGURE 3. KSC SLF BIRDSTRIKE RISK

WATERFOWL AND RAPTORS FOR ALL PERIODS



Relative Birdstrike Risk

Since bird census data were not available for the Edwards AFB and Vandenberg AFB, California, their bird weight distributions were not determined. However, a comparison between the three sites was possible, using the BAM risk estimates. No mathematical manipulations of the BAM estimates were made to bring the bird population estimates up to known census levels (as

FIGURE 4. KSC SLF WATERFOWL RISK

COMBINED FOR ALL PERIODS

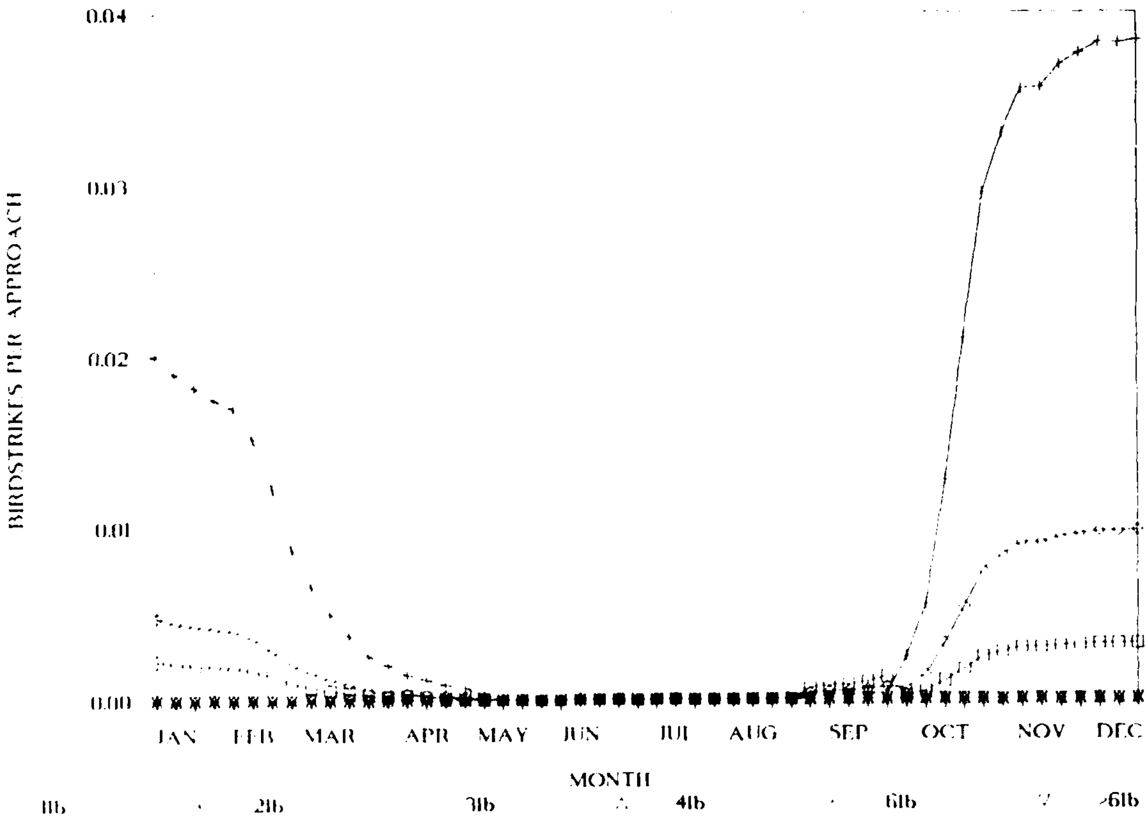
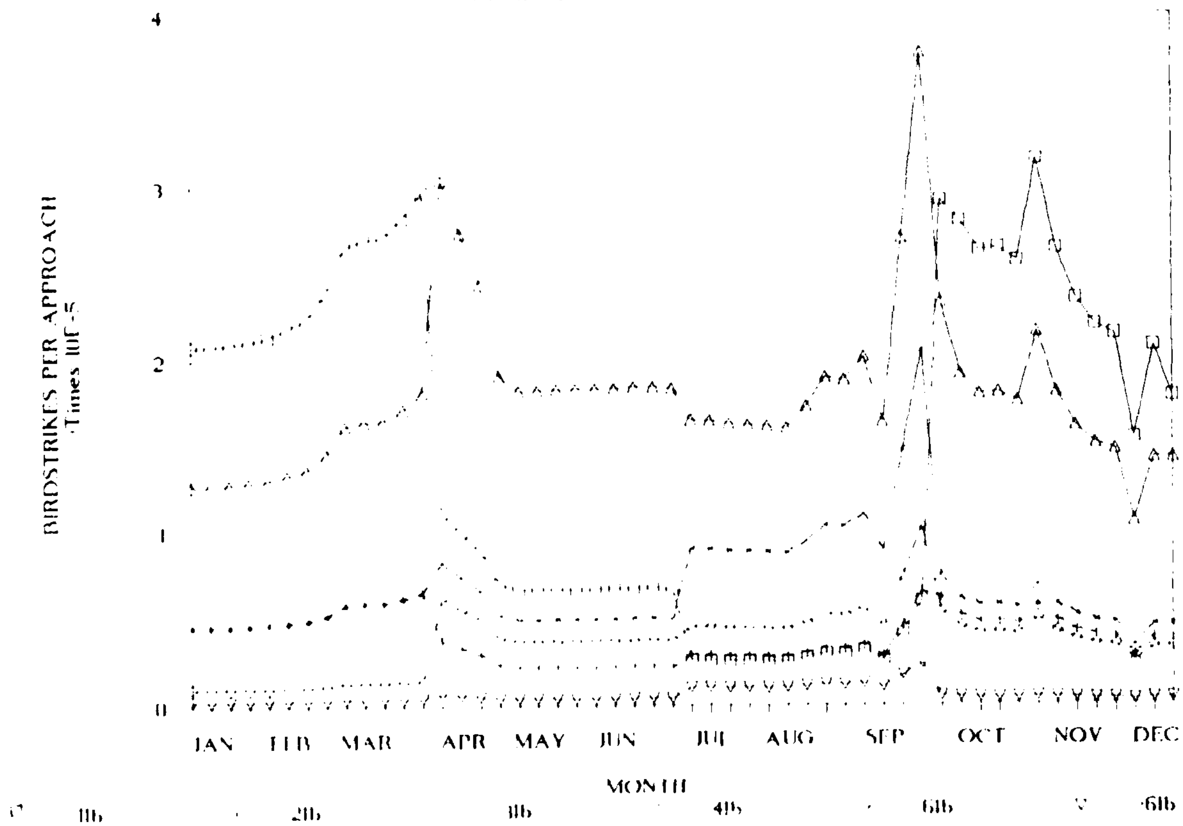


FIGURE 5. KSC SLF RAPTOR RISK

COMBINED FOR ALL PERIODS



in Figures 3 and 4). The estimated risks were plotted to show temporal birdstrike relationships.

