ROTORCRAFT BIRD STRIKE WORKING GROUP RECOMMENDATIONS TO THE AVIATION RULEMAKING ADVISORY COMMITTEE (ARAC)

Federal Aviation Administration

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EXECUTIVE SUMMARY

In August 1996, the Federal Aviation Administration (FAA) amended its regulations to incorporate bird strike protection rules for transport category rotorcraft (Part 29) with 14 CFR § 29.631, Amdt. 29-40, requiring transport category rotorcraft be designed to ensure continued safe flight and landing (CSFL) for Category A or safe landing (SL) for Category B following an impact with a 2.2-pound (1.0 kg) bird. At that time, bird strike protection was not adopted for normal category rotorcraft (Part 27). Since then, data show an increase in reported bird strikes with both normal category and transport category rotorcraft. An increase in bird strikes elevates the risk of potential serious injuries or fatalities to occupants and substantial damage to rotorcraft.

On March 23, 2016, the FAA assigned the Aviation Rulemaking Advisory Committee (ARAC) the task of providing recommendations regarding bird strike protection rulemaking, policy, and guidance for normal category rotorcraft, to evaluate existing bird strike protection standards for transport category rotorcraft, and to provide recommendations for enhancement. The ARAC accepted the tasks as defined below, establishing the Rotorcraft Bird Strike Working Group (RBSWG) to provide advice and recommendations to the ARAC.

As of the beginning of 2017, Part 27 normal category rotorcraft comprise approximately 94% of rotorcraft operating in the U.S. based on data analyzed during this study. Bird strike data from the FAA's National Wildlife Strike Database (NWSD) indicates about 75% of reported bird strikes from 1990–2013 involved normal category rotorcraft. These percentages suggest that an absence of bird strike protective requirements for normal category rotorcraft presents a risk for most U.S. rotorcraft.

Whether normal category or transport category, the unique operating profile of a rotorcraft presents a different exposure to bird strike risk than for fixed-wing aircraft.

Rotorcraft Bird Strikes

As noted in the (Federal Register, 2016) notice, which announced the formation of the RBSWG, "the FAA has observed increased strikes to the rotorcraft windshield area with a force of impact that has directly endangered occupants and elevated the risk to safe rotorcraft operations. Bird penetration into the cockpit and cabin areas has become increasingly common, elevating the probability of potential serious injuries or fatalities to occupants. Moreover, direct bird impact to the pilot has led to partial or complete pilot incapacitation in numerous cases, often causing an increased risk for loss of control of the rotorcraft and fatalities.[1]"

These observations reinforce previous findings from a study (Cleary, Dolbeer, & Wright, 2006) based on 15 years of data from the FAA's NWSD. The study concluded that:

(1) Rotorcraft were significantly more likely to be damaged by bird strikes than airplanes,

[1] FR Vol. 81, No. 81, Wednesday, April 27, 2016, Notices, 24930-24932

(2) Windshields on rotorcraft were more frequently struck and damaged than windshields on airplanes, and
(3) Rotorcraft bird strikes were more likely to lead to injuries to crew or passengers than airplane bird strikes.

Washburn, Cisar and DeVault (2013) conducted a comprehensive analysis of data available from reports of wildlife strikes with civil rotorcraft within the US from 1990 to 2011. They state, "*This analysis indicated that patterns of reported bird strikes to civil helicopters were very different from those involving civil fixed wing aircraft.*"

Strike Reporting Rate

Rotorcraft bird strike data indicates a 57% increase in bird strikes since 2009 and more than a 700% increase since the early 2000s. Although it was initially posited that this increased bird strike reporting after 2009 could be due to a growing population of larger birds, quieter aircraft, and/or an increase in the number of rotorcraft operations, the likely reason was the increased reporting rate for rotorcraft bird strike events following two significant events that occurred early in 2009: the January 4, 2009 fatal crash of N748P, PHI Sikorsky S-76C++ outside Morgan City, Louisiana following a bird strike with a female red-tailed hawk; and the January 15, 2009 US Airways Flight 1549 Airbus A320-214 that ditched in the Hudson River adjacent to Manhattan Island, New York after striking a flock of Canada geese, the event publicly referred to as the "Miracle on the Hudson".

Bird Mass

The risk of damage from bird strike increases with bird mass and speed, as one would expect. With respect to mass, the mean weight (mass) for all impacts with Part 29 rotorcraft was found to be 2.3 lb (1.05 kg), which is very close (104.5%) to the requirement for the current rule. Some events with higher weight bird species did occur as discussed in the main body of the report. The maximum reported bird weight in the NWSD that occurred on 14 CFR § 29.631-compliant rotorcraft, was 4.8 lb (2.2 kg) for multiple black vultures at 145 knots. In that event, however, the rotorcraft could continue with safe flight and landing (CSFL).

In reviewing events in the NWSD for 14 CFR § 29.631-compliant rotorcraft, no fatalities were found. The RBSWG concludes that bird strikes have not been a cause of accidents to § 29.631-compliant rotorcraft, not only during the study period since January 2009 but since the rule was enacted in August 1996. One fatal accident did occur with a Part 29 Amdt. 29-40 rotorcraft that was not compliant with 14 CFR § 29.631. This supports a conclusion that the current regulation has been effective in preventing fatalities and significant injuries including some events with larger than specified bird species (e.g., > 2.2 lb).

Rotorcraft Strike Impact Locations

Bird strike distributions on Part 27 rotorcraft show that 85% occurred forward of the main rotor mast on the windshield, main rotor, nose and fuselage. Only 4% of the strikes occurred on the tail rotor and empennage. Similarly, strike distributions on Part 29 rotorcraft show that 84% occurred forward of the main rotor mast on the windshield, main rotor, nose and fuselage and only 3% of the strikes occurred on the tail rotor and empennage. The RBSWG recommends reinforcing the structure in the forward section of the fuselage in a risk-based, safety-tiered approach.

Flocking Threat

Data from the NWSD for single vs. multiple bird strikes on normal and transport category rotorcraft indicate that the overwhelming majority, 94-96%, occurred with a single bird per strike event.

Phase of Flight

Two-thirds of the recorded bird strikes occurred during the *enroute* phase, with 8-9% during *approach* and 9-10% during *climb*. These three flight phases make up 85% of the reported bird strikes in the NWSD.

Time of Day

Of the reported bird strikes on Part 27 rotorcraft, 32% occurred during the day while 43% occurred during the night. This would suggest for a Part 27 rotorcraft there is a 34% higher probability of a bird strike at night compared with day. This is opposite the findings for Part 29 rotorcraft, where there are more incidents during the daytime (43%) than at night (29%). Correspondingly for a Part 29 rotorcraft, there is a 48% higher probability of a bird strike during the day compared with night. This disparity is likely due to the difference in the type of flight operations for Part 27 and Part 29 rotorcraft. While the use of Part 27 rotorcraft includes air medical transport and law enforcement at all hours of the day and night, Part 29 rotorcraft are heavily used in energy production transportation, predominately during the daytime.

Rotorcraft Airspeed

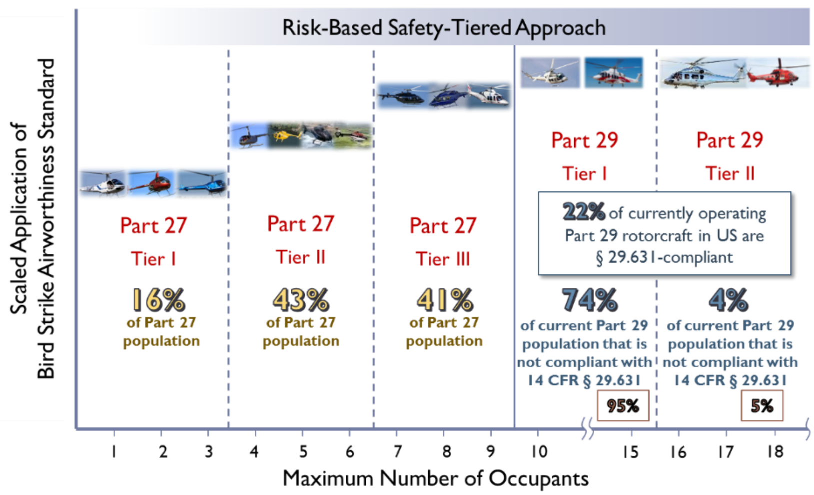
Rotorcraft speed is an important aspect in the likelihood and severity of bird-rotorcraft collisions. The higher the speed, the higher the likelihood of a bird strike and likelihood of damage. The speed that the rotorcraft approaches the bird reduces the time in which the bird can assess the threat and initiate evasive flight maneuvers to avoid the rotorcraft. Operators of rotorcraft have found that the number of strikes can be reduced by limiting airspeed to 80 knots or below, when practical. Of the bird strike records that had airspeed reported, slightly more than 3 out of 4 (77.1%) occurred above 80 knots. In addition to rotorcraft velocity reducing bird evasion potential, it also contributes to the severity of a strike in the event one occurs due to increased kinetic energy, $E_k = ½\ m\ v^2$.

Assumptions

A detailed list of assumptions used by the RBSWG in this report is provided at the end of the **Introduction** section in the main body of the report.

Risk-Based Approach

With the trend towards performance-based regulations, the most logical risk-based safety continuum is dependent upon the maximum number of occupants (crew and passengers) on board, therefore a risk-based tiered safety approach shown below is adopted for implementing regulation, policy and guidance.



SUMMARY OF RECOMMENDATIONS

The RBSWG proposes the following new airworthiness standard, 14 CFR § 27.631 for newly type certificated Part 27 normal category rotorcraft.

> *The rotorcraft with a maximum occupancy (pilot plus passengers) of 7 to 9 must be designed to ensure capability of safe landing after impact upon the windshield with a 2.2-lb (1.0-kg) bird when the velocity of the rotorcraft (relative to the bird along the flight path of the rotorcraft) is equal to V_{NE} or V_H (whichever is the lesser) at altitudes up to 8,000 feet. Compliance must be shown by tests or by analysis based on tests carried out on sufficiently representative structures of similar design.*

Based on results of the economic analysis, the RBSWG does not recommend implementing bird strike regulations via § 27.2 (Special retroactive requirements) for newly manufactured normal category rotorcraft.

The RBSWG recommends keeping the current regulation for newly type certificated Part 29 transport category rotorcraft.

The RBSWG proposes the following addition to airworthiness standard, 14 CFR § 29.2 (Special retroactive requirements) for newly manufactured transport category rotorcraft.

> *For each rotorcraft manufactured after January 1st, 2030,*

(a) *with maximum occupancy (crew plus passengers) of 16 or more, each applicant must show compliance to 14 CFR § 29.631.*
(b) *with maximum occupancy (crew plus passengers) of 10 to 15, each applicant must show compliance to 14 CFR § 29.631 applied only to the windshield and flight critical equipment/components forward of the main rotor mast that could prevent continued safe flight and landing for Category A or a safe landing for Category B rotorcraft.*

The RBSWG recommends a policy that encourages upgrading existing rotorcraft and/or implementing bird strike safety procedures for all rotorcraft operators as follows.

- Existing Part 27 normal category rotorcraft with maximum occupancy of 1 to 3 (crew plus passengers) should implement bird strike safety procedures described below.
- Existing Part 27 normal category rotorcraft with maximum occupancy of 4 to 6 should implement bird strike safety procedures described below.
- Existing Part 27 normal category rotorcraft with maximum occupancy of 7 to 9 must install a bird strike resistant (BSR) windshield that meets the same level of bird strike protection in the proposed 14 CFR § 27.631.
- Existing Part 29 transport category rotorcraft with maximum occupancy of 10 to 15 must install a BSR windshield that meets the requirements of 14 CFR § 29.631.
- Existing Part 29 transport category rotorcraft with maximum occupancy of 16 or more must install a BSR windshield that meets the requirements of 14 CFR § 29.631 and must protect flight critical equipment/components forward of the main rotor mast that if damaged could prevent CSFL for Category A or a SL for Category B rotorcraft.

The RBSWG recommends that rotorcraft OEMs, or third-parties with Parts Manufacturer Approval (PMA), develop and certify optional retrofit kits, particularly BSR windshields, for each rotorcraft model type delivered after 1996 (when 14 CFR § 29.631 became effective with Amdt. 29-40) that achieves an equivalent level of protection as the corresponding newly type certificated rotorcraft. The target certification date for these kits is January 1st, 2030.

The RBSWG recommends the following policy and guidance material be developed.

- Maintain guidance that no windshield penetration is permitted for the required bird regulation in showing compliance. This is thought to provide additional margin to the requirement for the most impacted and typically most critical area.
- Pursue establishing guidance for the temperature range required for windshields, undergoing bird strike tests.
- Pursue establishing guidance for induced effects such as shock pulse to critical equipment, such as instrument panel components, subjected to shock pulse from proximate bird strike.
- Pursue establishing guidelines on analytical substantiation techniques to show compliance to the bird-strike requirement. This could provide a path to lower cost means of substantiation and compliance. At the very least, higher confidence and possibly reduced testing may be possible.

Bird Strike Safety Procedures

The RBSWG further recommends that guidance be developed for operators to implement bird strike safety procedures which include the following.

- Reduce airspeed when practical. Training content should remind flight crews that more than 3 out of 4 bird strikes (77%) occur during airspeeds greater than 80 knots.
- Increase altitude as quickly as possible and practical, when allowed by other flight variables, and fly higher at night when possible, since birds also tend to fly higher at night.
- Utilize personal protective equipment (PPE) consisting of a helmet and visor, at least for the crew, when practical.
- Use taxi and/or landing lights in a continuous mode during sunny conditions and at night when practical, and a 2-Hz pulsed mode during partly cloudy conditions.

The RBSWG also recommends that a CAUTION be posted in all Rotorcraft Flight Manuals (RFMs) stating the following.

- CAUTION: Operating rotorcraft in areas of high concentrations of birds or flocking birds increases likelihood of a damaging bird strike as airspeed increases and altitude AGL decreases. When operating the rotorcraft at lower altitudes during takeoff and climb-out, the rotorcraft should be operated at lower airspeeds to decrease the likelihood and severity of a potential bird strike. Though regional differences exist during spring and fall migration periods, operating a rotorcraft at altitudes below 2,500 feet AGL may increase the likelihood of a damaging bird strike.

Further, the RBSWG recommends that air carriers and general aviation operators, working with the FSDO Safety Programs and Flight Service Briefing, should identify and publish known locations and probability of bird concentrations. The location of bird concentrations during seasonal migrations and the local bird nesting and roosting habitats, should be made available to the rotorcraft operator and pilot for preflight planning, to minimize the potential for bird strikes. Local recognition of these threat areas along with increased familiarity and examination of the NWSD into which reported bird strikes are recorded with increasing frequency and accuracy, can provide a valuable resource for flight crews. This information should be incorporated into alert bulletins, flight service Notice to Airmen (NOTAM) and other systems presently used to inform flight crews of the hazards of bird concentrations.

The RBSWG recommends that research in non-traditional means of bird strike protection be accelerated in at least the following areas:

- Alerting the bird – Rotorcraft light technology that would enhance day/night avian detection of and response to rotorcraft across multiple species of birds.

- Alerting the pilot – Inflight electronic bird detection devices and avoidance radar to provide the rotorcraft with spherical warning.

Finally, as noted in Appendix C, there is a sizable growth rate in the population of larger and medium size bird species. As a result, the USDA is encouraged to continue management of large and medium birds near airports in the U.S.

INTRODUCTION

BACKGROUND

In August 1996, the Federal Aviation Administration (FAA) amended its regulations to incorporate bird strike protection rules for transport category rotorcraft (Part 29) with 14 CFR § 29.631, Amdt. 29-40, requiring transport category rotorcraft be designed to ensure continued safe flight and landing (CSFL) for Category A or safe landing (SL) for Category B following an impact with a 2.2-pound (1.0 kg) bird. At that time, bird strike protection was not adopted for normal category rotorcraft (Part 27). Since then, data shows an increase in reported bird strikes with both normal and transport category rotorcraft. Increases in bird strikes elevates the risk of potential serious injuries or fatalities to occupants and substantial damage to rotorcraft.

On March 23, 2016, the FAA assigned the Aviation Rulemaking Advisory Committee (ARAC) the task of providing recommendations regarding bird strike protection rulemaking, policy, and guidance for normal category rotorcraft, to evaluate existing bird strike protection standards for transport category rotorcraft, and to provide recommendations for enhancement. The ARAC accepted the tasks as defined below, establishing the Rotorcraft Bird Strike Working Group (RBSWG) to provide advice and recommendations to the ARAC on bird strike protection rulemaking, policy, and guidance for Parts 27 and 29 rotorcraft.

TASKS

1. For normal category rotorcraft, specifically advise and make written recommendations on how to incorporate bird strike protection requirements into the Part 27 airworthiness standards for newly type certificated rotorcraft.

2. For normal category rotorcraft, specifically advise and make written recommendations on how the bird strike protection requirements in Task 1 should be made effective via § 27.2 for newly manufactured rotorcraft.

3. For transport category rotorcraft, specifically advise and make written recommendations on how to enhance the § 29.631 bird strike protection airworthiness standard in light of increases in bird weight and increased exposure to bird strikes for newly type certificated rotorcraft.

4. For transport category rotorcraft, specifically advise and make written recommendations on how the bird strike protection requirements in Task 3 should be made effective via § 29.2 for newly manufactured rotorcraft.

5. For normal and transport category rotorcraft, specifically advise and make written recommendations on incorporating rotorcraft bird strike protection improvements and standards into the existing rotorcraft fleet.

6. For Tasks 1 through 5, consider existing non-traditional bird strike protection technology, including the use of aircraft flight manual limitations (such as requiring airspeed limitations

at lower altitudes), when making the recommendations. These considerations must include: An evaluation of the effectiveness of such technology, assumptions used as part of that evaluation, validation of those assumptions, and any procedures to be used for operation with the technology or with the aircraft limitations.

7. Based on the recommendations in Tasks 1 through 6, specifically advise and make written recommendations for the associated policy and guidance.

8. Based on the Rotorcraft Bird Strike Working Group recommendations, perform the following:
    a. Estimate what the regulated parties would do differently as a result of the proposed recommendation and how much it would cost.
    b. Estimate the safety improvements of future bird encounters from the proposed recommendations.
    c. Estimate any other benefits (e.g., reduced administrative burden) or costs that would result from implementation of the recommendations.

9. Develop a report containing recommendations on the findings and results of the tasks explained above. The report should document:
    a. Both majority and dissenting positions on the findings and the rationale for each position.
    b. Any disagreements, including the rationale for each position and the reasons for the disagreement.

10. The working group may be reinstated to assist the ARAC in responding to the FAA's questions or concerns after the recommendation report has been submitted.