A breakdown of the birdstrike risk by period of day (Figures 6 - 8) shows that the highest risk occurs in early winter at all landing sites during the evening, night and early morning hours; the birdstrike risks at midday are slightly higher in mid-winter. Morning and evening risks can vary by as much as one order of magnitude between the California landing sites and KSC. However, nighttime risks, due primarily to migration, are higher at Edwards AFB than at KSC.

FIGURE 6. TOTAL MORNING/EVENING RISK

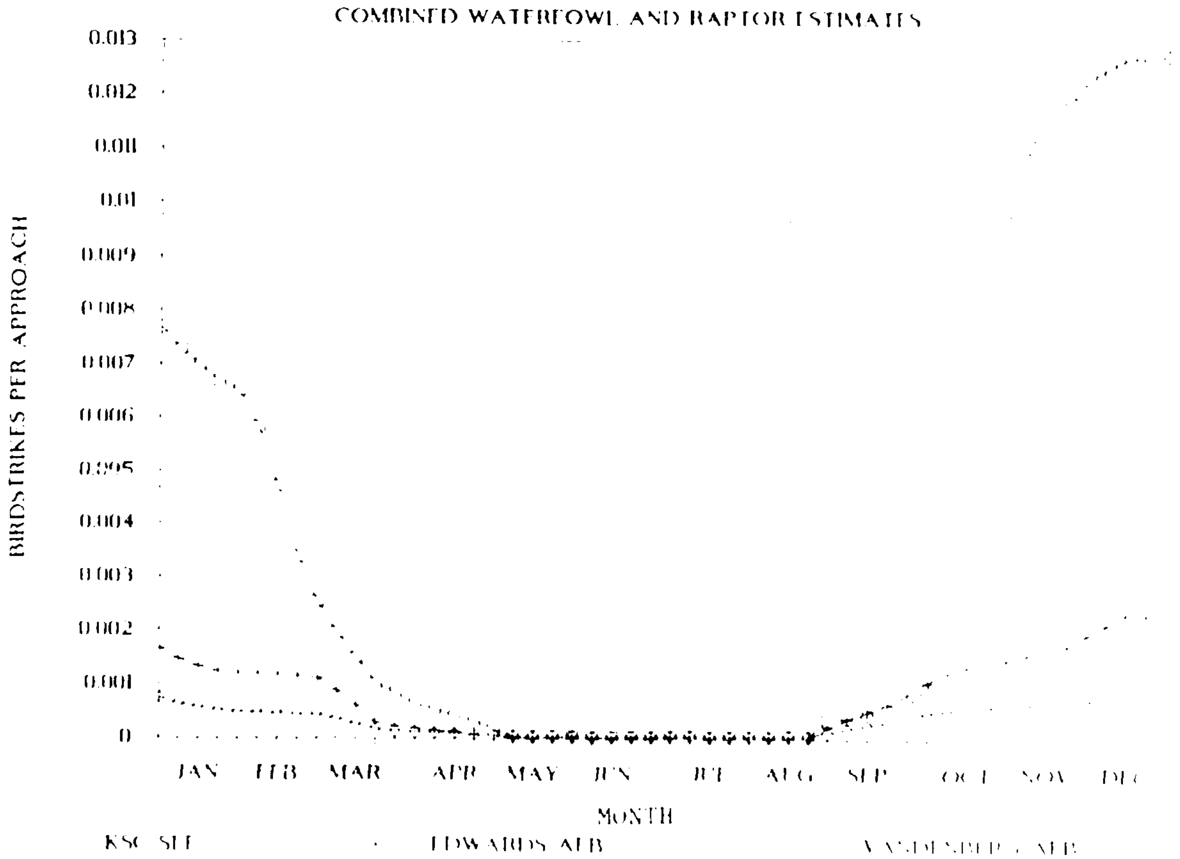


FIGURE 7. TOTAL MIDDAY RISK

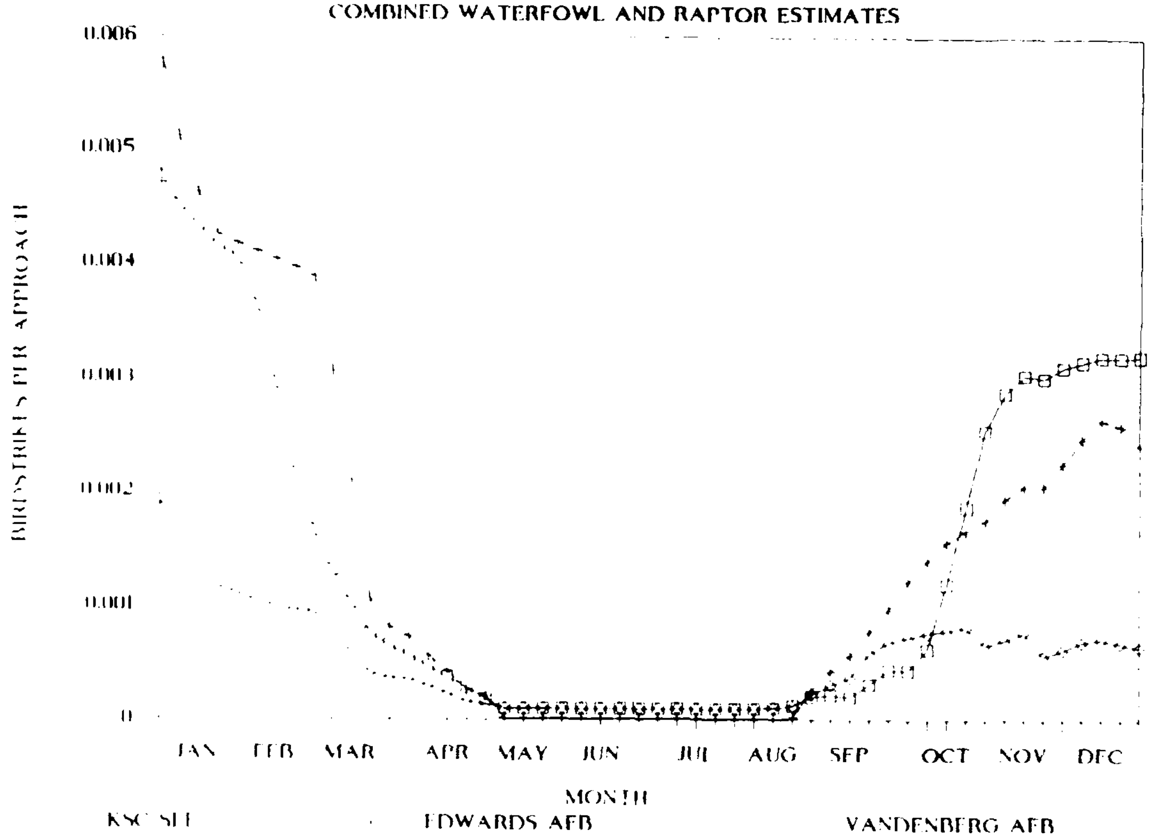