DATA

As of the beginning of 2017, Part 27 normal category rotorcraft comprise approximately 94% of rotorcraft operating in the U.S. based on data analyzed during this study (Figure 1). Bird strike data from the FAA's National Wildlife Strike Database (NWSD) that is maintained by the FAA for civil aviation in the U.S. indicates about 75% of reported bird strikes from 1990–2013 involved normal category rotorcraft. These percentages suggest that the absence of bird strike protective requirements for normal category rotorcraft results in risk for most U.S. rotorcraft.

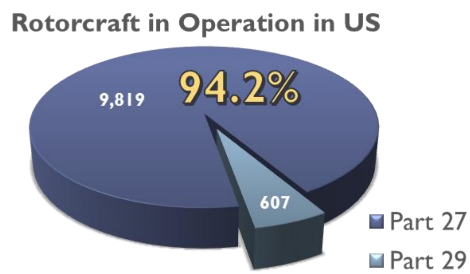


Figure 1. Total number of currently operating rotorcraft in the U.S.

Whether normal category or transport category, the unique operating profile of a rotorcraft leads to a different exposure to bird strike risk than to fixed-wing aircraft. The study in *Wildlife Strikes to Civil Helicopters in the U.S., 1990-2011* (Washburn, Cisar, & DeVault, 2013) discusses some of the differences, concluding that, unlike with fixed-wing aircraft, rotorcraft bird strikes occur with greatest frequency during the enroute phase of flight and in the off-airfield environment. It ascribes bird strikes that occur in the off-airfield environment as accounting for the majority of bird strike-related human injuries and fatalities for rotorcraft. Because rotorcraft operate at much lower altitudes than fixed-wing aircraft, the exposure to the risk of a bird strike is not limited to the departure and arrival phases of flight, but instead remains for the duration of the flight profile. And yet, the study found that, of the 32 reported damaging strikes that occurred to U.S. rotorcraft in 2014, 72% of those occurred more than 500 feet above ground level. The study opined that the more severe damage was likely attributable to the higher speed of the rotorcraft during the enroute phase of flight than during takeoff or landing.

Windshield

As noted in FR Vol. 81, No. 81, Wednesday, April 27, 2016, Notices, 24930-24932 (Federal Register, 2016), which announced the formation of the RBSWG, “the FAA has observed increased strikes to the rotorcraft windshield area with a force of impact that has directly endangered occupants and elevated the risk to safe rotorcraft operations. Bird penetration into the cockpit and cabin areas has become increasingly common, elevating the probability of potential serious injuries or fatalities to occupants. Moreover, direct bird impact to the pilot has led to partial or complete pilot incapacitation in numerous cases, often causing an increased risk for loss of control of the rotorcraft and fatalities. The typical scenario is that the bird strikes and shatters a portion of the front windshield. The bird’s remains, as well as damaged portions of the rotorcraft (such as the windshield), either hit the pilot in the head, neck, or upper torso, or proceed through the cockpit to strike the passengers or crew.”

The notice in the referenced Federal Register stated: “Some bird strike events where the bird penetrates the cockpit and cabin have received less attention either because the damage was limited to the windshield or because the injury to the crew and passengers was minor. However, a superficial examination of the rotorcraft damage and occupant injury levels is misleading. The

FAA has found that most of these cases had less to do with the sufficiency of aircraft design and equipage, and more to do with the crew's personal protective gear—such as helmets—that mitigated the potential event severity. Other cases of low severity are the result of fortuitous circumstance. One specific example occurred during a March 2015 police operation in Dallas, Texas, where a bird penetrated the cockpit and struck the pilot, who was not wearing a helmet. The pilot was incapacitated by the impact and—under ordinary circumstances—the event would likely have led to a fatal outcome from loss of rotorcraft control. However, the left seat occupant happened to be a rated helicopter pilot, something that was not typical for the police operation being conducted. The left seat occupant then assumed control of the rotorcraft and landed without incident. The result was an event with a low-severity outcome, but the underlying lesson from the relatively benign consequence cannot be dismissed."

These observations reinforce previous findings from the study (Cleary, Dolbeer, & Wright, 2006) based on 15 years of data from the FAA's NWSD. The study concluded that:

(1) Rotorcraft were significantly more likely than airplanes to be damaged by bird strikes,
(2) Windshields on rotorcraft were more frequently struck and damaged than windshields on airplanes, and
(3) Injuries to crew or passengers were more likely in rotorcraft bird strikes than airplane bird strikes.

Washburn, Cisar and DeVault (2013) conducted a comprehensive analysis of data available from wildlife strikes with civil rotorcraft within the US from 1990 to 2011. They state "*In 2006, the US Department of Agriculture and the FAA conducted a cursory investigation into reported bird strikes to civil helicopters during 1990–2005 (Cleary et al., 2006). This analysis indicated that patterns of reported bird strikes to civil helicopters were very different from those involving civil fixed wing aircraft.*"

The rotorcraft windshield provides the primary protective barrier directly in front of the pilot, much more so than in fixed wing aircraft. Windshield strike data from the NWSD shown in Table 1 and Figure 2 indicates that 40-47% of reported bird strikes occur on the windshield for both Parts 27 and 29 rotorcraft. There is no statistical difference in strike frequency between Part 27 and Part 29 rotorcraft. For rotorcraft that are not bird strike certified, approximately one-third (30-34%) of the bird strikes on windshield resulted in damage. The NWSD reports sometimes did not clarify if penetration occurred or if the damage was non-penetrating. Therefore, the RBSWG used a conservative approach that if the report did not clearly state that no penetration had occurred, it was assumed that penetration did occur. For rotorcraft that are certified to 14 CFR § 29.631, none of the windshield strikes reported damage to the windshield. This is statistically significant. (Note, as discussed under Task 3, the NWSD lists 2 damaged windshields on S-92A rotorcraft, a § 29.631

certified rotorcraft; however, one was damage to the overhead “eyebrow” window and the other was damage to the “chin” window, neither of which are the windshield forward of the pilots.[2])

Table 1. Frequency of Windshield Bird Strikes and Effectiveness of § 29.631 Regulation.

	Part 27	Part 29 Not Certified to § 29.631	Part 29 § 29.631 Certified
Total bird strikes	1664	378	83
Total windshield strikes	782 **47%**	151 **40%**	38 **46%**
Windshield strikes with damage	263 **34%**	45 **30%**	0 **0%**

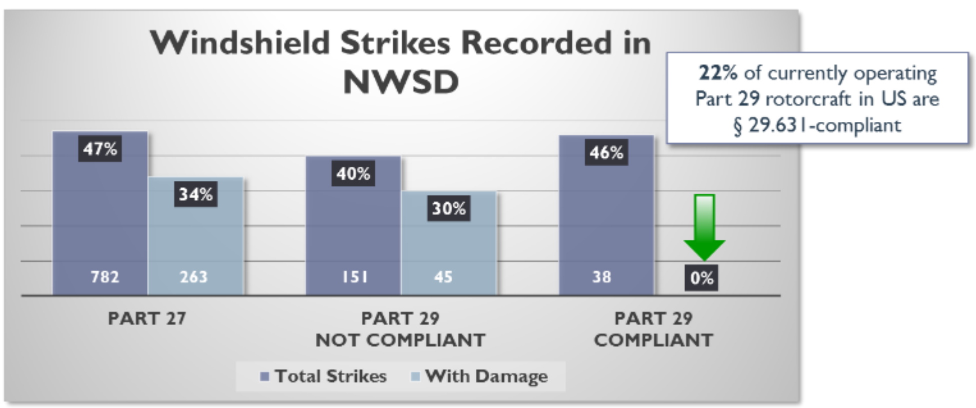


Figure 2. Effectiveness of current rule on windshield strikes for 14 CFR § 29.631-compliant rotorcraft.

Strike Reporting Rate

In Washburn, Cisar and DeVault (2013), the authors report a noticeable increase in strike events beginning in 2009.

[2] The pass/fail criteria for bird strike provided in AC 29-2C § 29.631(b), requires no penetration only for windshields. Continued safe flight and landing (CSFL) for Category A and safe landing (SL) for Category B is the criterion for strikes on all other components, including side, top and bottom windows, control surfaces, rotors, etc. AC 29-2C § 29.631(b) states:

> b. ***Procedures***. *For compliance with FAR 29.631, it should be demonstrated by test or analysis supported by test evidence that,*
>
> *(1) The windshields will withstand the bird strike, without penetration, …*

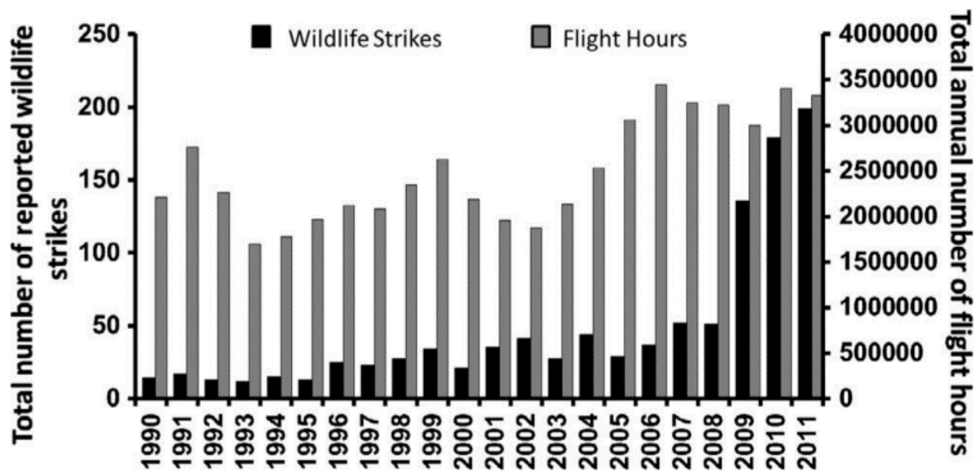


Figure 3. Annual number of reported wildlife strikes with civil helicopters
and of flight hours for civil helicopters (1990–2011).
(Washburn, Cisar, & DeVault, Wildlife Strikes to Civil Helicopters in the U.S.,1990–2011, 2013)

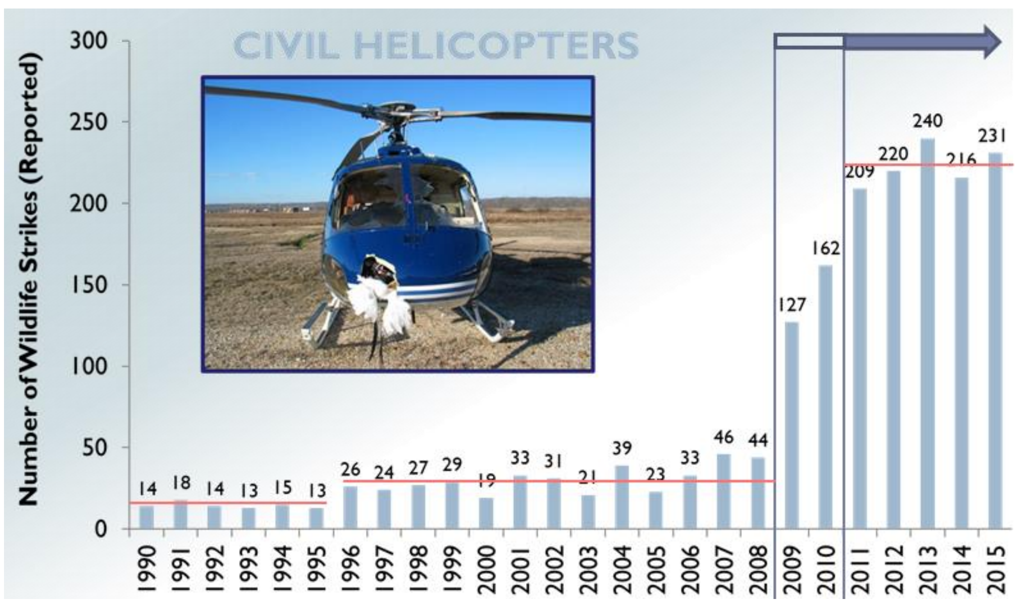


Figure 4. Annual number of reported bird strikes with civil helicopters in NWSD.
1990-1996 mean is **14.5** strikes per year
1996-2008 mean is **30.4** strikes per year
2011-2015 mean is **223.2** strikes per year

The rotorcraft bird strike data shown in Figure 3 and Figure 4 indicates a 57% increase in bird strikes since 2009 and more than a 700% increase since the early 2000s. In raw numbers, the percentages translate from around 20-40 reports of rotorcraft bird strikes per year in the early 2000s, to 155 strikes in 2009, to 244 strikes in 2015. Using rotorcraft flight hours to perform a rate-based analysis, reported bird strikes increased 49% in the five-year period from 2010 to 2014 (3.99 per 100,000 flight hours to 5.95 per 100,000 flight hours).

Although it was initially posited that this increased bird strike reporting after 2009 could be due to a growing population of larger birds (see Appendix C), quieter aircraft, and/or an increase in the number of rotorcraft operations, the likely reason was the increased reporting of rotorcraft bird strike events following two significant events that occurred early in 2009.

- January 4, 2009: The fatal crash of N748P, PHI Sikorsky S-76C++ outside Morgan City, Louisiana following a bird strike with a female red-tailed hawk (average weight of such a bird is 2.4 pounds). Note, this is the only fatal bird rotorcraft strike accident in the NWSD used for this report (National Transportation Safety Board , 2010).
- January 15, 2009: US Airways Flight 1549 Airbus A320-214 ditched in the Hudson River adjacent to Manhattan Island, New York after striking a flock of Canada geese, the event publicly referred to as the "Miracle on the Hudson" (average weight of a male Canada goose is from 8.41 to 9.23 pounds, and the average weight of a female Canada goose is from 7.31 to 7.75 pounds). While this was not a rotorcraft accident, it had direct influence upon bird strike reporting including rotorcraft (National Transportation Safety Board, 2010).

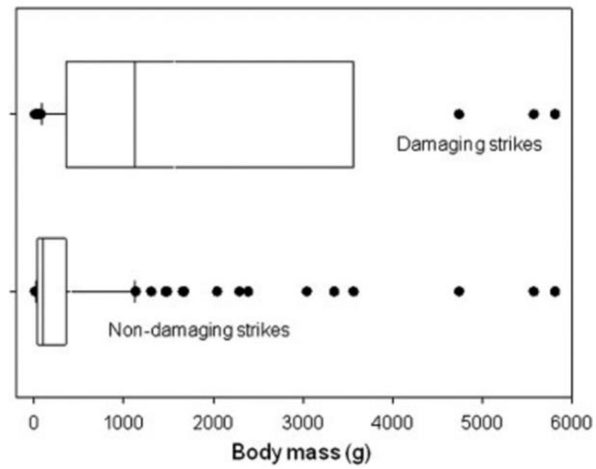
Data Sampling Period

Even though the reporting rate has increased since 2009 and appears to be stabilizing, there remains the possibility of under reporting. Not reporting a strike in which no damage occurred is a likely possibility. Such under reporting (especially prior to 2009) biases the records and tends towards overstating the percentage of damaging events. In addition, under reporting generally segregates out strikes with smaller birds in which no damage occurred skewing the data related to bird mass.

The RBSWG concluded that for this report all data contained with the FAA's NWSD will be used to assess the benefit of the 1996 bird strike regulation 14 CFR § 29.631. However, as noted, many bird strike events went unreported prior to 2009. Hence, due to stabilized bird strike reporting following the 2009 events, only the subset from January 2009 through February 2016 will be evaluated (the ending date being the most recent data available when the RBSWG began analyzing the data). This 86-month (7.17 years) period is used for assessing costs and benefits of additional or modified bird strike regulation.

Bird Mass

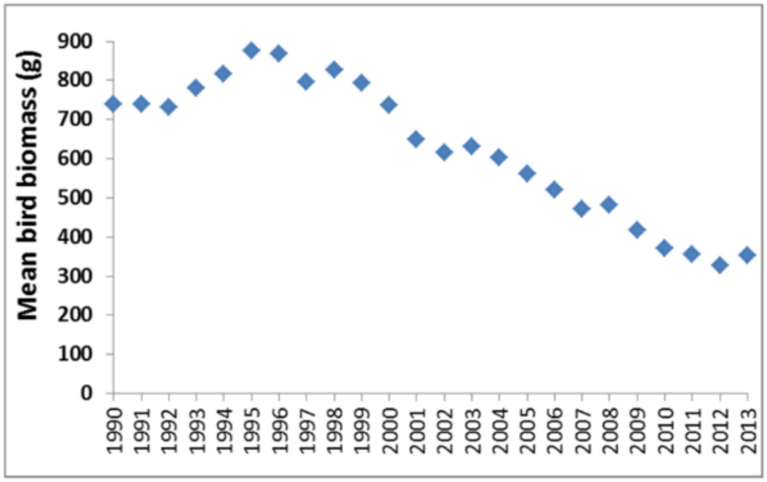
The recorded bird strikes within the FAA's NWSD provide a statistical sampling of bird strike threats against rotorcraft. The bird strike threat can be expressed in terms of momentum or kinetic energy, both of which are directly proportional to the bird mass. DeVault, Belant, Blackwell and Seamans (2011) analyzed the data in the NWSD from 1990 to 2009 for wildlife strikes on all U.S. aircraft types (airplanes and rotorcraft) and found that "*Median body mass for birds involved in* *damaging strikes was 1.125 kg; median body mass for birds involved in nondamaging strikes was 97 g*" as shown in Figure 5. They concluded "*Avian body mass was strongly associated with percentage of all strikes that caused damage, but not for species exceeding median body mass (1.125 kg) of birds in damaging strikes. In contrast, percentage of damaging strikes increased when multiple birds were involved, but only for those species with body mass ≥1.125 kg.*" Further, they concluded that "*Ten of the 15 most hazardous bird species or species groups are strongly associated with water.*"



(DeVault, Belant, Blackwell, & Seamans, 2011)

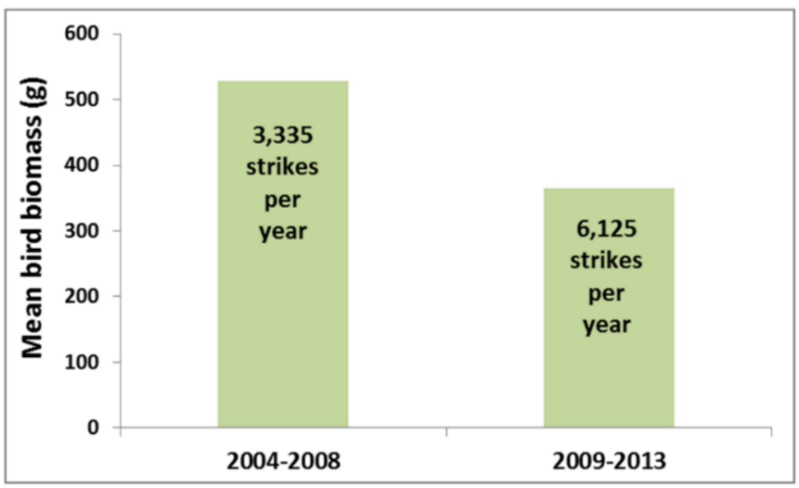
Figure 5. Frequency distribution of body masses for birds involved in damaging and nondamaging strikes with aircraft.

Data indicates as shown in Appendix C that large and medium size bird populations are increasing in North America. (Additional discussion on the North American population of large and medium-size birds can be found in Appendix C.) Yet, Dolbeer (2015) found that "the mean size (based on biomass) of birds reported struck by civil aircraft has declined by over 50% from about 800 grams in the mid-1990s to less than 400 grams in 2013" (Figure 6). Strikes involving birds in which the bird was not identified, at least as to species group, were excluded. The apparent decrease in mean biomass is likely due to increase in reporting of smaller bird strikes and not to be interpreted as a decline in mean mass of the U.S. bird population. Dolbeer also noted "*The number of airports reporting strikes increased substantially for all airport types in 2009-2013 compared to 2004-2008* (Figure 7)."



(Dolbeer, Trends in reporting of wildlife strikes with civil aircraft and in identification of species struck under a primarily voluntary reporting system, 1990-2013, 2015)

Figure 6. Mean biomass of birds reported struck by civil aircraft by year, 1990-2013.



(Dolbeer, Trends in reporting of wildlife strikes with civil aircraft and in identification of species struck under a primarily voluntary reporting system, 1990-2013, 2015)

Figure 7. Mean biomass of birds struck in 2004-2008 compared to 2009-2014.

Increases in large bird populations have been observed during the study period with the mean bird mass of events being approximately 1 kg. No impacts to safety of flight events have occurred to compliant aircraft during this time. Therefore, we deduce that the bird strike requirement of 1 kg at V_{NE} or V_H provides appropriate statistical protection. Further, we consider that an increase in requirement, for example to the 4.8 kg Sandhill crane, is not warranted based on the data. Considering bird mass, aircraft speed, and other factors; the current 14 CFR § 29.631 regulation has provided adequate requirements to assure CSFL and/or SL for events evaluated during the study period. This is further discussed in Task 3.

FAA's National Wildlife Strike Database (NWSD)

The rotorcraft bird strike data was extracted from the FAA's NWSD. A total of 2,151 bird strike events are recorded between January 1990 through February 2016 on U.S. registered rotorcraft. This included rotorcraft operated by civil operators plus government/public use operators like U.S. Coast Guard, U.S. Customs and Border Patrol, law enforcement, etc. Both single and multiple strikes are reported.

This database was truncated to narrow the time frame within the stabilized bird strike reporting period beginning January 2009 through February 2016, the end date being when the RBSWG data evaluation was initiated. This resulted in 1,574 bird strike events (including 15 bat strikes[3]) with the following distribution:

- 1233 (78.3%) bird strike events occurred on Part 27 rotorcraft (includes 15 bat strikes);
- 333 (21.2%) bird strike events occurred on Part 29 rotorcraft;
- 8 (0.5%) bird strike events occurred on unknown type rotorcraft (records unclear).

Rotorcraft Strike Impact Locations

Bird strike events on Part 27 rotorcraft were reported on the following components. The sum of the strikes below (1,614) is greater than the 1233 bird strike *events* reported on Part 27 rotorcraft since a *single event* often recorded *multiple strikes* on multiple components. The percentages shown within parentheses are per the 1,233 events.

- 584 (47.4%) on the windshield of which 142 had damaged windshield
    - 107 (8.7%) were clearly denoted as penetration with an additional 20 records unclear if penetration occurred, thus potentially 10%.
- 366 (29.7%) on the main rotor
- 235 (19.1%) on the nose/radome
- 181 (14.7%) on the fuselage
- 53 (4.3%) on the tail rotor or empennage
- 22 (1.8%) on the landing gear
- 21 (1.7%) on the engine(s)
    - 7 were reported ingested by engine
- 4 (0.3%) on light with no other component impacted
- 148 (12.0%) on other components

[3] *Bats are mammals, not birds but are included in the bird strike analysis since they are airborne threats. Bat species range in mass from 0.18 oz (5 grams) to 0.56 oz (16 grams). All strikes involving bats in the NWSD between January 2009 to February 2016 occurred with Part 27 rotorcraft; none were reported with Part 29 rotorcraft.*

The above strike distributions on Part 27 rotorcraft are shown graphically in Figure 8 with 85% occurring forward of the main rotor mast on the windshield, main rotor, nose and fuselage. Only 4% of the strikes occurred on the tail rotor and empennage.

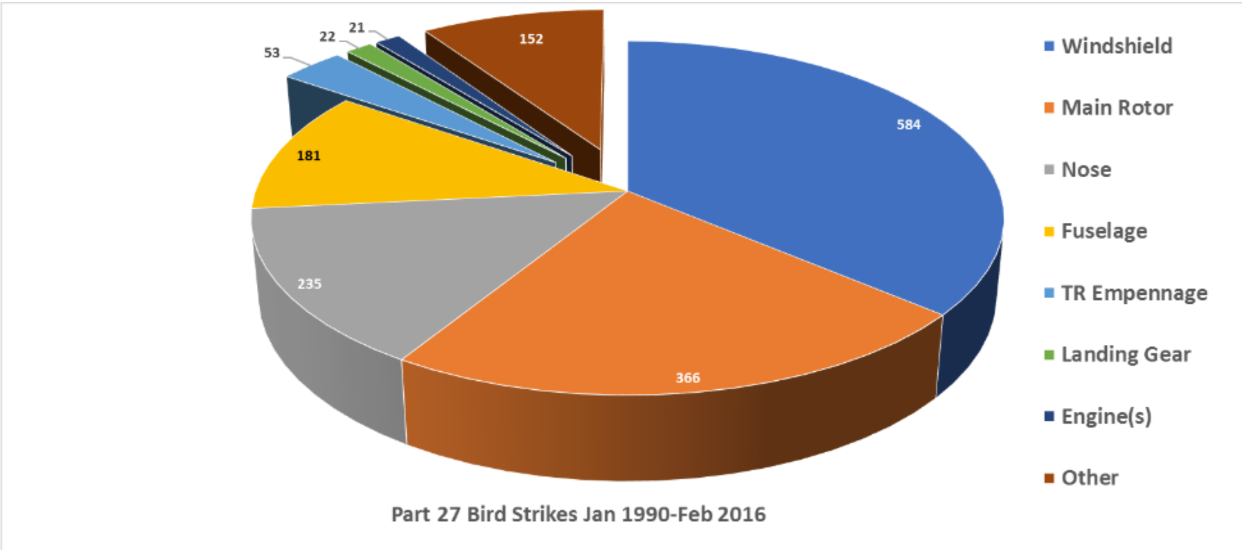


Figure 8. Distribution of bird strikes on the NSWD on Part 27 rotorcraft between Jan 1990 – Feb 2016.

Bird strike events on Part 29 rotorcraft were reported on the following components. The sum of the strikes below (424) is greater than the 333 bird strike events reported on Part 29 rotorcraft since a *single event* often recorded strikes on multiple components. The percentages shown within parentheses are per the 333 events.

- 133 (39.9%) on the windshield of which 18 had damaged windshield
    - 10 (3.0%) were clearly denoted as penetration with an additional 4 records unclear if penetration occurred, thus potentially 4%. Note these penetrations occurred on rotorcraft that were not compliant to 14 CFR § 29.631.
- 77 (23.1%) on the main rotor
- 78 (23.4%) on the nose/radome
- 69 (20.7%) on the fuselage
- 11 (3.3%) on the tail rotor or empennage
- 2 (0.6%) on the landing gear
- 11 (33.0%) on the engine(s)
    - 4 were reported ingested by engine
- 1 (0.3%) on light with no other component impacted
- 42 (12.6%) on other components

The above strike distributions on Part 29 rotorcraft are shown graphically in Figure 9 with 84% occurring forward of the main rotor mast on the windshield, main rotor, nose and fuselage. Only 3% of the strikes occurred on the tail rotor and empennage.

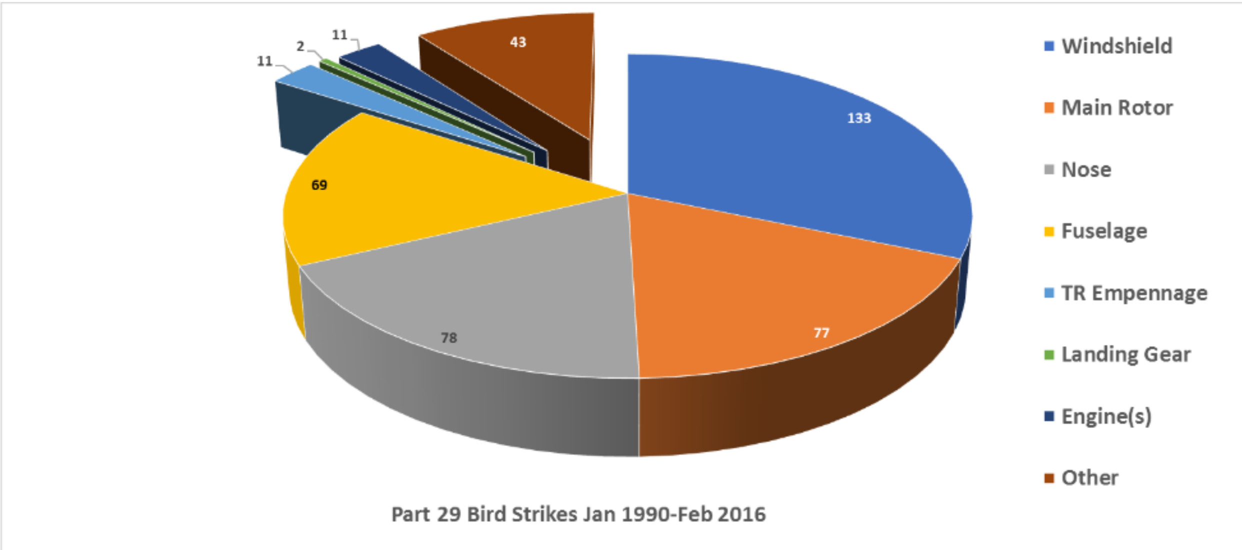


Figure 9. Distribution of bird strikes in the NSWD on Part 29 rotorcraft between Jan 1990 – Feb 2016.

Single vs. multiple bird strikes are recorded on normal and transport category rotorcraft are listed in Table 2. The overwhelming majority, 94-96% occurred with a single bird per strike event on rotorcraft. Strikes involving a single bird may result in multiple strike locations, however these are treated as a strike event involving a single bird.

Table 2. Number of birds reported for a strike event.

Number of Birds Per Strike Event	Part 27	Part 29
A single bird per strike event	1186 (96.2%)	312 (93.7%)
2-10 bird per strike event	43 (3.5%)	18 (5.4%)
11-100 bird per strike event	3 (0.2%)	2 (0.6%)
Unrecorded number of birds per strike event	1 (0.1%) **	1 (0.3%)

** - One record listed zero bird strikes, but rather a bird avoidance that caused a hard landing of Part 27 rotorcraft.

Phase of Flight

The phase of flight during which the reported bird strike event occurred are listed in Table 3. Two-thirds occurred during the *enroute* phase, with 8-9% during *approach* and 9-10% during *climb*. These three flight phases contain 85% of the reported bird strikes.

Table 3. Flight phase reported for a strike event.

Flight Phase	Part 27	Part 29
Approach	110 (8.9%)	28 (8.4%)
Arrival	1 (0.1%)	--
Climb	109 (8.8%)	34 (10.2%)
Departure	3 (2.4%)	--
Descent	47 (3.8%)	8 (2.4%)
Enroute	835 (67.7%)	221 (66.4%)
Local	6 (0.5%)	--
Parked	22 (1.8%)	6 (1.8%)
Take-off Run	1 (0.1%)	3 (0.9%)
Taxi	17 (1.4%)	4 (1.2%)
Blank	82 (6.7%)	29 (8.7%)

Figure 10. Distribution of bird strikes in the NSWD during flight phase between Jan 1990 – Feb 2016.

Time of Day

The time periods of the day reported in the NWSD during which the bird strike event occurred are listed in Table 4. While just over half of the bird strikes reported (51.5%) occurred during the night with Part 27 rotorcraft, Part 29 rotorcraft reports showed only 35.1% during the night. Only about 3% of strikes reported were during dawn and dusk.

Table 4. Time of day for reported strike event.

Time of Day	Part 27	Part 29
Dawn	9 (0.7%)	5 (1.5%)
Day	468 (38.0%)	171 (51.4%)
Dusk	25 (2.0%)	5 (1.5%)
Night	635 (51.5%)	117 (35.1%)
Blank	96 (7.8%)	36 (10.8%)

Normalizing these values based on the duration of each period of the day provides the number of strikes per hour of the day as shown in Figure 11 (e.g., dawn and dusk are each 1 hour representing 4.2% of a 24-hour period; and day and night are each on average 11 hours representing 45.8% of a 24-hour period). Of the reported bird strikes on Part 27 rotorcraft, 32% occurred per hour during the day while 43% occurred per hour during the night. This would suggest there is 1.34 times the probability of a bird strike at night compared with day in a Part 27 rotorcraft. Correspondingly for a Part 29 rotorcraft, there is 1.48 times the probability of a bird strike during the day compared with night. This disparity is likely due to the difference in the type of flight operations for Part 27 and Part 29 rotorcraft. While the use of Part 27 rotorcraft includes emergency air transport and law enforcement at all hours of the day and night, Part 29 rotorcraft are heavily used in oil and gas production transportation and mostly offshore with predominate use during the day.

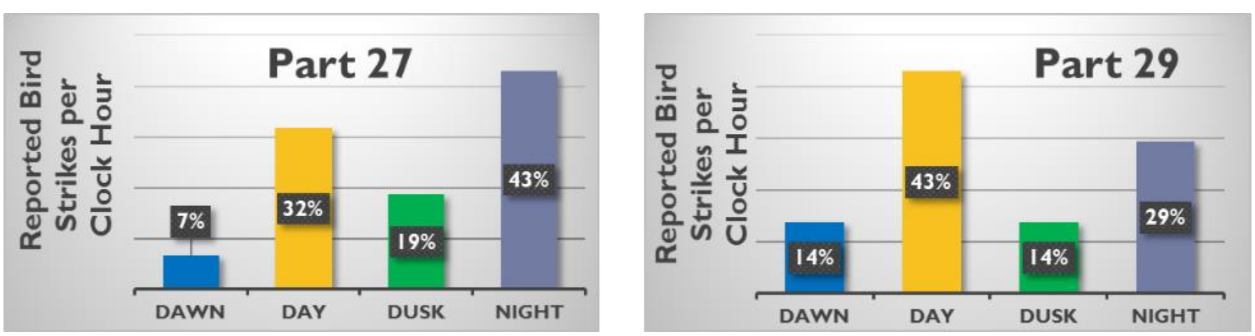


Figure 11. Normalized reported bird strikes during time of day.

Rotorcraft Airspeed

The reported airspeed during which the bird strike event occurred for Part 27 rotorcraft included the following:

- 219 (17.8%) records with 80 knots or less,
- 737 (59.8%) with speeds above 80 knots, and
- 277 (22.5%) with no speed listed.

Of these bird strike records that had the impact speed reported, slightly more than 3 out of 4 (77.1%) occurred above 80 knots. Of the 219 events that occurred below 80 knots, there were 12 (5.5%) reported windshield penetrations, plus an additional 5 events for which the windshield was impacted but the record was unclear if the bird penetrated. The lowest speed reported for which the windshield was penetrated on a Part 27 rotorcraft was 55 knots, which occurred enroute at 1,100 ft AGL at night. The lowest reported speed for a bird strike on a Part 29 windshield that resulted in penetration were two records at 120 knots, both of which occurred during enroute flight at night, one at 700 ft AGL and the other at 1,500 ft AGL.

While there is correlation between airspeed and both bird strike likelihood and bird strike damage, the RBSWG only assessed risk based on the maximum airspeed of existing rotorcraft products.

ASSUMPTIONS

The following assumptions have been established for this report.

(1) A consistent accident data time frame will be used for all assigned tasks: January 2009 through February 2016. Bird strike reporting stabilized following the fatal crash of the S-76C++, N748P in Morgan City, Louisiana on January 4, 2009 and the "Miracle on the Hudson" ditching of US Airways Flight 1549 on January 15, 2009. The data analysis period ended in February 2016, when the RBSWG was formed.

(2) Benefit values are based on fatalities or injuries using the FAA's Value of a Statistical Life at $9.9M, Value of a Serious Injury at $2,504,700, and Value of a Minor Injury at $29,700, based on economic values for FAA Investment and Regulatory Decisions.

(3) Repair and replacement of damaged components and attendant lost revenue during such repairs or replacement are not included in assessing cost of bird strike design changes since damage prevention (e.g., antenna) is not the primary objective of bird strike safety regulation; rather, it is the elimination of fatalities and prevention of injury to occupants due to bird strikes. Further, incorporation of bird resistant components such as windshields and other design changes will not guarantee cost avoidance of damage or lost revenue. The impact of these costs is minimal as compared to safety improvements. For example, the replacement cost of a damaged but not penetrated windshield should not reflect negatively on the value of (and regulated safety provided by) that windshield. Any replacement cost likely would be far less than the cost of injury or fatality had the windshield been penetrated

and therefore is not included in the economic analysis. Further, the cost of total loss of the rotorcraft due to not incorporating bird resistant design changes is not included in the economic assessment. While this cost of rotorcraft loss is substantial, varying from 0.1 to 10 times the cost of a single fatality depending upon the rotorcraft type (model), it is accommodated by slightly mitigating the COST PER EVENT scaling described in assumption (6) below and in the **Task 8 Benefit Analysis** section.

(4) All financial data is reported in 2016 US Dollars with an assumed 7% future value of money. Further, costs assessed in this report only reflect costs for U.S. registered rotorcraft and operation of those rotorcraft within the U.S. National Airspace System (NAS).

(5) Actual flight hours are not generally available to report and hence are assumed. Assessing the 10-year projected economic benefits in this report uses assumed flight hours factored-up from the under-reported flight hours using the FAA forecast algorithm and the FAA Aerospace Forecast of 2.5% increase per annum in flight hours (Jaworowski & Royce, 2016).