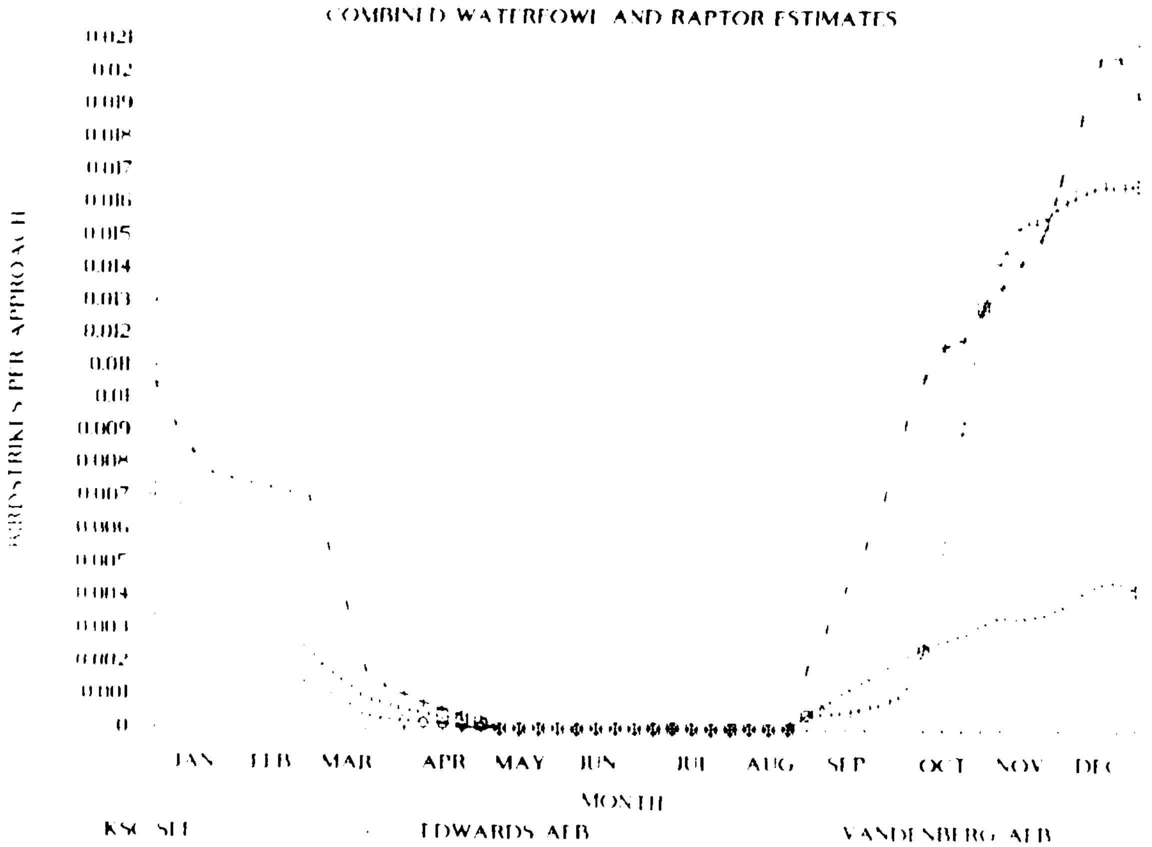


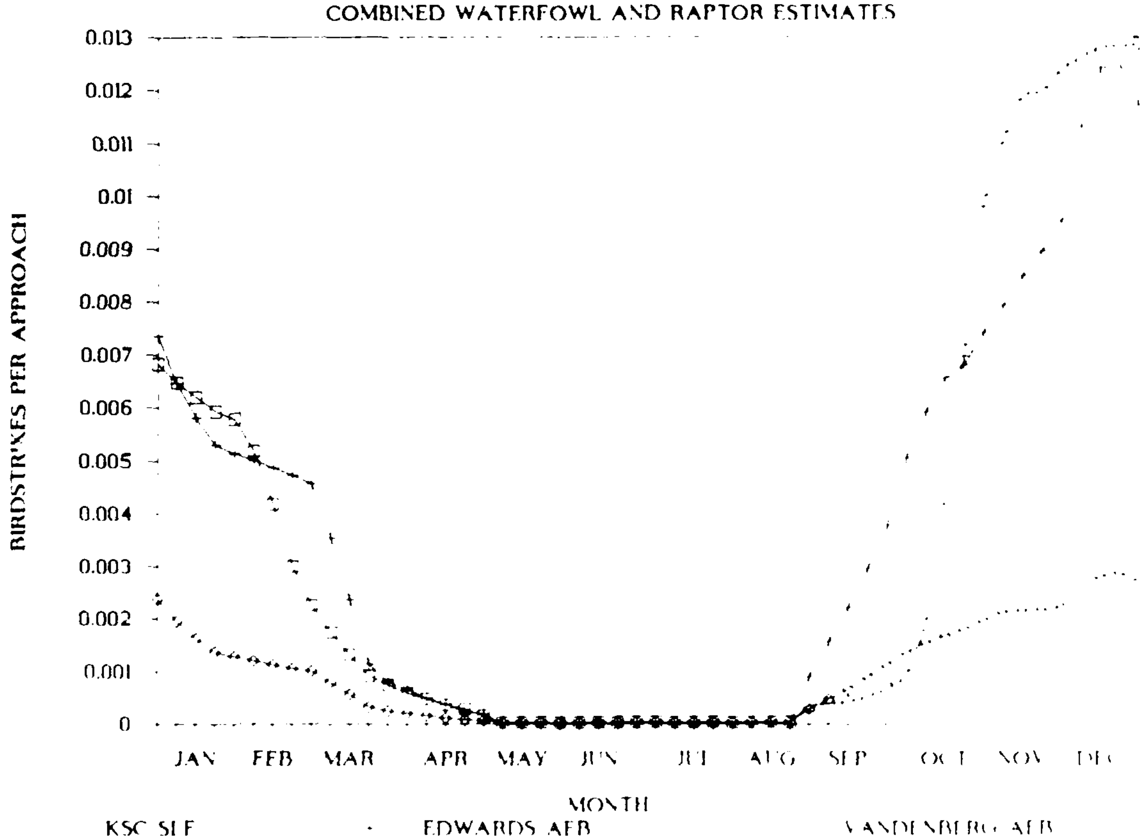
FIGURE 8. TOTAL NIGHTTIME RISK



After adjustment for the amount of daylight hours, Figure 9 shows that all three sites display the same temporal distribution of birdstrike risk; the greatest risk occurs in the late fall and early winter which is roughly twice the risk of the late winter. Based strictly on the BAM estimates, the birdstrike risk is the same at KSC and Edwards. Though usually lower than KSC, the birdstrike risk at Edwards AFB is higher in early spring and early fall. The birdstrike risk at Vandenberg AFB is higher than KSC in the early fall.

FIGURE 9. RELATIVE BIRDSTRIKE RISK

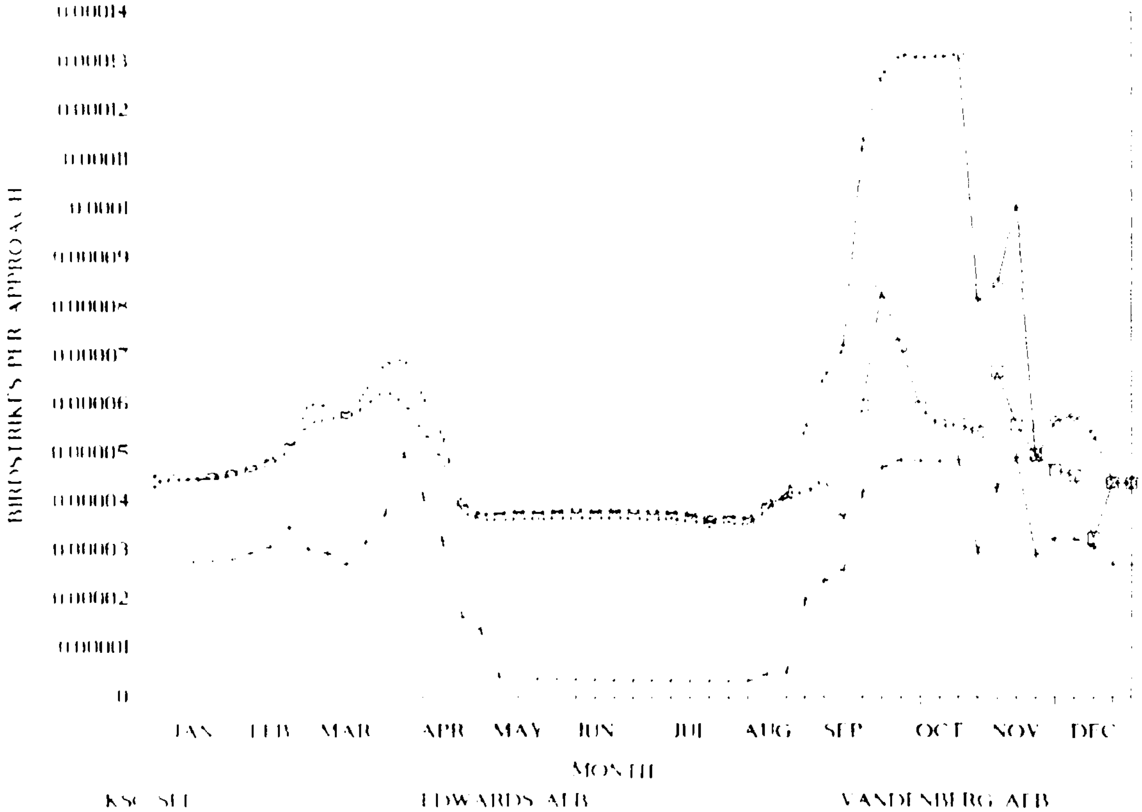
COMBINED WATERFOWL AND RAPTOR ESTIMATES



BAM estimates for raptors can be compared directly between the three landing sites (Figure 10). There is no nighttime risk of hitting a raptor since they are diurnal and are not known to migrate at night. It is important to note that there is twice the chance of hitting a raptor in the late summer and early fall at Vandenberg as at either the SLF or Edwards. Figure 10 also shows several "pulses" of raptor risk in the spring and fall.

FIGURE 10. RELATIVE RAPTOR RISK

BAM ESTIMATES COMBINED FOR ALL PERIODS



SECTION IV

DISCUSSION

If approaches are flown during the periods of high risk, the Shuttle can expect to hit at least one bird in every 100 approaches at either KSC or Edwards and two birds in every 1000 approaches at Vandenberg. This level of birdstrike hazard is due to the relatively large proportion of waterfowl in the nearby bird populations and is the most intense during the fall migration and subsequent overwintering each year.

Waterfowl typically migrate at altitudes below 5,000 feet AGL and are most likely encountered at altitudes below 500 feet AGL during local movements; e.g., when engaged in feeding activities around refuges. They tend to travel in flocks and fly directly between resting areas and feeding sites. Waterfowl are frequently involved in multiple birdstrikes (more than one bird at a time) with USAF aircraft.

Large birds can cause serious damage to aircraft. A 4-pound bird will release 15,928 foot-pounds of energy when struck at 300 knots. The risk of hitting a 4-pound raptor ranges from about three in the summer to thirteen in the fall for every 100,000 approaches at KSC and Vandenberg AFB, respectively. Raptor populations comprise a relatively small part of the birdstrike risk at all landing sites but the hazard may be greater to the Shuttle because of their large size and soaring behavior. Their flight paths are erratic and may reach thousands of feet in the air creating problems at the higher Shuttle approach altitudes and speeds.

Wader/shorebird populations are not included in the BAM, (as well as other major components of typically hazardous bird populations such as gulls) so their effects on birdstrike risk at the various sites are not included in this analysis. This means that the calculated birdstrike risk estimates presented here are somewhat less than the actual risks expected, especially during the summer months when waders/shorebirds are concentrated in large nesting colonies. These two groups constitute a substantial part of the birdstrike hazard at KSC in the summer months (Reference 2). For example, in 1981 nesting colonies of the Least (now called Little) Tern used the overruns of the SLF, creating BASH problems for aircraft. Also, sizable rookeries of wading birds are located on MI NWR and feeding movements of Cattle Egrets on the SLF airdrome create a major hazard. Large populations of gulls and extremely large birds (e.g., Brown Pelicans) could create serious hazards if ever attracted to the vicinity of the SLF.