(6) For events in the FAA's NWSD in which a bird strike resulted in windshield penetration, a consistent risk-based cost assessment is assigned even though injury may or may not have occurred or been reported. Direct bird impact to the pilot has led to partial or complete pilot incapacitation in numerous cases, increasing the risk of additional fatalities. Areas with substantial damage other than directly in front of the pilot were assessed and found to be less critical/consequential in comparison. Therefore, the cost basis for a damaging event is developed based on the following posit:

a. Assume the average windshield is about 3 feet by 3 feet; that's 9 square feet.

b. Assume a pilot would be incapacitated if s/he were struck by a bird in the head/neck/upper chest. That's roughly 1 ft by 1 ft or 1 square foot of body area. Hence, a strike in 1 ÷ 9 (11%) of the windshield would incapacitate the pilot, likely bringing down the rotorcraft.

c. Assume an impact on an additional 1 ft by 2 ft or 2 square foot of pilot (i.e., in the mid-abdomen) would "partially incapacitate" the pilot, resulting in the potential for an unsafe landing with serious injuries to all occupants. This is an additional factor of 2 ÷ 9, rounded up to 25%.

d. With these assumptions, 11% of windshield strikes are assumed to cause fatalities and an additional 25% would cause serious injuries.

e. Not all rotorcraft flights operate with 100% of the seats occupied. Assume each event occurs with the rotorcraft half occupied based on the maximum seating in the Type Certification Data Sheet (TCDS). This is a compromise between operations such as tours which are generally fully occupied, airborne observation with two persons on board, helicopter air ambulance with typically 3-5 on board, and private flying with one or more on board.

f. Hence the COST PER EVENT uses the costs described in Task 8 Fleet size and is assumed to be (0.11x$9.9M + 0.25x$2.5M) x (50% of normalized seats on board when windshield penetrating events occurred) = ~$1.71M x 0.5 max seat count. This is further discussed in **Task 8 Benefit Analysis**.

(7) Because only current production rotorcraft are considered for Tasks 2 and 4, rotorcraft that are no longer in production would incur additional costs for restarting assembly lines. This consequence is recognized but determined to be unlikely to affect this assumption of only using current production rotorcraft for Tasks 2 and 4.

(8) An attempt is made to assess the accuracy of the economic benefits by comparing the following two approaches:

a. Applied methodologies implemented or used by the ARAC Occupant Safety Working Group to assess the effectiveness of the proposed solutions based on the strike region of the rotorcraft involved.

b. Use experience of 14 CFR § 29.631-compliant rotorcraft over the same time period to determine the improvement or avoidance of injury in the instances of noncompliant rotorcraft.

(9) A risk-based tiered safety approach shown in Figure 12 is adopted for implementing regulation, guidance and policy consistent with the trend towards performance-based regulations. The most logical risk-based safety basis is dependent upon the maximum number of occupants (crew and passengers) on board[4]. The risk-based safety assessment uses the maximum occupancy listed on the TCDS for Part 27 normal category rotorcraft and Part 29 transport category rotorcraft. While kinetic energy is also identified as directly proportional to safety risk, it is intrinsic within the § 29.631 regulation[5].

[4] *Using the multiplication product of the number of occupants and flight hours (or flight miles) was discussed as a risk basis. However, it was determined that introducing helicopter usage as an attribute for a Part 27 or 29 airworthiness design standard would be problematic since such operational usage (i.e., flight hours or miles) is not quantifiable during the design process. Therefore, we determined to use number of occupants as the basis of risk.*

[5] *Kinetic energy is the product of the bird mass and the square of the strike velocity. Hence this risk is appropriately addressed through the regulation by requiring testing to the velocity of the particular rotorcraft, either V_H or V_{NE}, whichever is less, and standardizes the bird mass based on the statistical sampling contained in the bird strike database. Each rotorcraft bird strike incident is in effect a sampling of the rotorcraft bird strike threat environment.*

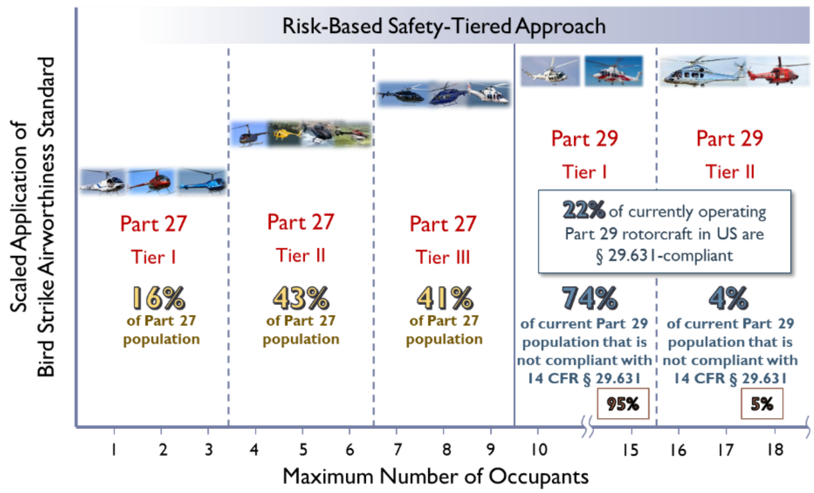


Figure 12. Risk-Based Tiered Safety Approach to Bird Strike Regulation.

The percentage of rotorcraft currently operating within each of the tiers shown in Figure 12 are listed below and are based on data collected by the RBSWG from OEM members. For Part 27 rotorcraft, Tiers II and III are about equal in quantity for currently operating rotorcraft in the U.S. are 2.5 times more populous than those operating in Tier I. About 1 out of 5 Part 29 rotorcraft currently operating in the U.S. comply with the current 14 CFR § 29.631 bird strike rule. Of those that do not comply, 95% are in Tier I with seating capacity for 10-15 occupants (crew plus passengers).

- 16% of Part 27 currently operating are in Part 27 Tier I
- 43% of Part 27 currently operating are in Part 27 Tier II
- 41% of Part 27 currently operating are in Part 27 Tier III
- 22% of Part 29 currently operating are § 29.631-compliant
- 74% of Part 29 currently operating that are not § 29.631-compliant are in Part 29 Tier I
- 4% of Part 29 currently operating that are not § 29.631-compliant are in Part 29 Tier II

Document Structure

This document is structured per the ARAC RBSWG tasks published in the Federal Register, 2016. For Tasks 1 through 6, the pertinent data and associated assumptions are discussed and conclusions are provided. Task 7 summarizes the results from the previous tasks and provides recommended regulations, policy and guidance. The economic benefits and associated costs resulting from this policy are discussed and summarized in Task 8. Task 9 provides majority and dissenting positions.

TASK 1 – BIRD STRIKE PROTECTION RECOMMENDTIONS FOR PART 27 NEWLY TYPE CERTIFICATED ROTORCRAFT

TASK DESCRIPTION

As published in FR Doc. 2016–09781 (Federal Register, 2016), Task 1 states:

> *For normal category rotorcraft, specifically advise and make written recommendations on how to incorporate bird strike protection requirements into the part 27 airworthiness standards for newly type certificated rotorcraft.*

DISCUSSION

The RBSWG developed the proposed airworthiness standard below for adding bird strike protection to various sizes of newly type certificated normal category rotorcraft. The result places the various Part 27 rotorcraft into three risk-based safety tiers based on rotorcraft seating capacity shown in Figure 12. The three tiers are as follows:

- Tier I with 1-3 occupants,
- Tier II with 4-6 occupants, and
- Tier III with 7-9 occupants.

By separating each category by occupancy, differences in costs and benefits resulting from the scale of the rotorcraft and the intended markets can be better evaluated. Because new designs can accommodate new requirements much more easily than existing designs, the added cost of design, certification, and manufacture is largely limited to the marginal cost and weight increase of the new components and the attendant costs associated with the required certification regime.

The occupancy of Tier III ranges from seven occupants to the maximum allowable in Part 27 of nine persons. These rotorcraft have the largest associated risk because of both their high occupancy and generally higher airspeeds. Because these rotorcraft have higher maximum gross weights, the marginal empty weight increase resulting from implementing bird strike protection would have less of an effect on the overall usability of a design. Similarly, because these larger rotorcraft carry larger prices and are typically used in commercial operations, the increases in price incurred by the operators, and eventually consumers, would not be as significant as in the case for smaller, privately owned rotorcraft. Because of the increased risks associated with larger capacity, less design sensitivity to added weight, and the dispersed marginal cost increases, Tier III has the most restrictive bird strike protection requirements.

Tier II contains rotorcraft with four to six occupants. Because of reduced occupancy and slightly slower airspeeds, these rotorcraft carry less risk, but their lighter gross weight and lower prices than Tier III make them more sensitive to any marginal increase in empty weight and cost. Making matters worse, while large businesses that operate Tier III rotorcraft can spread incurred costs to their many consumers, the smaller business enterprises and private individuals operating Tier II rotorcraft have fewer options. Common operators for Tier II rotorcraft are tour operations, law enforcement agencies, air ambulance, news agencies, and agricultural operations where any decrease in usable payload or increase in procurement or operating costs result in sharply reduced practicality and lost revenue. For these reasons, it is likely over-burdensome to require as restrictive bird strike protections as Tier III. As previously noted in Figure 8, over 85% of the components that had reported bird strikes on Part 27 rotorcraft are forward of the main rotor mast. Therefore, the RBSWG scaled the Tier II requirements to a level that affords significant occupant protection without imposing undue burden.

Tier I contains small, light rotorcraft with one to three occupants. Even lower gross weights and costs further amplify the concerns noted for Tier II rotorcraft. Like Tier II, operators of Tier I rotorcraft are primarily used for flight training, personal transportation or agriculture, where any increase in costs or empty weight results in reduced utility. As noted in the early discussion on the NWSD, 47.4% of bird strike events reported on Part 27 rotorcraft were on the windshield (see text associated with Figure 8). Hence, addressing the windshield provides the greatest improvement in safety commensurate with the risk associated with Tier I. However, because of the high level of sensitivity to cost and weight increases with Tier I rotorcraft, the economic assessment did not support integration of a BSR windshield.

Based on the data from NWSD, discussed previously in the **Introduction**, the RBSWG concludes that the existing 2.2 lb (1.0 kg) avian mass appropriately represents the threat for bird strikes on Part 27 rotorcraft, as it does for Part 29 rotorcraft.

Next, we consider rotorcraft speed. Recognizing that bird strike risk trends with kinetic energy, velocity is a more significant factor to risk than bird mass since velocity is raised to the second order while mass remains linear; $E_k = ½ m v^2$. Hence, any proposed bird strike airworthiness standard should consider the maximum speed of the rotorcraft in a similar manner as 14 CFR § 29.631 (V_H or V_{NE}, whichever is lesser). While this implies conservatism, as not all bird strikes occur at the maximum speed of the rotorcraft, it does account for the potential. This is appropriate since probabilistics is not acceptable for showing or finding compliance to airworthiness regulations. In fact, using data from the NWSD from January 1990 through February 2016 reveals that only 9.0% of all bird strikes in which the airspeed was reported occurred near V_H (or V_{NE} if lower) for the particular rotorcraft type. This percentage is 7.1% (86 out of 1219) when considering only Part 27 rotorcraft, which reveals that the potential for bird strike at maximum velocity is less for Part 27 rotorcraft than for Part 29 rotorcraft. (Note, when considering only Part 29 rotorcraft, the percentage is 15.5%, 56 out of 362 strikes, that were reported near V_H, or V_{NE} if lower).

Recommendations For Part 27 Airworthiness Standards For Newly Type Certificated Rotorcraft

The RBSWG investigated proposing a risk-based tiered safety approach for newly type certificated Part 27 rotorcraft as shown in Figure 12. The risk is tiered based on the maximum number of occupants (crew and passengers) on board. Three different tiers are considered.

- Tier III with 7-9 occupants should meet the same level of bird strike airworthiness standard as a Part 29 Category B rotorcraft.
- Tier II with 4-6 occupants should meet the same requirements as Tier III but only for the windshield and flight critical equipment/components forward of the main rotor mast that could prevent a SL if damaged.
- Tier I with 1-3 occupants should meet the same requirements as Tier II but applied only to windshield.

However, the Task 8 economic analysis revealed that all three tiers were not economically viable for newly type certificated normal category rotorcraft. As a result, they were reassessed by considering only a requirement to have a BSR windshield. This resulted in Tier III becoming economically viable while the cost for implementing BSR windshields for both Tiers I and II still exceeded the benefits.

Hence a new rule, § 27.631 is proposed:

> *The rotorcraft with a maximum occupancy (pilot plus passengers) of 7 to 9 must be designed to ensure capability of safe landing after impact upon the windshield with a 2.2-lb (1.0-kg) bird when the velocity of the rotorcraft (relative to the bird along the flight path of the rotorcraft) is equal to V_{NE} or V_H (whichever is the lesser) at altitudes up to 8,000 feet. Compliance must be shown by tests or by analysis based on tests carried out on sufficiently representative structures of similar design..*

TASK 2 – BIRD STRIKE PROTECTION RECOMMENDTIONS FOR PART 27 NEWLY MANUFACTURED ROTORCRAFT

TASK DESCRIPTION

As published in FR Doc. 2016–09781 (Federal Register, 2016), Task 2 states:

> *For normal category rotorcraft, specifically advise and make written recommendations on how the bird strike protection requirements in Task 1 should be made effective via § 27.2 for newly manufactured rotorcraft.*

DISCUSSION

The RBSWG developed the proposed airworthiness standard below for adding bird strike protection to various sizes of newly manufactured normal category rotorcraft. The same three tiers utilized for Task 1, based on rotorcraft seating capacity shown in Figure 12, are used for Task 2 as well. The three tiers are as follows:

- Tier I with 1-3 occupants,
- Tier II with 4-6 occupants, and
- Tier III with 7-9 occupants.

As noted in Task 1, by defining the tiers based on maximum possible occupancy, the proposed safety improvements can be scaled commensurate with risk exposure. Previously certified designs may not be able to accommodate new requirements without added cost of re-design, re-certification, and changed manufacturing processes. The differences in costs and benefits (discussed in Task 8) for various rotorcraft in their intended markets can be more appropriately assessed within these tiers. Utilizing the proposed tier structure facilitates scaling the benefits and costs with economic viability.

The risk-based tiered safety approach for newly manufactured normal category rotorcraft have proposed protections decremented one tier down from the corresponding tiers for newly type certificated Part 27 rotorcraft (i.e., Task 1). Specifically, Tier III newly manufactured Part 27 rotorcraft will be required to meet the same safety protections as Tier II newly type certificated Part 27 rotorcraft. Tiers I and II newly manufactured Part 27 rotorcraft will be required to meet the same safety protections as Tier I newly type certificated Part 27 rotorcraft.

Further, the RBSWG proposes that by implementing one or more of the recommended non-traditional means of protection as defined in Task 6, the requirements are reduced to the next lower safety tier. For example, a Tier III newly manufactured rotorcraft could meet the requirements for Tier II newly manufactured rotorcraft, if at least one recommended non-traditional means from Task 6 is implemented as well.

Based on the data from NWSD discussed previously in the **Introduction**, we conclude that the existing 2.2 lb (1.0 kg) avian mass appropriately represents the threat for bird strikes on Part 27 rotorcraft, as it does for Part 29 rotorcraft.

RECOMMENDATIONS FOR NEWLY MANUFACTURED PART 27 ROTORCRAFT

The RBSWG investigated proposing a risk-based tiered safety approach for newly manufactured Part 27 rotorcraft manufactured after January 1st, 2025 (2 years after implementation of proposed 14 CFR § 27.631 followed by 3 years for certification). The risk is tiered based on the maximum number of occupants (crew and passengers) on board. Three different tiers were considered. Implementation of one or more non-traditional means of bird strike protection recommended in Task 6 consisting of airspeed-altitude limitation and/or helmet and visor for flight crew would enable meeting the requirements of the next lower tier.

- Tier III with 7-9 occupants should meet the same level of proposed bird strike airworthiness standard § 27.631 (proposed in Task 1) for newly type certificated normal category rotorcraft but only for the windshield and flight critical equipment/components forward of the main rotor mast that could prevent a SL. Alternatively, with implementation of one or more recommended non-traditional means, meet the requirements of proposed 14 CFR § 27.631, but only for the windshield.
- Tier II with 4-6 occupants should meet the same requirements as Tier III but applied only to windshield.
- Tier I with 1-3 occupants should meet the same requirements as Tier II or implementation of one or more of the recommended non-traditional means of bird strike protection.

However, the Task 8 economic analysis revealed that all three tiers were not economically viable for newly manufactured normal category rotorcraft. Further, the cost of implementing non-traditional means also exceeded the calculated benefits. As a result, they were reassessed by considering only a requirement to have a BSR windshield. However, the cost for implementing BSR windshields for all three tiers still exceeded the benefits. Therefore, the RBSWG does not recommend implementing via § 27.2 (Special retroactive requirements) for newly manufactured rotorcraft the bird strike regulation recommended for Task 1. The RBSWG does, however, recommend developing guidance for operators to implement bird strike safety procedures which include the following non-traditional means (as presented in Task 6):

- Reduce airspeed when practical.
- Increase altitude as soon as possible and practical.
- Utilize personal protective equipment (PPE) consisting of a helmet and visor, at least for the crew, when practical.
- Use taxi and/or landing lights in a continuous mode during sunny conditions and at night when practical, and a 2-Hz pulsed mode during partly cloudy conditions, and/or install lighting systems that provide the equivalent.

TASK 3 – BIRD STRIKE PROTECTION RECOMMENDTIONS FOR PART 29 NEWLY TYPE CERTIFIED ROTORCRAFT

TASK DESCRIPTION

As published in FR Doc. 2016–09781 (Federal Register, 2016), Task 3 states:

> *For transport category rotorcraft, specifically advise and make written recommendations on how to enhance the § 29.631 bird strike protection airworthiness standard in light of increases in bird weight and increased exposure to bird strikes for newly type certificated rotorcraft.*

Current Rule

The 14 CFR § 29.631 current rule is:

> *The rotorcraft must be designed to ensure capability of continued safe flight and landing (for Category A) or safe landing (for Category B) after impact with a 2.2-lb (1.0 kg) bird when the velocity of the rotorcraft (relative to the bird along the flight path of the rotorcraft) is equal to V_{NE} or V_H (whichever is the lesser) at altitudes up to 8,000 feet. Compliance must be shown by tests or by analysis based on tests carried out on sufficiently representative structures of similar design.*
>
> *Amdt. 29-40, Eff. 8/8/96*

DATA AND ASSUMPTIONS

The data and assumptions used for assessing Task 3 are described in the corresponding sections of the **Introduction** with the following modification; only rotorcraft models currently in production are considered. The Part 29 rotorcraft that are compliant with 14 CFR § 29.631 exclusively include AW139, AW169, AW189, S-92A and H225 (EC225LP). However, of these, only the AW139 and S-92A have reported bird strikes within the NWSD during January 2009 through February 2016.