The BAM mathematically depicts patterns of bird movement according to basic assumptions about similarities of flight habits; i.e., what a certain bird population is doing at a certain moment and at what altitude they are doing it. Since the BAM makes no distinction other than numbers of birds found at certain altitudes during certain periods, it is possible to include taxonomically diverse groups of birds in the analysis. For instance, the soaring behavior exhibited by certain waders, especially the Wood Stork, at MI NWR would create a hazard to flight similar to soaring raptors. However, including Wood Storks as a part of the raptor analysis --with the assumption that the Wood Stork flights occur in similar ways-- would only increase the estimated birdstrike risks at the SLF by approximately one birdstrike per 1000 flights for those birds 6 pounds and over.

Since this analysis is based on a frontal area of 818 square feet, an evaluation of the birdstrike risks to any component of the Shuttle, such as the windscreen, can be made. For example, if the windscreen area is 40 square feet, the birdstrike risk would be about 5 percent of those depicted in the figures.

The design for the windscreen should represent the highest level of bird hazard encountered. At KSC, the chance of hitting a 2- to 3-pound duck close to touchdown ranges between 1 and 4 per 100 flights except during summer when it is essentially zero. While the probability of hitting a 4-pound bird may be numerically remote in the fall and winter each year, the warmer months offer a good chance of encountering a soaring, large (heavier than 4-pound) bird, such as a vulture or stork, at higher approach altitudes and consequently, higher airspeeds. The risk of hitting a raptor (weight unknown) at Vandenberg is higher than at KSC.

Operational constraints on where and when an approach may be conducted could reduce the prospect of a birdstrike; however, this could adversely affect mission accomplishment. Scheduled landings should be avoided at night during the spring and fall migrations. The raptor hazard could be avoided by scheduling daytime landings in the winter months or by early morning landings in the summer (to avoid soaring flights on thermals).

SECTION V

CONCLUSIONS

Birdstrike risks for shuttle landings will vary according to location, time of year, time of day and altitude. The estimates presented here are based on population averages and are subject to changes in the abundance of birds from year-to-year resulting from habitat modification, breeding success or changing weather patterns. Additional population data for other bird groups (e.g., gulls) at the landing sites would enhance the BAM's capabilities to predict the weight distribution of birdstrikes.

BAM results for the KSC SLF show that as much as 4 percent of the shuttle approaches in the late fall would encounter a 2-pound bird while about 1 percent would involve a 3-pound bird. About two Shuttle approaches in every 100,000 during the summer months at the SLF would involve a 4-pound raptor. Birdstrike risk to the Shuttle will be highest in the fall at all landing sites. The relative birdstrike risk (waterfowl and raptors for all daily periods) was the highest at the KSC SLF during the last 3 months of the year. The highest risks from raptors occur at Vandenberg AFB during the early fall. Nighttime risks are highest at KSC and Edwards AFB in the early winter.

Approach birdstrike hazards are created by waterfowl at low altitudes and, to a lesser extent, by raptors at high altitudes. The raptor strikes have a higher potential for damage because of their large size and because of increased Shuttle speeds at high altitudes. Some soaring waders could create a hazard similar to raptors.

Shuttle landings could be scheduled to avoid the highest birdstrike risks at the sites which are normally found during migratory periods. Active bird control techniques can be used in conjunction with bird avoidance procedures to reduce the probability of birdstrike to the Shuttle.

REFERENCES

1. Beason, R.C. and J.P. Nemergut. 1974. Bird-Strike Hazard at the John F. Kennedy Space Center Runway. Air Force Weapons Laboratory, Kirtland AFB NM Report No. AFWL-TR-74-1.

2. Skole, D. 1978. A Preliminary Report on the Species Specific Avian Populations at KSC in Relation to Bird-Strike Hazard. Unpublished report to KSC/MD-B: 115 pp.

3. Dunning, J.B. 1984. Body Weights of 686 Species of North American Birds. Western Bird Banding Association, Monograph No.1. Eldon Publishing; Cave Creek, AZ: 38 pp.

4. Berens, A.P., B.S. West and M.A. Turella. 1978. On a Probabilistic Model for Evaluating the Birdstrike Threat to Aircraft Crew Enclosures. University of Dayton Research Institute, Dayton OH Report No. UDR-TR-78-124: 45 pp.

5. Kolodziejczyk, P. 1984. Evaluation of the Birdstrike Threat to the F-15 Present Fleet, Rapid Deployment Force, and Dual Role Fighter Transparencies. Aeronautical Systems Division, Wright-Patterson AFB OH Report No. ASD-TR-84-5026: 147 pp.

6. Skinn, D., D.L. Applegate and A.P. Berens. 1981. The Bird Avoidance Model (BAM) Phase II/III Report: Programmer's guide. University of Dayton Research Institute, Dayton OH Report No. UDR-TR-81-10. 137 pp.

7. Skinn, D. and A.P. Berens. 1980. Bird Avoidance Model (BAM) Phase I Report: Feasibility Demonstration. University of Dayton Research Institute, Dayton OH Report No. UDR-TR-80-122. 100 pp.

APPENDIX A

BIRD POPULATION CENSUS/SURVEY RESULTS FOR MERRITT ISLAND NATIONAL WILDLIFE REFUGE (MI NWR) CONDUCTED FROM 1978-84.

Appendix A-1. MI NWR Waterfowl Census Results.

SPECIES	WEIGHT (LBS)	QUARTER JAN-MAR	APR-JUN	JUL-SEP	OCT-DEC	TOTALS
G-W TEAL	0.8	1949	52	25	1195	3221
B-W-TEAL	0.9	10808	732	2394	7793	21726
BUFLHEAD	1	297	0	0	32	329
RUDDY	1.3	166	0	0	135	300
SHOVELER	1.4	2232	99	68	1065	3464
HARLEQUIN	1.5	0	0	0	0	0
HOOD MERG	1.5	8	0	0	75	83
WOOD	1.5	192	26	18	63	299
R-N DUCK	1.6	2802	17	0	2715	5533
COOT	1.6	78875	3657	502	64505	147538
F-W DUCK	1.6	1	0	0	4	5
WIDGEON	1.7	12583	83	37	27719	40423
SCAUP	1.9	18848	360	0	12350	31558
GADWALL	2.2	545	0	8	147	700
MOTTLED	2.3	785	1036	1191	727	3739
PINTAIL	2.3	10258	33	112	18518	28920
MALLARD	2.4	45	0	0	18	62
REDHEAD	2.4	14085	0	3	7519	21607
R-B MERG	2.5	303	16	0	220	539
CANVASBAK	2.7		25	0	380	405
BLACK	3.1	50	0	2	21	73
SNOW GOOS	7.6	1	0	0	6	7
CANADA G	8.4	1	0	0	2	3
	TOTALS	156199	6134	4360	145207	311900

Appendix A-2. MI NWR Raptor Survey Results.