Fleet Groupings

The current rule segregates the requirement into Category A and Category B. After impact with the specified bird, Category A should ensure CSFL while Category B should ensure SL. No change to these categories is being considered for newly type certified rotorcraft to meet bird strike requirements.

DISCUSSION

There are six rotorcraft models that are compliant with 14 CFR § 29.631 that are considered for Task 3. These rotorcraft models are: H215 (AS332L2), H225, AW139, AW169, AW189 and S-92A. However, of these, only the AW139 and S-92A have reported bird strikes within the

NWSD. (In addition, the H155 is complaint to JAR § 29.631 and the 412 and 214ST are compliant to BCAR § 29.631.) The estimated total number for these six 14 CFR § 29.631-compliant rotorcraft models are 1.331 million total flight hours.

An evaluation of bird strike events for Task 3 effort was performed. A summary (Table 3) indicates that two-thirds of all events were enroute. As shown in Figure 9, 84% of all events were to the frontal area of the rotorcraft with 40% occurring on the windshield. Of those rotorcraft that are 14 CFR § 29.631-compliant, none were reported to have damaged the windshield (Table 1). Two of the bird strike events on windshields were reported with birds heavier than the 2.2 lb standard. While the identification of bird species post-strike can be difficult, one of these events was identified as a turkey vulture with average species weight of 3.1 lb (1.4 kg) (NWSD Index No. 322865). The other was an unknown species. In addition, there are two reported events involving multiple birds. Neither of these impacts penetrated the windshields of these two 14 CFR § 29.631-compliant rotorcraft. As noted in Table 2, 96.2% (Part 27) and 93.7% (Part 29) of reported strikes in the NWSD involved single rather than multiple birds.

The two 14 CFR § 29.631-compliant rotorcraft with reported strikes in the FAA's NWSD were investigated in more detail, namely the Leonardo AW139 and the Sikorsky S-92A. The AW139 had 34 reported strike events. Of those, 30, including 15 windshield strikes, had no damage. Four events resulted in minor damage to the rotorcraft. The S-92A had 49 reported strike events. Of those, 43 had no damage, 1 substantial damage, 4 minor damage and 1 with unreported level of damage. The substantial damage event was for a strike to the forward sliding fairing around the main rotor pylon. This area is designed to protect against a strike as required, but not without damage, and CSFL was achieved. There were 23 transparency strikes, of which 21 were to the windshield with no damage. The two damaging transparency strikes were to non-critical areas for bird strike that maintained CSFL. One was to the chin window involving gulls at a reported 120 knots and 1,000 feet AGL (NWSD Index No. 243301). The chin window is located below and generally outboard of the windshield. Strikes in this area have the potential for impact of the tail rotor pedals but no hazardous input or jamming occurred. The other event was to the eyebrow window at a reported 145 knots and 2,500 feet AGL (NWSD Index No. 325807). The eyebrow window is above the windshield to the outboard side of the rotorcraft. This penetration did not impact the flight crew or critical systems. A precautionary landing was performed for that event.

In all events involving 14 CFR § 29.631-compliant rotorcraft, CSFL was achieved following bird strikes. While damage was reported for some events, this is not the criterion for meeting the bird strike requirement per AC 29-2C § 29.631. There were no windshield penetrations and no catastrophic losses or fatalities. For example, one bird strike event on an H225 (not in the NWSD) resulted in damage to the lower (chin) window (not the windshield) with fragments causing injury to the pilot's leg. However, the rotorcraft continued safe flight and returned to base.

Effectiveness of Current Rule

As noted in the **Introduction – Data Sampling Period**, there remains the possibility of under reporting. Not reporting a strike in which no damage occurred is conceivable. Such under reporting biases the records and tends towards overstating the percentage of damaging events (see Figure 6). Presumably under reporting may also bias the records towards overstating the bird mass, since smaller birds that did not cause damage are more likely to not be reported (or even detected, e.g., rotor strike).

For the two 14 CFR § 29.631-compliant rotorcraft with bird strikes reported in the NWSD discussed above, only ten (4 on AW139 and 6 on S-92A) out of 83 recorded strike events had damage, and only one of these was substantial damage. This minimal number of damage-producing strikes (12%) on 14 CFR § 29.631-compliant rotorcraft implies a statistical level of protection afforded by the current rule. See also the data presented in Table 1 and Figure 2 which substantiates that the current rule sufficiently protects the most frequently impacted component: the windshield.

As discussed in Task 1, the risk of damage from a bird strike increases with bird mass and speed, as one would expect. With respect to mass, the mean weight (mass) for all impacts with rotorcraft was found to be 2.3 lb (1.05 kg), which is very close (104.5%) to the requirement for the current rule. Some events with higher weight bird species did occur as noted. The maximum reported bird weight in events with 14 CFR § 29.631-compliant rotorcraft is 4.8 lb (2.2 kg) for multiple black vultures at 145 knots and 1,200 ft AGL, with CSFL achieved for that event (NWSD Index No. 352226). With respect to speed, its influence on the magnitude of a strike is largely determined by rotorcraft performance and flight profile. If the risk trends with kinetic energy, as one would expect, the velocity is more significant since it is raised to the second order while mass remains linear. It is reasonable to conclude that not all impacts will occur at the maximum speed of the rotorcraft (V_H or V_{NE}, whichever is lesser). In fact, using data from the NWSD from January 1990 through February 2016 reveals that only 9.0% of all strikes in which the airspeed was reported occurred near V_H for the particular rotorcraft type. This percentage increases to 15.5% when just considering Part 29 rotorcraft. (It drops to 7.1% for Part 27 rotorcraft.) Hence the current rule implies conservatism.

Events of multiple bird impacts are rare in the data study period since 2009 (Table 2). Multiple strikes may be more critical due to “pre-loading” of structure or possibly repetitive impacts in a localized area. This has been observed in large jet engines, which have different dynamic response than rotorcraft airframe structures. Rotorcraft systems may also be vulnerable to multiple bird strike events. This may include: air data sensors, antennas, lights, and various equipment. It appears from the data that separation, redundancy or low criticality of these systems effectively minimizes that hazard. The NWSD data did not indicate a significantly increased risk for multiple birds and thus implies an adequate level of protection is provided by the current rule.

In reviewing events in the NWSD of 14 CFR § 29.631-compliant rotorcraft, no fatalities were found. Thus, we conclude that bird strikes have not been a cause of accidents to § 29.631-compliant rotorcraft, not only during the study period since January 2009 but since the rule was enacted 21 years ago, in August 1996. One fatal accident did occur with a rotorcraft type certificated prior to Part 29 Amdt. 29-40 that introduced § 29.631. This suggests that the current regulation has been effective in preventing fatalities and significant injuries including some events with bird species larger than the current 2.2 lb standard.

RECOMMENDATION FOR 14 CFR § 29.631 BIRD STRIKE REGULATION

Accident and incident data from rotorcraft that were fully compliant with current bird strike regulations were evaluated to measure the effectiveness of the rule. While most Part 29 rotorcraft are not currently compliant with the rule, approximately 22% of the currently operating fleet are compliant, completing an estimated 1.331 million flight hours with no fatalities or significant injuries reported over the two-decade period since Part 29 Amdt. 29-40 became effective. The criticality of a bird strike is the result of many factors, with the overall risk being primarily dependent upon bird mass (species), velocity, and impact location. It may not be possible to fully quantify forward looking risk with any confidence given the many variables. However, it is apparent that for § 29.631-compliant rotorcraft, accidents due to bird strikes are relatively rare. Thus, the RBSWG concludes that the current risk is acceptable with the existing 14 CFR § 29.631 requirements for bird quantity (implied), bird mass, and strike velocity over the altitude range specified, and thus no change to this regulation is warranted.

TASK 4 – BIRD STRIKE PROTECTION RECOMMENDTIONS FOR PART 29 NEWLY MANUFACTURED ROTORCRAFT

TASK DESCRIPTION

As published in FR Doc. 2016–09781 (Federal Register, 2016), Task 4 states:

> *For transport category rotorcraft, specifically advise and make written recommendations on how the bird strike protection requirements in Task 3 should be made effective via § 29.2 for newly manufactured rotorcraft.*

DEVELOPMENT OF DATASET

As of the writing of this report, there have been 225 bird strike occurrences recorded in the NWDS occurring from January 4, 2009 to March 18, 2015. Only 30 occurrences resulted in damages (4 rotorcraft types). There are 13 occurrences recorded with windshield damage, of which 5 had windshield penetration (3 of them due to multiple bird strike). Except for the S-76 crash of January 2009, there are no further records of injuries or fatalities during this period.

Currently-produced transport category rotorcraft were grouped, using a risk-based tiered safety approach, according to total seating capacity (including crew) of up to 15 people (Part 29 Tier I) or greater than 15 people (Part 29 Tier II).

Within Tier I, only one rotorcraft model is fully compliant with 14 CFR § 29.631, whereas all but two of the rotorcraft models in Tier II are fully compliant with 14 CFR § 29.631. This indicates that the bulk of the costs of compliance are likely to lie within Tier I, while the benefits will be proportionately less than for Tier II.

ASSUMPTIONS

The data and assumptions used for assessing Task 4 are described in the corresponding sections of the **Introduction** with the following modification; only current production rotorcraft are considered. Table B-1 in Appendix B lists rotorcraft used in this assessment, plus those rotorcraft no longer in production that were excluded.

Implementation Date

The economic analysis of Task 8 presumes the date for enacting the recommended rule for all tiers of newly manufactured Part 29 transport category rotorcraft is January 1st, 2020. However, while January 1st, 2020 is presumed for the economic analysis, the RBSWG does not recommend mandatory implementation for newly manufactured Part 29 rotorcraft at this early date since doing so would place an undue burden on OEMs (and PMAs) to immediately initiate STC programs for certification by 2020 for all current rotorcraft types (models). Hence the recommendation below sets an implementation date of January 1st, 2027 (2 years after implementation of 14 CFR § 29.2, followed by 5 years for certification).

RECOMMENDATIONS FOR NEWLY MANUFACTURED PART 29 ROTORCRAFT

The RBSWG investigated proposing a risk-based tiered safety approach for newly manufactured Part 29 transport category rotorcraft manufactured after January 1st, 2027 as follows. The risk is tiered based on the maximum number of occupants (crew and passengers) on board as shown in Figure 12. Two different tiers were considered. Implementation of one or more non-traditional means of bird strike protection recommended in Task 6 would enable Tier II to meet only the requirements of Tier I, analogous to alternate means of compliance (AMOC).

- Tier II with 16 or more occupants should meet 14 CFR § 29.631 or should meet Tier I requirements plus implementation of one or more recommended non-traditional means.
- Tier I with 10-15 occupants should meet the requirements of § 29.631 but applied only to the windshield and flight critical equipment/components forward of the main rotor mast that could prevent CSFL for Category A or a SL for Category B rotorcraft.

However, the Task 8 economic analysis revealed that both tiers were economically viable for newly manufactured transport category rotorcraft. As a result, only the traditional means of bird strike protection will be recommended via § 29.2 (Special retroactive requirements) for newly manufactured transport category rotorcraft. In addition, the RBSWG recommends developing guidance for operators to implement bird strike safety procedures as discussed under Task 2.

TASK 5 – BIRD STRIKE PROTECTION RECOMMENDTIONS FOR PARTS 27 AND 29 EXISTING ROTORCRAFT

TASK DESCRIPTION

As published in FR Doc. 2016–09781 (Federal Register, 2016), Task 5 states:

> *For normal and transport category rotorcraft, specifically advise and make written recommendations on incorporating rotorcraft bird strike protection improvements and standards into the existing rotorcraft fleet.*

As stated previously, the data contained in the NWSD shows that thus far, the protections afforded by 14 CFR § 29.631 provide adequate measures to prevent catastrophic consequences of bird strike. To transition the non-compliant fleet toward that standard, without undue economic burden to rotorcraft owners and operators, a 10-year period that allows incorporation of non-traditional means of bird strike protection as discussed in Task 6 into existing Part 27 and non-compliant Part 29 rotorcraft is proposed.

RECOMMENDATIONS FOR BIRD STRIKE AIRWORTHINESS STANDARDS FOR EXISTING OPERATING ROTORCRAFT

The RBSWG investigated the following bird strike requirements for existing Part 27 normal category rotorcraft and Part 29 transport rotorcraft must meet the following to operate after the implementation date defined below.

- Part 27 Tier I rotorcraft, with 1-3 occupants, must meet the same level of proposed bird strike airworthiness standard 14 CFR § 27.631 for the windshield, or alternatively should implement one or more of the recommended non-traditional means of bird strike protection.
- Part 27 Tier II rotorcraft, with 4-6 occupants, must meet the same level of proposed bird strike airworthiness standard 14 CFR § 27.631 for the windshield, or alternatively should implement one or more of the recommended non-traditional means of bird strike protection.
- Part 27 Tier III rotorcraft, with 7-9 occupants, must meet the same level of proposed bird strike protection in 14 CFR § 27.631 (proposed in Task 1 for newly type certificated normal category rotorcraft) for the windshield.
- Part 29 Tier I rotorcraft, with 10-15 occupants, must meet the requirements of 14 CFR § 29.631 applied only to the windshield, plus one or more of the recommended non-traditional means of bird strike protection should be implemented.
- Part 29 Tier II rotorcraft, with 16 or more occupants, must meet 14 CFR § 29.631 for CSFL for Category A or a SL for Category B for only the windshield and flight critical equipment/components forward of the main rotor mast. Alternatively, only the windshield may be shown to comply with 14 CFR § 29.631 if one or more of the recommended non-traditional means of bird strike protection is implemented.

However, the Task 8 economic analysis revealed that Part 27 Tiers I and II were not economically viable when considering traditional BSR windshield protection, but Part 27 Tier III, Part 29 Tier I, and Part 29 Tier II were economically viable when considering traditional bird strike prevention methods (BSR windshield). It is cost effective to implement the helmet-visor PPE non-traditional means for Part 27 Tier II as well as for Part 29 Tiers I and II, but only marginally cost-effective for Part 27 Tier I in 2016 dollars. Based on the findings of the economic analysis in Task 8, the RBSWG recommends the following bird strike protection for existing rotorcraft under Task 5:

For each rotorcraft operating after the implementation defined below:

- Existing Part 27 normal category rotorcraft with maximum occupancy of 1 to 3 (crew plus passengers) should implement bird strike safety procedures (as discussed in Task 2 and outlined in the Task 7 section of this report).
- Existing Part 27 normal category rotorcraft with maximum occupancy of 4 to 6 (crew plus passengers) should implement bird strike safety procedures (as discussed in Task 2 and outlined in the Task 7 section of this report).
- Existing Part 27 normal category rotorcraft with maximum occupancy of 7 to 9 (crew plus passengers) must install a BSR windshield that meets the same level of the proposed bird strike protection in the proposed 14 CFR § 27.631.
- Existing Part 29 transport category rotorcraft with maximum occupancy of 10 to 15 (crew plus passengers) must install a BSR windshield that meets the requirements of 14 CFR § 29.631.
- Existing Part 29 transport category rotorcraft with maximum occupancy of 16 or more must install a BSR windshield that meets the requirements of 14 CFR § 29.631 and should protect flight critical equipment/components forward of the main rotor mast that if damaged could prevent CSFL for Category A or a SL for Category B rotorcraft.

Implementation Date

The RBSWG recommends for implementing bird strike safety procedures the non-mandatory implementation date be January 1st, 2020. Further the RBSWG recommends that development and certification of BSR kits be available for installation on existing rotorcraft by January 1st, 2030. Finally, since there are approximately 4,500 rotorcraft currently operating in the U.S. that are Part 27 Tier III and Part 29 Tiers I and II that are not already compliant with 14 CFR § 29.631, the RBSWG recommends that operation after January 1st, 2035 require installation of a certified BSR kit.

TASK 6 – NON-TRADITIONAL BIRD STRIKE PROTECTION RECOMMENDTIONS FOR PARTS 27 AND 29 ROTORCRAFT

TASK DESCRIPTION

As published in FR Doc. 2016–09781, Task 6 states:

> *For Tasks 1 through 5, consider existing non-traditional bird strike protection technology, including the use of rotorcraft flight manual limitations (such as requiring airspeed limitations at lower altitudes), when making the recommendations. These considerations must include: An evaluation of the effectiveness of such technology, assumptions used as part of that evaluation, validation of those assumptions, and any procedures to be used for operation with the technology or with the rotorcraft limitations.*

DISCUSSION

Assumptions Used as Part of the Evaluation

This task evaluates non-traditional means of preventing bird strikes on rotorcraft. Operating differences between Part 27 and Part 29 rotorcraft are not significant. Both types operate at lower altitudes and within close radius in comparison with fixed wing airplanes. In addition, analysis of the FAA's NWSD indicates that the size of the rotorcraft does not cause or create a condition of flight that differs from larger or smaller rotorcraft.

The bird research and data gathered during the last 10 to 15 years indicates that both the behavior of birds and the profile of the rotorcraft combine to provide some indication of when and where reported bird strikes will occur. These areas differ in the phase of flight from takeoff and landing to cruise flight. In the Dolbeer (2006) analysis, 93% of all strikes occurred below 3,500 ft AGL with 32% decrease in bird strikes every 1,000 ft above 500 ft AGL.

Reduced Airspeeds

Rotorcraft speed is an important aspect in the likelihood and severity of bird-rotorcraft collisions. The speed that the rotorcraft approaches the bird reduces the time required for the bird to assess the threat and initiate evasive flight maneuvers to avoid the rotorcraft. Laboratory-based research has determined that birds are less likely to avoid oncoming aircraft successfully as aircraft speed increases. Operators of rotorcraft have found that strikes with some bird species can be reduced when limiting flight speeds to 80 knots. The NWSD data indicates that many rotorcraft bird strikes occur during airspeeds greater than 80 knots. As noted at the end of the **Introduction**, slightly more than 3 out of 4 (77.1%) reported bird strikes on Part 27 rotorcraft in which the impact speed was recorded in the NWSD occurred above 80 knots. Out of 1664 reported bird strikes in the NWSD, zero occurred below 55 knots.

Additionally, when rotorcraft bird strikes do occur the kinetic energy is reduced as flight speed decreases, thus rotorcraft damage is less likely at lower flight speeds. For some flight operations, however, there is no flexibility to decrease flight speeds, such as airborne law enforcement or air ambulance operations. Average cruise speed for Part 27 rotorcraft is close to 120 knots, thus restricting the rotorcraft to 80 knots may not be feasible for many rotorcraft operations (Figure 13). Nonetheless, a reduction in flight speed can help minimize the chance of damaging bird strikes and should be implemented whenever practical.

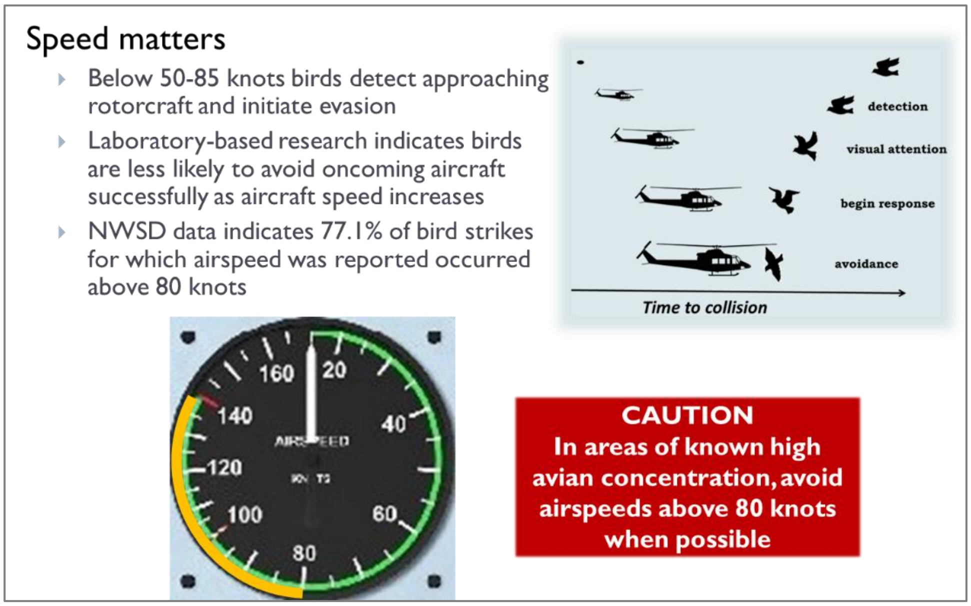


Figure 13. Non-traditional means: speed.

Increased Altitudes

The altitudes that bird strikes occur are inversely proportional with altitude. Thus, when practical and allowed by other flight variables, rotorcraft operators should fly at higher altitudes. Operators should consider that mean altitude for bird strikes is higher at night than during day and higher during spring and fall (migration) than during summer and winter (non-migration). As shown in Table 3, while two out of three (66-68%) of reported bird strikes on all rotorcraft occurred during the *enroute* phase of flight, one out of five (17-19%) occur during *approach* and *climb*. This is a significant percentage when recognizing that the time spent during landing and take-off represents a minority of the flight time. These three flight phases, *enroute*, *approach* and *climb*, contain 85% of all reported rotorcraft bird strikes.

Data from the FAA's NWSD including all aircraft types indicates that the strike altitudes vary, but most collisions occur below 3,500 ft AGL. This is corroborated by Dolbeer (2006) in Figure 14 for bird strikes on all civil aircraft (not just rotorcraft) in the US from 1990-2004. Dolbeer reported that "*74% of the total reported strikes occurred at ≤500 feet, 19% occurred between 501-3,500 feet and only 7% occurred above 3,500 feet.* ***The number of reported strikes declined consistently by 32% for each 1,000-foot gain in height****. Thus* ***93% of the strikes (and presumably birds) were below 3,500 feet****. Based on my findings, changing the height of training flight from 1,500 feet to 3,500 feet would reduce the mean probability of a bird strike by 54%. Because of a fundamental relationship between energy (e), mass (m), and velocity (v) expressed in the equation* $E_k = \frac{1}{2} m v^2$*, aircraft velocity is even more critical than bird mass in determining the energy imparted to an aircraft by a strike (Dolbeer and Eschenfelder 2002). To reduce the probability and severity of strikes with these larger species, pilots should minimize flight time and airspeed, especially below 3,500 feet at night during periods of migration by increasing the rate of climb on departure and delaying descent into these zones on arrival until necessary to descend to land.*"

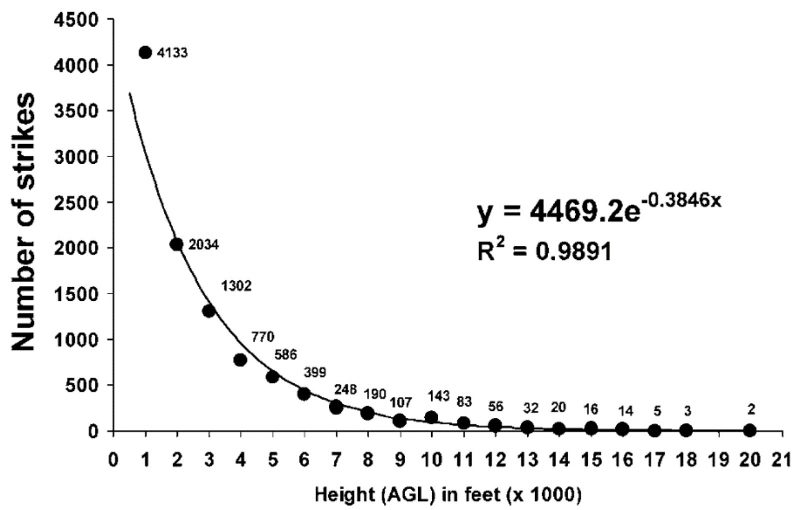


Figure 14. Number of reported bird strikes with civil aircraft in the US from 1990-2004 (Dolbeer, 2006).

Strike data from the FAA's NWSD reveals that the time of day and the month influences the altitude for a likely bird strike on a rotorcraft as shown in Figure 15 and Figure 16. Altitude tended to be higher at night and dawn (probably due to lack of visibility of threats, possibly due to air density) and in spring and fall (probably due to migration). This is corroborated by Dr. Richard A. Dolbeer (2006).

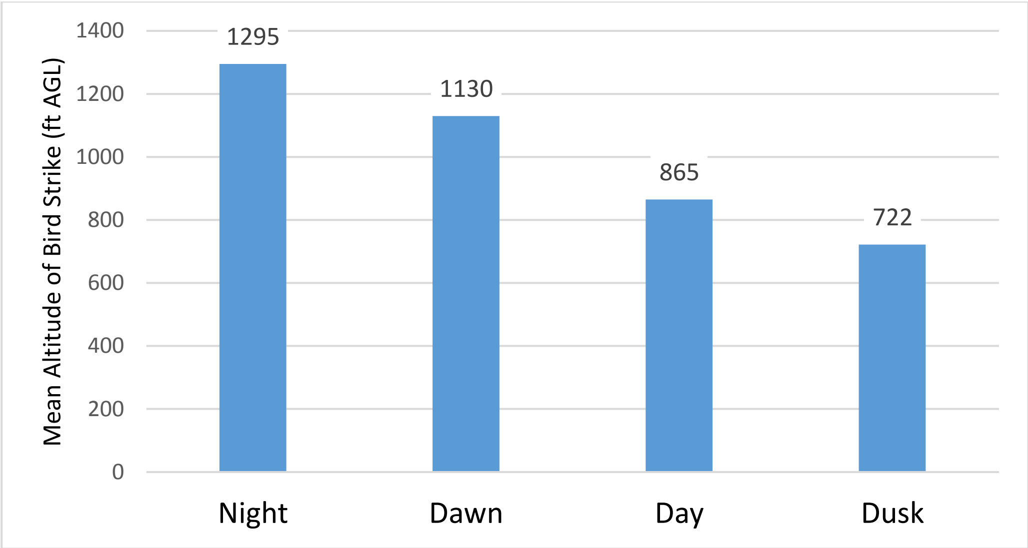


Figure 15. Mean altitude for bird strike for time of day.

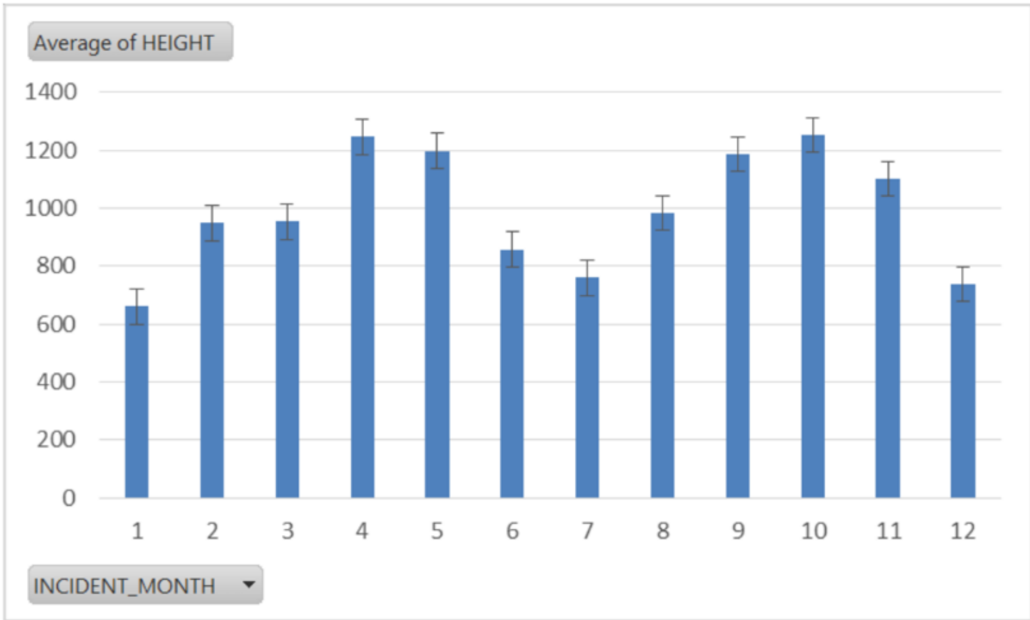


Figure 16. Mean altitude for bird strike for the month.

The RBSWG recommends that, when practical and allowed by other flight variables, rotorcraft operators should fly at higher altitudes, as data shows the bird strike threat is reduced by one-third for each 1,000 ft. gain in altitude above the ground.

Rotorcraft Flight Manuals

A CAUTION statement in all RFMs alerting the rotorcraft operator and/or pilot that while operating in areas of high concentrations of birds or flocking birds, the likelihood of a damaging bird strike increases with airspeeds. This caution is not an operating limitation but an informational caution that, with an increase in the rotorcraft's airspeed, the likelihood of damage to the rotorcraft and injury of its occupants increases if a bird strike occurs. The caution should also note that when operating the rotorcraft at lower altitudes during takeoff and climb-out, the rotorcraft should be operated at lower airspeeds to decrease the likelihood and severity of a bird strike.

Dolbeer (2006) found that 93% of bird strikes occur below 3,500 ft AGL. Operations during spring and fall migration periods at altitudes below 3,500 ft AGL increases the likelihood of a damaging bird strike. This should also be stated in the RFM caution to increase awareness of the rotorcraft operator and/or pilot for increased risk of a migratory bird strike.

The above RFM notations will increase awareness of the flight staff of the hazards faced while operating a rotorcraft within these flight parameters. By including these notations in the RFM, flight training programs for certificated (14 CFR 135) air carriers and non-certificated carriers (14 CFR 91) will be informed of flight environments that present the highest risk for inflight bird strike.

In summary, the RBSWG recommends that a CAUTION be posted in all RFMs stating the following.

- CAUTION: Operating rotorcraft in areas of high concentrations of birds or flocking birds increase likelihood of a damaging bird strike as airspeed increases and altitude AGL decreases. When operating the rotorcraft at lower altitudes during takeoff and climb-out, the rotorcraft should be operated at lower airspeeds to decrease the likelihood and severity of a potential bird strike. Though regional differences exist during spring and fall migration periods, operating a rotorcraft at altitudes below 3,500 feet AGL may increase the likelihood of a damaging bird strike during those seasons.

Flight Crew Training

Training programs may provide the most effective and immediate response to bird strike avoidance. The location of bird concentrations during seasonal migrations and the local bird nesting and roosting habitats, should be made available to the rotorcraft operator/pilot for preflight planning to minimize the potential for bird strikes. Air carriers and general aviation operators working with the FSDO Safety Programs and Flight Service Station briefers should identify and publish the known locations and probability of bird concentrations. This information should be incorporated into alert bulletins, flight service Notice to Airmen (NOTAM) and other systems presently used to inform flight crews of the hazards of bird concentrations.

Training requirements are not currently based on locally observed behavior of the bird population. Such training along with flight planning, should include recognition of common birds in the operating areas, enroute, and airport environments plus seasonal migratory times and concentration patterns. Certain areas around airports and cities provide a food source and protection for birds and hence increased population density. These areas should be identified and made known to the flight crews for planning (avoidance) routes, altitudes and airspeeds. Local recognition of these threat areas along with increased familiarity and examination of the NWSD into which reported bird strikes are recorded with increasing frequency and accuracy, can provide a valuable resource for flight crews.

Further, training should remind flight crews that most bird strikes (2 out of 3) occur during airspeeds greater than 80 knots and at lower altitudes. Therefore, if flight operations allow slower airspeeds in areas known to have a high-density bird population, reduce the airspeed to 80 knots or less. In addition, when practical and allowed by other flight variables, rotorcraft operators should fly at higher altitudes. Data shows bird strike threat is reduced by one-third for each 1,000-ft gain in altitude above the ground.

Information for Operators (InFO) should be developed as shown in Figure 17. Per FAA Order 8000.91[6], InFOs contain valuable information and recommended action to be taken by the respective operators identified in each individual InFO. In addition to FAA inspectors, InFOs address air carrier certificate holders particularly directors of safety (DOS) and directors of operations (DO), fractional ownership program managers, training center managers, directors of maintenance, accountable managers at repair stations, and other parties, as applicable. The FAA does not distribute hard copies of individual InFOs, but rather posts InFOs on an FAA public Website maintained by the Flight Standards Service[7].

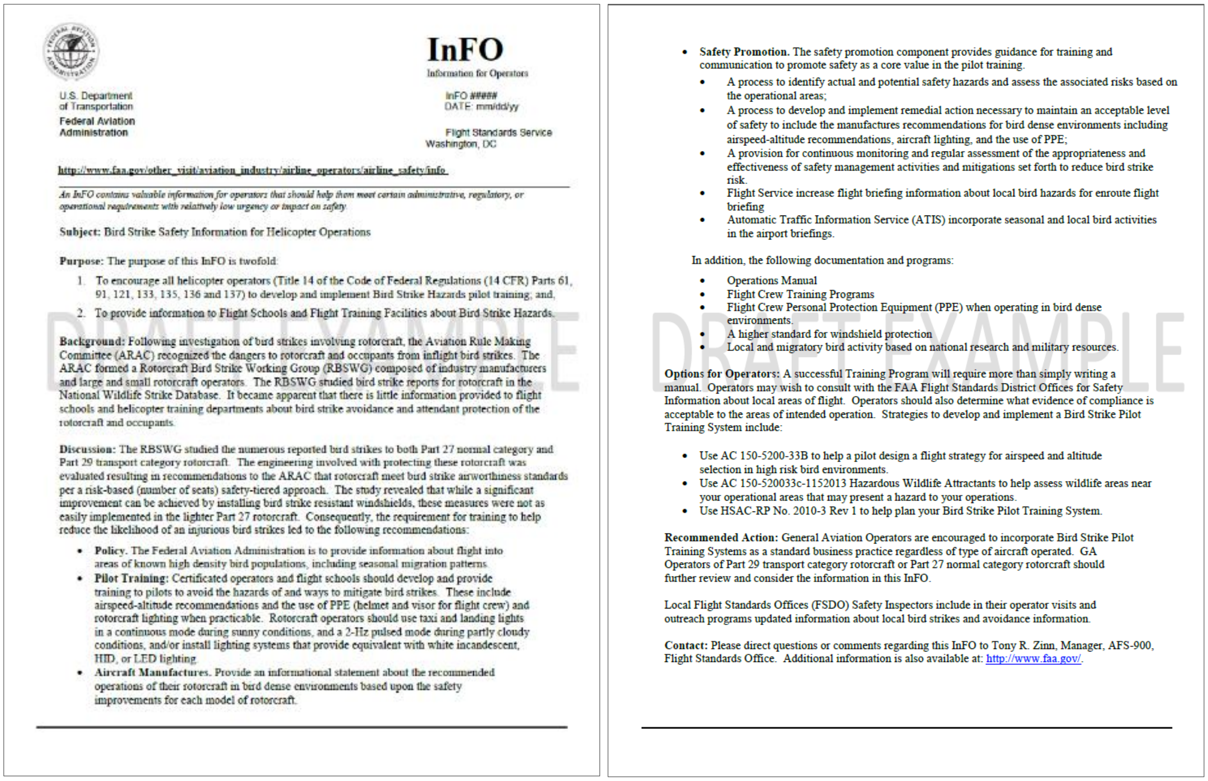
Personal Protective Equipment (PPE)

Many operators who perform low-level rotorcraft missions currently require Personal Protective Equipment. The law enforcement community, air medical crews and governmental agencies, among others use some type of PPE during their flights. The use of helmets with visors (Figure 18), both tinted for day use and clear for night, are a common tool for protecting flight crews and passengers. The effectiveness of these technologies provides head and eye protection; however, the body of the occupants are not likely to be protected.

Other rotorcraft operators do not find that using this equipment is viable for their missions. The reasons for this can be mission-related and due to public perception. The passenger that is not a professional crewmember, assumes that the flight will be flown in a professional and safe manner. Flight crew wearing obvious protective equipment could erode the confidence of passengers that are not provided this equipment, in the tour industry, for example.

[6] http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgOrders.nsf/0/04d2c1f298de11448625721400591c30/$FILE/8000-91.pdf

[7] http://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/info



U.S. Department of Transportation
Federal Aviation Administration

InFO
Information for Operators

InFO #####
DATE: mm/dd/yy

Flight Standards Service
Washington, DC

http://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/info

An InFO contains valuable information for operators that should help them meet certain administrative, regulatory, or operational requirements with relatively low urgency or impact on safety.

Subject: Bird Strike Safety Information for Helicopter Operations

Purpose: The purpose of this InFO is twofold:

1. To encourage all helicopter operators (Title 14 of the Code of Federal Regulations (14 CFR) Parts 61, 91, 121, 133, 135, 136 and 137) to develop and implement Bird Strike Hazards pilot training; and,
2. To provide information to Flight Schools and Flight Training Facilities about Bird Strike Hazards.