SPECIES	WEIGHT (LBS)	QUARTER JAN-MAR	APR-JUN	JUL-SEP	OCT-DEC	TOTALS
KESTREL	0.3	450	75	23	475	1023
SCREECH	0.4	100	0	0	0	100
S-S HAWK	0.4	0	60	0	0	60
MRSH HAWK	1.2	60	20	0	75	155
R-S HAWK	1.4	60	25	25	25	135
PEREGRIN	2.1	2	5	0	12	19
R-T HAWK	2.7	25	70	40	75	210
TRKY VLTR	3.2	270	300	85	300	955
OSPREY	3.5	40	40	37	50	167
G-H OWL	3.9	25	30	25	30	110
BLK VLTR	4.8	120	100	80	120	420
BALD EAGL	11.6	8	8	9	8	33
	TOTALS	1160	733	324	1170	3387

Appendix A-3. MI NWR Wader/Shorebird Survey Results.

SPECIES	WEIGHT (LBS)	QUARTER JAN-MAR	APR-JUN	JUL-SEP	OCT-DEC	TOTALS
SANDERLIN	0.1	500	200	175	500	1375
SEMIPSNDP	0.1	275	300	300	450	1325
DUNLIN	0.1	1200	300	200	2000	3700
LEAST TN	0.1	0	400	100	0	500
SORA RAIL	0.2	4000	375	400	4000	8775
LEAST BIT	0.2	150	500	400	200	1250
KILLDR	0.2	500	400	500	460	1860
S-B DOWTC	0.3	600	650	300	450	2000
FRSTRS TN	0.3	400	250	200	500	1350
G-B TERN	0.4	0	200	250	0	450
GRTR YLLG	0.4	500	200	200	250	1150
BLKNK STL	0.4	0	275	400	0	675
B-B-PLVR	0.5	300	100	170	400	970
WILLET	0.5	350	300	400	250	1300
GALLINULE	0.6	400	750	1100	500	2750
LAUGH GL	0.7	500	3000	3000	350	6850
CATL EGRT	0.7	650	700	1700	500	3550
BLK SKIM	0.8	400	700	1000	400	2500
SNOWY EGT	0.8	400	900	1000	500	2800
L-B HERON	0.8	300	300	200	350	1150
LA HERON	0.9	1300	1000	600	1400	4300
ROYAL TN	1	400	2700	3000	450	6550
P-B GREBE	1	3000	400	350	3000	6750
GLOSY IBS	1.1	350	125	300	350	1125
R-B GULL	1.2	650	175	200	600	1625
CSPN TRN	1.5	500	300	200	500	1500
AM BIT	1.6	100	0	0	125	225
GRT EGRET	2.1	1000	1500	1300	1100	4900
WHITE IBS	2.3	2500	800	1200	2600	7100
ANHINGA	2.7	350	500	500	400	1750
CORMORANT	4	2000	800	1500	2000	6300
G-B HERON	5.7	350	425	200	400	1375
WOOD STRK	6	150	525	375	150	1200
BRN PEL	8	1000	1550	655	1100	4305
WHT PEL	16.5	100	300	0	600	1000
	TOTALS	25175	21900	22375	26835	96285

APPENDIX B

SEGMENT COORDINATES AND ALTITUDES FOR SHUTTLE LANDING SITES USED IN BIRD AVOIDANCE MODEL ANALYSIS

APPENDIX B. Segment Coordinates and Altitudes for Shuttle Landing Sites used in Bird Avoidance Model analysis.

	Start		End		Altitude (Ft AGL)
	LAT	LONG	LAT	LONG	
SLF, KSC FL					
Segment A:	28 44'N	80 47'W	28 43'N	80 46'W	10,000
Segment B:	28 43'N	80 46'W	28 42'N	80 45'W	5,000
Segment C:	28 42'N	80 45'W	28 40'N	80 44'W	2,100
Segment D:	28 40'N	80 44'W	28 39'N	80 43'W	1,700
Segment E:	28 39'N	80 43'W	28 38'N	80 42'W	100
EDWARDS AFB, CA					
Segment A:	35 00'N	117 49'W	34 59'N	117 49'W	10,000
Segment B:	34 59'N	117 49'W	34 58'N	117 50'W	5,000
Segment C:	34 58'N	117 50'W	34 55'N	117 50'W	2,100
Segment D:	34 55'N	117 50'W	34 54'N	117 51'W	1,700
Segment E:	34 54'N	117 51'W	34 54'N	117 52'W	100
VANDENBERG AFB, CA					
Segment A:	34 50'N	120 40'W	34 48'N	120 39'W	10,000
Segment B:	34 48'N	120 39'W	34 47'N	120 38'W	5,000
Segment C:	34 47'N	120 38'W	34 45'N	120 36'W	2,100
Segment D:	34 45'N	120 36'W	34 44'N	120 35'W	1,700
Segment E:	34 44'N	120 35'W	34 43'N	120 34'W	100

APPENDIX C. WEEKLY BIRDSTRIKE RISKS AT SHUTTLE LANDING SITES.

APPENDIX C-1. WEEKLY BIRDSTRIKE RISKS AT THE SHUTTLE LANDING FACILITY (SLF), KENNEDY SPACE CENTER (KSC) FLORIDA.

APPENDIX C-2. WEEKLY BIRDSTRIKE RISKS AT EDWARDS AIR FORCE BASE, CALIFORNIA.

APPENDIX C-3. WEEKLY BIRDSTRIKE RISKS AT VANDENBERG AIR FORCE BASE, CALIFORNIA.

Appendix C-1. Weekly Birdstrike Risks at the SLF, KSC FL.