DRAFT EXAMPLE

Background: Following investigation of bird strikes involving rotorcraft, the Aviation Rule Making Committee (ARAC) recognized the dangers to rotorcraft and occupants from inflight bird strikes. The ARAC formed a Rotorcraft Bird Strike Working Group (RBSWG) composed of industry manufacturers and large and small rotorcraft operators. The RBSWG studied bird strike reports for rotorcraft in the National Wildlife Strike Database. It became apparent that there is little information provided to flight schools and helicopter training departments about bird strike avoidance and attendant protection of the rotorcraft and occupants.

Discussion: The RBSWG studied the numerous reported bird strikes to both Part 27 normal category and Part 29 transport category rotorcraft. The engineering involved with protecting these rotorcraft was evaluated resulting in recommendations to the ARAC that rotorcraft meet bird strike airworthiness standards per a risk-based (number of seats) safety-tiered approach. The study revealed that while a significant improvement can be achieved by installing bird strike resistant windshields, these measures were not as easily implemented in the lighter Part 27 rotorcraft. Consequently, the requirement for training to help reduce the likelihood of an injurious bird strikes led to the following recommendations:

- **Policy.** The Federal Aviation Administration is to provide information about flight into areas of known high density bird populations, including seasonal migration patterns.
- **Pilot Training:** Certificated operators and flight schools should develop and provide training to pilots to avoid the hazards of and ways to mitigate bird strikes. These include airspeed-altitude recommendations and the use of PPE (helmet and visor for flight crew) and rotorcraft lighting when practicable. Rotorcraft operators should use taxi and landing lights in a continuous mode during sunny conditions, and a 2-Hz pulsed mode during partly cloudy conditions, and/or install lighting systems that provide equivalent with white incandescent, HID, or LED lighting.
- **Aircraft Manufactures.** Provide an informational statement about the recommended operations of their rotorcraft in bird dense environments based upon the safety improvements for each model of rotorcraft.

- **Safety Promotion.** The safety promotion component provides guidance for training and communication to promote safety as a core value in the pilot training.
  - A process to identify actual and potential safety hazards and assess the associated risks based on the operational areas;
  - A process to develop and implement remedial action necessary to maintain an acceptable level of safety to include the manufactures recommendations for bird dense environments including airspeed-altitude recommendations, aircraft lighting, and the use of PPE;
  - A provision for continuous monitoring and regular assessment of the appropriateness and effectiveness of safety management activities and mitigations set forth to reduce bird strike risk.
  - Flight Service increase flight briefing information about local bird hazards for enroute flight briefing
  - Automatic Traffic Information Service (ATIS) incorporate seasonal and local bird activities in the airport briefings.

In addition, the following documentation and programs:

- Operations Manual
- Flight Crew Training Programs
- Flight Crew Personal Protection Equipment (PPE) when operating in bird dense environments.
- A higher standard for windshield protection
- Local and migratory bird activity based on national research and military resources.

DRAFT EXAMPLE

Options for Operators: A successful Training Program will require more than simply writing a manual. Operators may wish to consult with the FAA Flight Standards District Offices for Safety Information about local areas of flight. Operators should also determine what evidence of compliance is acceptable to the areas of intended operation. Strategies to develop and implement a Bird Strike Pilot Training System include:

- Use AC 150-5200-33B to help a pilot design a flight strategy for airspeed and altitude selection in high risk bird environments.
- Use AC 150-520033c-1152013 Hazardous Wildlife Attractants to help assess wildlife areas near your operational areas that may present a hazard to your operations.
- Use HSAC-RP No. 2010-3 Rev 1 to help plan your Bird Strike Pilot Training System.

Recommended Action: General Aviation Operators are encouraged to incorporate Bird Strike Pilot Training Systems as a standard business practice regardless of type of aircraft operated. GA Operators of Part 29 transport category rotorcraft or Part 27 normal category rotorcraft should further review and consider the information in this InFO.

Local Flight Standards Offices (FSDO) Safety Inspectors include in their operator visits and outreach programs updated information about local bird strikes and avoidance information.

Contact: Please direct questions or comments regarding this InFO to Tony R. Zinn, Manager, AFS-900, Flight Standards Office. Additional information is also available at: http://www.faa.gov/.

Figure 17. Example InFO – Bird Strike Safety Information for Helicopter Operations.

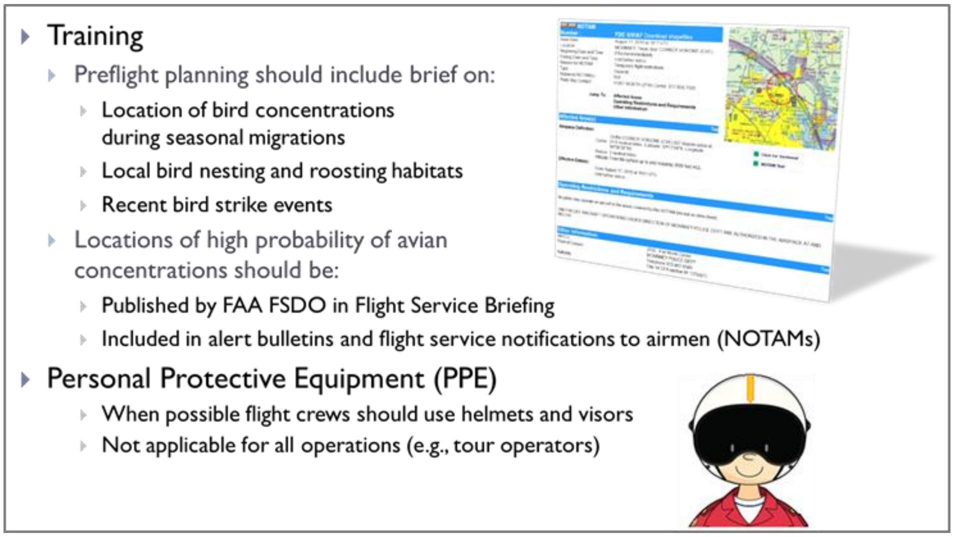


Figure 18. Non-traditional means: awareness.

Electronic Detection Devices

Gerringer, Lima, & DeVault (2016) assessed the detection and tracking abilities of a commercially available avian radar system in an airport environment in Indiana during October 2011–March 2012. Transits by free-flying birds enabled assessment of "radar tracking performance as influenced by flock size, altitude, and distance from the radar unit. Most of the single large-bird targets (raptors) observed within 2 nautical miles (NM) of the radar were tracked ≥1 time, but such targets were generally tracked <30% of the time observed. Flocks of large birds such as geese … and cranes … were nearly always tracked ≥1 time, and were generally tracked approximately 40–80% of the time observed, even those several NMs away from the radar unit." The results of this study suggest that "avian radar can be a useful tool for monitoring bird flock activity at airports, but less so for monitoring single large-bird targets such as thermalling raptors."

Electronic detection devices such as inflight bird detection and avoidance radar may in the future provide the rotorcraft with a spherical warning area that prevents the rotorcraft from encountering bird strikes. However, research to date does not support a recommendation for requiring this technology at this time (Figure 19).

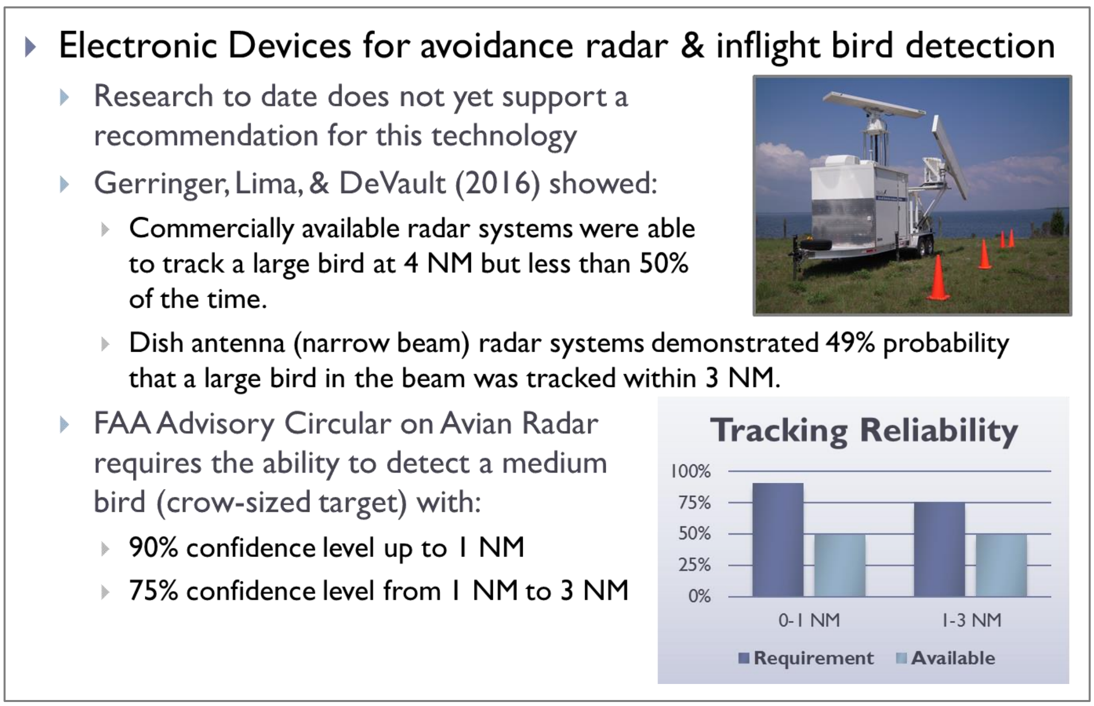


Figure 19. Non-traditional means: detection.

Paint or Rotorcraft Colors

One study suggests that rotorcraft coloring may provide specific species of birds with early recognition of an approaching rotorcraft, allowing the birds to evade. However, research to date does not support a recommendation for this technology at this time.

Rotorcraft Lighting

Lighting technology is advancing quickly in helping to avoid bird strikes. Although the research is not yet complete, operational data does anecdotally indicate that lighting technology possibly influences the number of bird strikes. During experiments, birds show signs of early recognition of an approaching vehicle allowing the bird to recognize and initiate evasion. This increased recognition period may allow a bird more time to avoid the rotorcraft's path. As the technology advances it may be able to provide additional guidance in the frequency of the light pulses and alternate timing of the pulses to provide birds with enhanced notice of approaching rotorcraft.

Birds are visual animals, but their visual capabilities vary by species, and these capabilities differ markedly from that of humans. Recent research that targeted how birds see and respond to visual stimuli including approaching vehicles and lighting regimens has offered new insights as to how rotorcraft lighting might be used to enhance detection of the rotorcraft by birds and reduce bird-rotorcraft collisions (DeVault T. L., Blackwell, Seamans, Lima, & Fernández-Juricic, 2015). Birds appear to become alert to aircraft sooner that are more visible/conspicuous to them.

Admittedly, published research to date on avian response to vehicle approach and lighting is limited to three species, but the researchers suggest that inferences drawn from this work might be helpful to rotorcraft operators until more studies are completed. First, early work showed that a blackbird species (brown-headed cowbird) and the mourning dove responded to vehicle approach better if the vehicle was using lighting (here, rotorcraft lighting in the form of standard incandescent "white" or high-intensity discharge lamps of near full spectrum; see Blackwell & Bernhardt (2004) and Blackwell, Fernández-Juricic, Seamans, & Dolan, (2009). More importantly, Blackwell, et al. (2009) showed for the first time that detection of an approaching vehicle by birds is not only enhanced by lighting, but also affected by the pulse frequency (2 Hz) of the lighting relative to ambient light conditions. More specifically, these researchers showed enhanced detection of vehicle approach with continuous lighting under sunny conditions, whereas detection improved during partly cloudy conditions by use of a 2-Hz pulse. Subsequent work with Canada geese (Blackwell B. F., et al., 2012) showed that this species responded sooner to the approach of a large, radio-controlled aircraft exhibiting pulsed (2 Hz) LED, near-full-spectrum lighting. Although, the researchers did not compare continuous, pulsed, and no-light scenarios against Canada geese in Blackwell et al. (2012), they did show that the pulsed LEDs stimulated earlier alerts compared with no lights. Common to each of these studies is the enhanced detection of an aircraft with lighting, but also the necessary contrast of the vehicle to background conditions, which can be achieved via pulse rate and the type of lighting used (see below). Finally, recall that Doppler et al. (2015) showed, using a visually salient light for brown-headed cowbirds, that under sunny conditions a continuous light improved the statistical interaction between light treatment and aircraft speed. In other words, Doppler et al. (2015) corroborated what Blackwell et al. (2009) found in their study, namely, use continuous light in sunny conditions, even with the use of a wavelength-specific, more salient light. By using continuous light in sunny conditions, we can enhance avian detection of approaching aircraft and corresponding escape behavior.

More recently, this same research team has moved even farther into the realm of quantifying how a species sees its world and shown how specific wavelengths and pulse frequencies might serve better to fine tune aircraft lighting beyond the multi-wavelength "white" light. Specifically, Doppler et al. (2015) showed that the brown-headed cowbird responded sooner to lighting tuned to its visual capacity and that lighting can, when ambient light conditions are considered relative to pulse vs. no pulse, reduce the negative effects of vehicle approach speed to some extent. This interaction of vehicle lighting and speed is critical given that published research indicates that birds respond to approaching vehicles using a spatial decision process, not necessarily by adjusting their escape behavior to vehicle speed [DeVault et al. (2014) (2015)].

Light placement on the rotorcraft can cause the blockage or obstruct the lights from being visible to the birds. The encounter with a bird in flight is not always from the forward position and bird strikes do occur from the sides, above and below the rotorcrafts flight path. Manufacturers and secondary providers should continue to research the visual technology that may provide opportunity for birds to avoid approaching rotorcraft with visual lighting aids. Conclusive research results do not yet exist for rotorcraft lighting that would effectively enhance avian detection of and response to rotorcraft across multiple species of birds.

Based on inference from the research cited for white incandescent, HID, or LED lighting, the RBSWG recommends guidance material be published recommending that rotorcraft operators use taxi and/or landing lights in a continuous mode during sunny conditions and at night when practical and a 2-Hz pulsed mode during partly cloudy conditions, and/or install lighting systems that provide the equivalent.

Recommendations for Implementing Non-Traditional Means of Bird Strike Protection

Of the non-traditional means of bird strike protection, the RBSWG determined the following three non-traditional means have the greatest potential for protection.

- Airspeed-altitude limitation
- Helmet and visor for flight crew
- Use taxi and/or landing lights

Airspeed-Altitude Limitation

Research indicates that avian evasion from an approaching aircraft is enhanced as the aircraft speed decreases. As noted earlier, 77% of reported bird strikes on Part 27 rotorcraft in the NWSD in which airspeed was recorded occurred above 80 knots. Therefore, one recommended non-traditional means of bird strike protection is to limit airspeed to 80 knots or less at lower altitudes.

The highest mean altitude for reported bird strikes throughout the year as shown in Figure 16 is 1,295 ft AGL (in April) and is approximately equal to the mean altitude throughout the 24-hour day shown in Figure 15. Hence, we recommend a means of bird strike prevention by restricting airspeed below 1,300 ft AGL to 80 knots or less.

Quoting again from Dolbeer (2006), "*Above 500 feet, strikes declined exponentially by a remarkably consistent 32% per 1,000-foot interval up to 20,500 feet. … 93% of the strikes (and presumably birds) were below 3,500 feet.*"

Setting the kinetic energy from a bird strike to be inversly related to the increase in strike probability enables us to relate velocity with altitude. At 80 knots, a 2.2-lb bird produces 623 ft-lb of kinetic energy. Flying 1,000 ft higher and 60 knots faster at 140 knots, the same bird produces three times more kinetic energy at 1,909 ft-lb. Thus the 3x kinetic energy threat due to 60 knot increased speed is directly offset by the 1/3rd decrease in strike threat due to 1,000 ft increased altitude. The equation shown below and in Figure 20 relates the 1,000-ft increase in altitude with the 1/3rd decrease in bird strike probability.

$$Airspeed = 24.152e^{0.0008369(Altitude)} \tag{1}$$

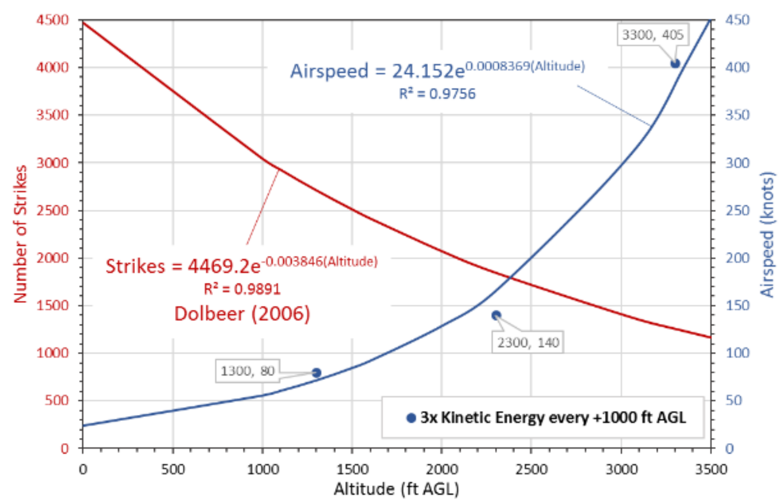


Figure 20. Relationship between airspeed and strike threats.

Expressing equation (1) with altitude as the dependent variable results in the following.

$$Altitude = 1195\ln(Airspeed) - 3805 \tag{2}$$

Equation (2) is shown in Figure 21 along with the kinetic energy of a 2.2-lb bird. Proposed airspeed-alitude operational parameters is also shown simplified to three points with linear realtionships between them: 80 knots at 1,300 ft AGL, 140 knots at 2,300 ft AGL, and 200 knots at 2,500 ft AGL. Since most rotorcraft have V_H or V_{NE} less than 200 knots, no airspeed-altitude is defined above this last point.