WEEK	DATE	MIDDAY	A.M./P.M.	NIGHT	COMBINED
1	01JAN-07JAN	0.0047489	0.0076979	0.0072231	0.00683128
2	08JAN-14JAN	0.0045030	0.0072909	0.0068381	0.00647046
3	15JAN-21JAN	0.0043144	0.0069789	0.0065430	0.00619494
4	22JAN-28JAN	0.0041353	0.0066823	0.0062625	0.00593300
5	29JAN-04FEB	0.0040298	0.0065078	0.0060974	0.00578122
6	05FEB-11FEB	0.0036210	0.0058266	0.0054527	0.00517706
7	12FEB-18FEB	0.0029483	0.0047094	0.0043956	0.00418560
8	19FEB-25FEB	0.0021528	0.0033776	0.0031345	0.00300290
9	26FEB-03MAR	0.0016619	0.0025340	0.0023336	0.00225459
10	04MAR-10MAR	0.0013116	0.0019520	0.0017830	0.00173760
11	11MAR-17MAR	0.0010254	0.0014813	0.0013380	0.00131916
12	18MAR-24MAR	0.0007560	0.0010241	0.0009045	0.00091293
13	25MAR-31MAR	0.0006497	0.0008319	0.0007212	0.00074366
14	01APR-07APR	0.0005532	0.0006442	0.0005571	0.00058640
15	08APR-14APR	0.0004589	0.0005258	0.0004486	0.00047810
16	15APR-21APR	0.0003679	0.0004116	0.0003441	0.00037366
17	22APR-28APR	0.0002780	0.0003241	0.0002671	0.00029050
18	29APR-05MAY	0.0001800	0.0001741	0.0001264	0.00015565
19	06MAY-13MAY	0.0000987	0.0000404	0.0000000	0.00003613
20	14MAY-20MAY	0.0000981	0.0000403	0.0000000	0.00003622
21	21MAY-27MAY	0.0000974	0.0000402	0.0000000	0.00003637
22	28MAY-03JUN	0.0000969	0.0000401	0.0000000	0.00003639
23	04JUN-11JUN	0.0000967	0.0000401	0.0000000	0.00003643
24	12JUN-18JUN	0.0000967	0.0000401	0.0000000	0.00003652
25	19JUN-25JUN	0.0000966	0.0000401	0.0000000	0.00003649
26	26JUN-02JUL	0.0000964	0.0000400	0.0000000	0.00003641
27	03JUL-09JUL	0.0000963	0.0000400	0.0000000	0.00003631
28	10JUL-16JUL	0.0000963	0.0000400	0.0000000	0.00003622
29	17JUL-23JUL	0.0000963	0.0000400	0.0000000	0.00003589
30	24JUL-30JUL	0.0000963	0.0000400	0.0000000	0.00003572
31	31JUL-06AUG	0.0000963	0.0000400	0.0000000	0.00003556
32	07AUG-13AUG	0.0000963	0.0000400	0.0000000	0.00003522
33	14AUG-20AUG	0.0001082	0.0000418	0.0000000	0.00003804
34	21AUG-27AUG	0.0001236	0.0000441	0.0000000	0.00004182
35	28AUG-03SEP	0.0001997	0.0003595	0.0004129	0.00034957
36	04SEP-10SEP	0.0002201	0.0003926	0.0004537	0.00038390
37	11SEP-17SEP	0.0001988	0.0004300	0.0005089	0.00041750
38	18SEP-24SEP	0.0003095	0.0005199	0.0006085	0.00051685
39	25SEP-01OCT	0.0004334	0.0006592	0.0007723	0.00066517
40	02OCT-08OCT	0.0004340	0.0009198	0.0011054	0.00090716
41	09OCT-15OCT	0.0006246	0.0019086	0.0024100	0.00188346
42	16OCT-22OCT	0.0011931	0.0043207	0.0055713	0.00428397
43	23OCT-29OCT	0.0018658	0.0071049	0.0092168	0.00706937
44	30OCT-05NOV	0.0025400	0.0099255	0.0129116	0.00990478
45	06NOV-12NOV	0.0028687	0.0110865	0.0144220	0.01108390
46	13NOV-19NOV	0.0030262	0.0119141	0.0155142	0.01192250
47	20NOV-26NOV	0.0030040	0.0119127	0.0155169	0.01194139
48	27NOV-03DEC	0.0030964	0.0123409	0.0160793	0.01239343
49	04DEC-10DEC	0.0031437	0.0125543	0.0163602	0.01261566
50	11DEC-17DEC	0.0031879	0.0127560	0.0166252	0.01280643
51	18DEC-24DEC	0.0031840	0.0127433	0.0166037	0.01281332
52	25DEC-31DEC	0.0031950	0.0127891	0.0166686	0.01285939

Appendix C-2. Weekly Birdstrike Risks at Edwards AFB, CA.

WEEK	DATE	MIDDAY	A.M./P.M.	NIGHT	COMBINED
1	01JAN-07JAN	0.0057904	0.001655	0.0104668	0.00736305
2	08JAN-14JAN	0.0050987	0.0014618	0.0092262	0.00645755
3	15JAN-21JAN	0.0046084	0.0013247	0.0083456	0.00579716
4	22JAN-28JAN	0.0042408	0.0012209	0.0076752	0.00529233
5	29JAN-04FEB	0.0041579	0.0011979	0.0075278	0.00513778
6	05FEB-11FEB	0.0040964	0.0011801	0.0074096	0.00500621
7	12FEB-18FEB	0.004029	0.0011609	0.007284	0.00487097
8	19FEB-25FEB	0.0039584	0.0011393	0.007132	0.00472298
9	26FEB-03MAR	0.0038773	0.0011066	0.0069992	0.00456874
10	04MAR-10MAR	0.003055	0.0008727	0.0054846	0.00353723
11	11MAR-17MAR	0.0020871	0.0005977	0.0037072	0.00236560
12	18MAR-24MAR	0.0010636	0.000303	0.0017767	0.00113690
13	25MAR-31MAR	0.0008093	0.0002275	0.001267	0.00081431
14	01APR-07APR	0.0007289	0.0001909	0.0010164	0.00066413
15	08APR-14APR	0.0005529	0.000146	0.0007579	0.00049079
16	15APR-21APR	0.0004265	0.000115	0.0005892	0.0003775
17	22APR-28APR	0.0002535	0.0000743	0.00038	0.00023520
18	29APR-05MAY	0.0002064	0.0000624	0.0003131	0.00019169
19	06MAY-13MAY	0.0000115	0.0000039	0.0000000	0.00000398
20	14MAY-20MAY	0.0000109	0.0000038	0.0000000	0.00000385
21	21MAY-27MAY	0.00001	0.0000036	0.0000000	0.00000359
22	28MAY-03JUN	0.0000094	0.0000036	0.0000000	0.00000350
23	04JUN-11JUN	0.0000091	0.0000035	0.0000000	0.00000341
24	12JUN-18JUN	0.0000092	0.0000035	0.0000000	0.00000343
25	19JUN-25JUN	0.000009	0.0000035	0.0000000	0.00000339
26	26JUN-02JUL	0.0000088	0.0000035	0.0000000	0.00000335
27	03JUL-09JUL	0.0000087	0.0000035	0.0000000	0.00000332
28	10JUL-16JUL	0.0000087	0.0000035	0.0000000	0.00000331
29	17JUL-23JUL	0.0000087	0.0000035	0.0000000	0.00000329
30	24JUL-30JUL	0.0000087	0.0000035	0.0000000	0.00000315
31	31JUL-06AUG	0.0000087	0.0000035	0.0000000	0.00000323
32	07AUG-13AUG	0.0000087	0.0000035	0.0000000	0.00000320
33	14AUG-20AUG	0.0000139	0.0000042	0.0000000	0.00000452
34	21AUG-27AUG	0.0000155	0.0000044	0.0000000	0.00000488
35	28AUG-03SEP	0.0002639	0.0002184	0.0018052	0.00090226
36	04SEP-10SEP	0.0004227	0.0003631	0.0030859	0.00156101
37	11SEP-17SEP	0.0005677	0.0005	0.0043064	0.00221112
38	18SEP-24SEP	0.0007753	0.0006533	0.0056057	0.00294856
39	25SEP-01OCT	0.0009641	0.0008229	0.0071043	0.00377055
40	02OCT-08OCT	0.0012196	0.0010743	0.0093046	0.00504825
41	09OCT-15OCT	0.001401	0.0012371	0.0107508	0.00590917
42	16OCT-22OCT	0.0015594	0.0013472	0.0116935	0.00654300
43	23OCT-29OCT	0.0016581	0.0013785	0.0119067	0.00678858
44	30OCT-05NOV	0.0017547	0.0014781	0.0128369	0.00740443
45	06NOV-12NOV	0.0019352	0.001577	0.0135175	0.00792038
46	13NOV-19NOV	0.002046	0.0016655	0.0142799	0.00847245
47	20NOV-26NOV	0.0020491	0.0017366	0.0150213	0.00894220
48	27NOV-03DEC	0.002246	0.0019394	0.016849	0.00952019
49	04DEC-10DEC	0.0024611	0.0021427	0.0186646	0.01129607
50	11DEC-17DEC	0.0026345	0.0023451	0.0205176	0.01240026
51	18DEC-24DEC	0.002586	0.0023459	0.0205802	0.01246279
52	25DEC-31DEC	0.0024113	0.002206	0.019356	0.01171702

Appendix C-3. Weekly Birdstrike Risks at Vandenberg AFB, CA.

WEEK	DATE	MIDDAY	A.M./P.M.	NIGHT	COMBINED
1	01JAN-07JAN	0.0019189	0.0007473	0.003268	0.00237776
2	08JAN-14JAN	0.0015961	0.0006418	0.0026713	0.00194838
3	15JAN-21JAN	0.0013497	0.0005628	0.0022156	0.00161858
4	22JAN-28JAN	0.0011635	0.0005025	0.0018713	0.00137023
5	29JAN-04FEB	0.0011063	0.0004856	0.0017651	0.00128665
6	05FEB-11FEB	0.0010439	0.0004679	0.0016416	0.00119431
7	12FEB-18FEB	0.001003	0.000455	0.0015594	0.00113054
8	19FEB-25FEB	0.0009571	0.0004394	0.001449	0.00105202
9	26FEB-03MAR	0.0009537	0.0004328	0.0013922	0.00101102
10	04MAR-10MAR	0.0007836	0.0003535	0.001091	0.00079648
11	11MAR-17MAR	0.0005908	0.0002623	0.0007583	0.00056320
12	18MAR-24MAR	0.0004058	0.0001667	0.0003949	0.00032107
13	25MAR-31MAR	0.0003619	0.0001413	0.0002799	0.00024933
14	01APR-07APR	0.0003493	0.0001136	0.0002142	0.00020671
15	08APR-14APR	0.000285	0.0000947	0.0001571	0.00016088
16	15APR-21APR	0.0002301	0.0000804	0.0001156	0.00012627
17	22APR-28APR	0.0001511	0.0000613	0.0000717	0.00008421
18	29APR-05MAY	0.000131	0.0000557	0.0000532	0.00007043
19	06MAY-13MAY	0.0001013	0.0000405	0.0000000	0.00003755
20	14MAY-20MAY	0.0001008	0.0000404	0.0000000	0.00003783
21	21MAY-27MAY	0.0000999	0.0000403	0.0000000	0.00003777
22	28MAY-03JUN	0.0000994	0.0000402	0.0000000	0.00003796
23	04JUN-11JUN	0.0000991	0.0000402	0.0000000	0.00003806
24	12JUN-18JUN	0.0000992	0.0000402	0.0000000	0.00003808
25	19JUN-25JUN	0.000099	0.0000402	0.0000000	0.00003812
26	26JUN-02JUL	0.0000988	0.0000401	0.0000000	0.00003804
27	03JUL-09JUL	0.0000987	0.0000401	0.0000000	0.00003793
28	10JUL-16JUL	0.0000987	0.0000401	0.0000000	0.00003777
29	17JUL-23JUL	0.0000987	0.0000401	0.0000000	0.00003752
30	24JUL-30JUL	0.0000987	0.0000401	0.0000000	0.00003593
31	31JUL-06AUG	0.0000987	0.0000401	0.0000000	0.00003685
32	07AUG-13AUG	0.0000987	0.0000401	0.0000000	0.00003651
33	14AUG-20AUG	0.0001124	0.0000421	0.0000000	0.00003973
34	21AUG-27AUG	0.0001166	0.0000427	0.0000000	0.00004039
35	28AUG-03SEP	0.000224	0.0001251	0.0004305	0.00027549
36	04SEP-10SEP	0.0003076	0.0001875	0.0007748	0.00046824
37	11SEP-17SEP	0.0003746	0.0002479	0.001141	0.00067246
38	18SEP-24SEP	0.0005801	0.0003277	0.001479	0.00090799
39	25SEP-01OCT	0.0006774	0.0003959	0.0018177	0.00111509
40	02OCT-08OCT	0.0007267	0.0004908	0.0022108	0.00136408
41	09OCT-15OCT	0.0007607	0.0005433	0.0024819	0.00153363
42	16OCT-22OCT	0.0007904	0.0005799	0.0026897	0.00167423
43	23OCT-29OCT	0.0008166	0.0005989	0.0028671	0.00179724
44	30OCT-05NOV	0.000657	0.0006179	0.003218	0.00196943
45	06NOV-12NOV	0.0006982	0.0006501	0.0034159	0.00211216
46	13NOV-19NOV	0.0007675	0.0006739	0.003397	0.00214572
47	20NOV-26NOV	0.0005665	0.0006667	0.0034928	0.00216487
48	27NOV-03DEC	0.0006159	0.0007251	0.003696	0.00220017
49	04DEC-10DEC	0.0006832	0.0008011	0.0041192	0.00260149
50	11DEC-17DEC	0.0007065	0.0008649	0.0044432	0.00279996
51	18DEC-24DEC	0.0006788	0.0008712	0.0045551	0.00286493
52	25DEC-31DEC	0.0006473	0.0008242	0.0042892	0.00270031