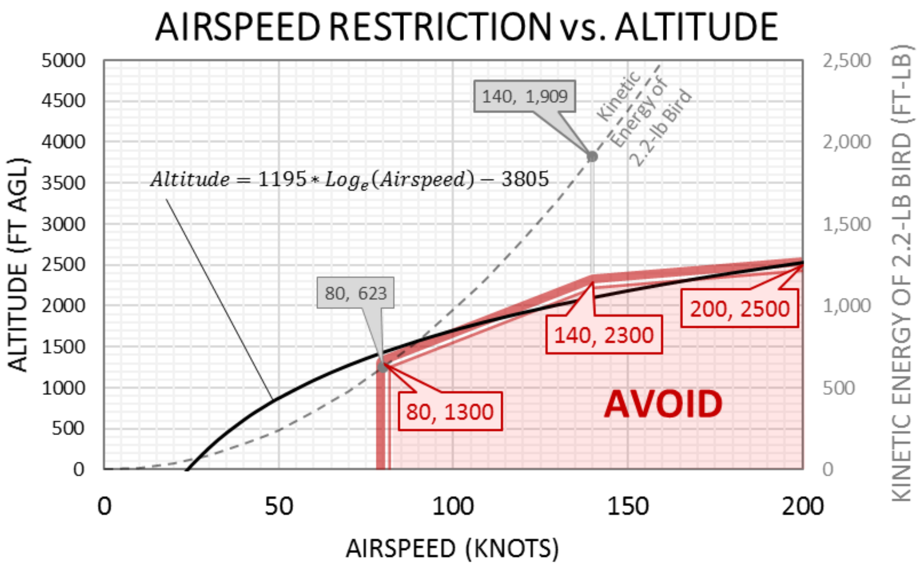


Figure 21. Bird strike avoidance as a function of airspeed and altitude.

The RBSWG recommends for existing rotorcraft and newly manufactured rotorcraft that do not meet the proposed airworthiness standard for bird strike, that the airspeed-altitude operational parameters as shown in Figure 21 be considered as a means of bird strike prevention when practical. Specifically, this would be an airspeed of 80 knots or less below 1,300 ft AGL, ramping linearly to 140 knots or less at 2,300 ft AGL, then ramping linearly to 200 knots or less at 2,500 ft AGL, with no airspeed definition above 2,500 ft AGL.

Personal Protective Equipment

The RBSWG recommends that flight crew wear personal protective equipment (PPE) consisting of a helmet and visor as a means of bird strike protection. We further recommend that helmets and visors be worn by all occupants whenever possible.

Rotorcraft Lighting

The RBSWG recommends that rotorcraft operators use taxi and/or landing lights in a continuous mode during sunny conditions and at night when practical, and use a 2-Hz pulsed mode during partly cloudy conditions, and/or install lighting systems that provide the equivalent.

TASK 7 – POLICY AND GUIDANCE RECOMMENDATIONS FOR ROTORCRAFT BIRD STRIKE PROTECTION

TASK DESCRIPTION

As published in FR Doc. 2016–09781, Task 7 states:

> *Based on the recommendations in Tasks 1 through 6, specifically advise and make written recommendations for the associated policy and guidance.*

The recommendations provided in this section summarize the recommendations from Tasks 1 through 6 as aligned by the economic analysis of Task 8.

RECOMMENDATIONS FOR POLICY AND GUIDANCE

Proposed Part 27 Airworthiness Standards for Newly Type Certificated Rotorcraft

The RBSWG proposes the following airworthiness standard, 14 CFR § 27.631 for newly type certificated Part 27 normal category rotorcraft.

> *The rotorcraft with a maximum occupancy (pilot plus passengers) of 7 to 9 must be designed to ensure capability of safe landing after impact upon the windshield with a 2.2-lb (1.0-kg) bird when the velocity of the rotorcraft (relative to the bird along the flight path of the rotorcraft) is equal to V_{NE} or V_H (whichever is the lesser) at altitudes up to 8,000 feet. Compliance must be shown by tests or by analysis based on tests carried out on sufficiently representative structures of similar design.*

The RBSWG encourages operators to implement bird strike safety procedures described below in the **Proposed Policy and Guidance Material** section.

Proposed Part 27 Airworthiness Standards for Newly Manufactured Rotorcraft

Based on the economic analysis, the RBSWG does not recommend implementing bird strike regulations via § 27.2 (Special retroactive requirements) for newly manufactured normal category rotorcraft. The RBSWG encourages operators to implement bird strike safety procedures described below in the **Proposed Policy and Guidance Material** section.

Proposed Retention of Existing 14 CFR § 29.631 Bird Strike Regulation

The RBSWG concludes that the current risk is acceptable with the existing 14 CFR § 29.631 airworthiness standard in terms of bird quantity (implied), bird mass, and strike velocity over the altitude range specified. Accordingly, the RBSWG recommends keeping the current regulation for newly type certificated Part 29 transport category rotorcraft and encouraging operators to implement bird strike safety procedures described below in the **Proposed Policy and Guidance Material** section.

Proposed Part 29 Airworthiness Standard for Newly Manufactured Rotorcraft

The RBSWG proposes the following airworthiness standard, 14 CFR § 29.2 (Special retroactive requirements) for newly manufactured transport category rotorcraft.

> *For each rotorcraft manufactured after January 1st, 2027 (2 years after implementation of 14 CFR § 29.2, followed by 5 years for certification),*
>
> *(c) with maximum occupancy (crew plus passengers) of 16 or more, each applicant must show compliance to 14 CFR § 29.631.*
> *(d) with maximum occupancy (crew plus passengers) of 10 to 15, each applicant must show compliance to 14 CFR § 29.631 applied only to the windshield and flight critical equipment/components forward of the main rotor mast that could prevent continued safe flight and landing for Category A or a safe landing for Category B rotorcraft.*

The RBSWG encourages operators to implement bird strike safety procedures described below in the **Proposed Policy and Guidance Material** section.

Proposed Bird Strike Airworthiness Standards for Existing Operating Rotorcraft

The RBSWG recommends a policy that encourages upgrading existing rotorcraft and/or implementing bird strike safety procedures as follows.

- Existing Part 27 normal category rotorcraft with maximum occupancy of 1 to 3 (crew plus passengers) should implement bird strike safety procedures described below in the **Proposed Policy and Guidance Material** section.
- Existing Part 27 normal category rotorcraft with maximum occupancy of 4 to 6 should implement bird strike safety procedures described below in the **Proposed Policy and Guidance Material** section.
- Existing Part 27 normal category rotorcraft with maximum occupancy of 7 to 9 must install a BSR windshield that meets the same level of the proposed bird strike protection in the proposed 14 CFR § 27.631.
- Existing Part 29 transport category rotorcraft with maximum occupancy of 10 to 15 must install a BSR windshield that meets the requirements of 14 CFR § 29.631.
- Existing Part 29 transport category rotorcraft with maximum occupancy of 16 or more must install a BSR windshield that meets the requirements of 14 CFR § 29.631 and should protect flight critical equipment/components forward of the main rotor mast that if damaged could prevent CSFL for Category A or a SL for Category B rotorcraft.

The RBSWG proposes the non-mandatory implementation date for the above recommendation to be January 1st, 2020 for implementing bird strike safety procedures and the recommended date of

January 1st, 2030 for development and certification of BSR kits to be available for installation on existing rotorcraft. The RBSWG further recommends that operation after January 1st, 2035 require installation of the BSR kit. There are approximately 4,500 rotorcraft currently operating in the U.S. that are Part 27 Tier III and Part 29 Tiers I and II that are not already compliant with 14 CFR § 29.631.

The above are summarized in Table 5.

Table 5. Summary of RBSWG Recommendations.

RBSWG Group	Definitions					
	Task 1 - Part 27 Newly TC'd Implemented after 2020	Task 2 - Part 27 Newly Mfg'd Implemented after 2020	Task 5 - Part 27 Existing Implemented after 2029	Task 3 - Part 29 Newly TC'd Implemented 1996	Task 4 - Part 29 Newly Mfg'd Implemented after 2029	Task 5 - Part 29 Existing Implemented after 2029
Tier I	1-3 occupants, operators implement bird strike safety procedures	1-3 occupants, operators implement bird strike safety procedures	1-3 occupants, operators implement bird strike safety procedures	10-15 occupants must comply with 14 CFR §29.631	10-15 occupants must show compliance to 14 CFR § 29.631 applied only to the windshield and flight critical equipment / components forward of the main rotor mast that could prevent continued safe flight and landing for Category A or a safe landing for Category B rotorcraft.	10-15 occupants, install BSR windshield that meets same level of bird strike protection in 14 CFR §29.631, and operators implement bird strike safety procedures
Tier II	4-6 occupants, operators implement bird strike safety procedures	4-6 occupants, operators implement bird strike safety procedures	4-6 occupants, operators implement bird strike safety procedures	16 or more occupants must comply with 14 CFR §29.631	16 or more occupants must comply with 14 CFR § 29.631	16 or more occupants, install BSR windshield that meets § 29.631 and protect flight critical equipment / components forward of main rotor mast that if damaged could prevent continued safe flight and landing for Category A or a safe landing for Category B rotorcraft. Operators implement bird strike safety procedures.
Tier III	7-9 occupants: new § 27.631 - must be designed to ensure safe landing after impact upon windshield with a 2.2 lb bird with velocity equal to VNE or VH (whichever is the lesser) at altitudes up to 8,000 feet.	7-9 occupants, operators implement bird strike safety procedures	7-9 occupants, install BSR windshield that meets same level of bird strike protection in proposed § 27.631, and operators implement bird strike safety procedures			

Proposed Policy and Guidance Material

The RBSWG further recommends the following policy and guidance material be developed.

- Maintain guidance that no windshield penetration is permitted for the required bird regulation in showing compliance. This is thought to provide additional margin to the requirement for the most impacted and typically most critical area.
- Pursue establishing guidance for the temperature range required for windshields undergoing bird strike tests.

- Pursue establishing guidance for induced effects such as shock pulse to critical equipment such as instrument panel components subjected to shock pulse from proximate bird strike.
- Pursue establishing guidelines on analytical substantiation techniques to show compliance to the bird-strike requirement. This could provide a path to lower-cost means of substantiation and compliance. At the very least, higher confidence and possibly reduced testing may be possible.
- The RBSWG recommends clarification be added to Advisory Circular AC 29-2C to improve clarity of the intent and purpose for delineating altitudes up to 8,000 feet. The rule could be misunderstood to require that rotorcraft be designed to ensure capability of CSFL after impact with a 2.2-lb bird at altitudes up to 8,000 ft, with the implication that if the rotorcraft operates more than 8,000 ft above sea level, it is not subject to the bird strike airworthiness standard. Rather, AC 29-2C should clarify that the maximum horizontal velocity, V_H, varies as a function of density altitude, hence the necessity for defining the altitude range over which the V_H velocity must be considered.

The RBSWG recommends that guidance be developed for operators to implement bird strike safety procedures which include the following.

- <u>Reduce airspeed when practical.</u> Training should remind flight crews that more than 3 out of 4 bird strikes (77%) occur during airspeeds greater than 80 knots. No bird strikes have been reported in the NWSD below 55 knots. Therefore, if flight operations allow slower airspeeds in areas known to have a high-density bird population, reduce the airspeed to 80 knots or less, particularly at lower altitudes.
- <u>Increase altitude as soon as possible and practical</u>, when allowed by other flight variables. Rotorcraft operators should be reminded that there is a 32% decrease of bird strike likelihood with every 1,000 ft gained above 500 ft AGL and that 93% of all strikes occur below 3,500 ft AGL. Fly higher at night when possible, since birds also fly higher at night.
- <u>Utilize personal protective equipment (PPE)</u> consisting of a helmet and visor, at least for the crew, when practical.
- <u>Use taxi and/or landing lights</u> in a continuous mode during sunny conditions and at night when practical, and a 2-Hz pulsed mode during partly cloudy conditions, and/or install lighting systems that provide the equivalent.

The RBSWG also recommends that a CAUTION be posted in all RFMs stating the following.

- CAUTION: Operating rotorcraft in areas of high concentrations of birds or flocking birds increases likelihood of a damaging bird strike as airspeed increases and altitude AGL decreases. When operating the rotorcraft at lower altitudes during takeoff and climb-out, the rotorcraft should be operated at lower airspeeds to decrease the likelihood and severity of a potential bird strike. Though regional differences exist during spring and fall migration periods, operating a rotorcraft at altitudes below 2,500 feet AGL may increase the likelihood of a damaging bird strike during those seasons.

Further, the RBSWG recommends that air carriers and general aviation operators, working with the FSDO Safety Programs and Flight Service Briefing, should identify and publish known locations and probability of bird concentrations. The location of bird concentrations during seasonal migrations and the local bird nesting and roosting habitats, should be made available to the rotorcraft operator and pilot for preflight planning to minimize the potential for bird strikes. Local recognition of these threat areas along with increased familiarity and examination of the NWSD into which reported bird strikes are recorded with increasing frequency and accuracy, can provide a valuable resource for flight crews. This information should be incorporated into alert bulletins, flight service Notice to Airmen (NOTAM) and other systems presently used to inform flight crews of the hazards of bird concentrations.

The RBSWG recommends that research in non-traditional means of bird strike protection be accelerated in at least the following areas:

- Alerting the bird – Rotorcraft light technology that would enhance a bird's day/night detection of and response to rotorcraft across multiple species of birds.
- Alerting the pilot – In-flight electronic bird detection and avoidance devices (e.g., radar) to provide the rotorcraft with spherical warning.

Finally, as noted in Appendix C, there is a sizable growth rate in the population of larger and medium size bird species. As a result, the USDA is encouraged to continue management of large and medium birds near airports in the U.S.

TASK 8 – ESTIMATED BENEFITS OF PROPOSED RECOMMENDATIONS

TASK DESCRIPTION

As published in FR Doc. 2016–09781, Task 8 states:

> *Based on the Rotorcraft Bird Strike Working Group recommendations, perform the following:*
>
> a. *Estimate what the regulated parties would do differently as a result of the proposed recommendation and how much it would cost.*
> b. *Estimate the safety improvements of future bird encounters from the proposed recommendations.*
> c. *Estimate any other benefits (e.g., reduced administrative burden) or costs that would result from implementation of the recommendations.*

DATA

The general approach was to examine accident and incident data for rotorcraft over the period from January 2009 through February 2016 (86 months or 7.17 years) and determine the injuries, fatalities and damage that occurred. Assuming a constant rate of incidents, the benefit of preventing future bird strike injuries and fatalities was compared to the cost of implementing the bird strike protection. Current fleet size data was collected and future fleet size projections were made to estimate the benefits and costs associated with implementation of recommended changes. The analyses support the conclusions and recommendations put forth by the RBSWG in Task 9.

ASSUMPTIONS

As noted previously, the 86-month period selected assumes the data over this timeframe provides accurate representation of actual strike events. Assuming the rate of bird strikes remains constant, the number of future bird strike events is estimated. The benefits of preventing injuries and fatalities in these future bird strike events are scaled as described in assumption 6 of the **Introduction** section. All calculations reflect the benefit that should be realized for future rotorcraft that are compliant with the regulations recommended herein and summarized in Task 7.

The fleet forecast affects both the benefits and costs. For purposes of this evaluation, we conservatively assume that all certifications are approved one year after the rule is codified with an estimated effectivity beginning January 2019. Further, production and deliveries are assumed to begin the following year (2020). The number of deliveries and the corresponding delivery years depend upon the rotorcraft safety tier group based on current fleet size and future projected growth. We develop and explain these numbers in the “Fleet Size” section of this analysis.

This analysis focuses on the incremental benefits and costs that accrue to U.S. operators and manufacturers. For both the benefits and the costs, we use a time value of money with a 7% future value rate as prescribed by Office of Management and Budget (OMB)[8] to reflect the present value of money in 2016 U.S. dollars. Present value costs account for the decreasing value of money with time due to an estimated 7% annual investment return rate over the next 10-year period. The benefits consider current fleet size based on input from RBSWG members and scaled to match the projected future fleet growth[9].

The benefits and costs are driven by past accidents, industry cost information, and the projected future fleet size. The benefits are based on projected future accidents which are evaluated as preventable fatalities and scaled for injuries based on Fractional Values of Life provided by the Office of Aviation Policy and Plans in the *2016 Revised Value of a Statistical Life Guidance*[10], and estimated cost of repairs. The societal costs include the overhead costs that are allocated to labor as well as direct costs. We use $140 per hour as the burdened wage rate for engineers.

As noted, any bird strike regulations are assumed to go into effect in January 2020. To evaluate the cost benefit, this study will project data forward 10 years through December 2029 to assess net benefits of implementation.

FLEET SIZE

This section outlines the methodology used to estimate the number of rotorcraft model types, fleet size, and projected future fleet sizes of rotorcraft that will be affected by the final rule. Our reasoning and the underlying assumptions used in this analysis are described.

The RBSWG included representatives from all major rotorcraft manufactures, foreign and domestic, who manufacture Part 27 and/or Part 29 rotorcraft for the U.S. market. Each manufacturer provided information on their respective products which included date of original FAA Type Certificate, maximum number of occupants (crew plus passengers) for each model type, and total number of rotorcraft for each model type currently operating in the U.S. Additionally, a comprehensive review of the FAA aircraft registry was conducted to determine fleet population. This fleet does not include kit-built rotorcraft.

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[8] OMB Circular A-4 Page 33 and A-94 Section 8-b-1 https://www.transportation.gov/regulations/omb-circular-no-4 https://www.transportation.gov/regulations/omb-circular-94.

[9] FAA AEROSPACE FORECAST Fiscal Years 2017-2037.

[10] *2016 Revised Value of a Statistical Life Guidance* https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis.

Rotorcraft Groupings

The RBSWG used this data to develop risk-based tiered safety approach based on maximum occupant capacity (Figure 12). The logic for this approach is that the number of occupants directly correlates with risk. Since not all operations deploy with maximum occupancy, the analysis is conservative.

Table B-1 (in Appendix B) lists all the rotorcraft included in this economic analysis and shows the groupings and number of rotorcraft currently operating in the U.S. for each type. Table 6 is a summary of this information by rotorcraft grouping. This data is the basis for the existing fleet and is used to forecast future fleet sizes for each group.

The forecasted future fleet size looked back at the FAA Type Certificates issued over the past 20 years within each tier to project the same growth rate for the next 10 years. Part 27 Tier I had zero TCs issued in the past 20 years, but RBSWG members projected two new TCs over the next decade in this tier. Part 27 Tier II had two TCs issued, hence one new TC is projected in the next 10 years for this tier. Part 27 Tier III had four TCs issued, hence two new TCs are projected for this tier. Part 29 Tier I had three TCs issued over the past two decades (of which two were compliant with 14 CFR § 29.631), hence one new TC is projected in the next decade for this tier. Part 29 Tier II had four TCs issued over the past 20 years (all of which were compliant with 14 CFR § 29.631), hence two new TCs are projected in the next 10 years for this tier.

Table 6. Rotorcraft in Operation in the U.S. by Rotorcraft Group.

Rotorcraft Group		Total in Operation in the US	Total Types Currently Being Manufactured	Projected New TCs between 2020-2030	Years for Projected New TCs
Part 27 - Tier I	Part 27 with 1-3 occupants	1,601	3	1	2020
Part 27 - Tier II	Part 27 with 4-6 occupants	4,231	11	1	2020
Part 27 - Tier III	Part 27 with 7-9 occupants	3,987	13	2	2020, 2025
Part 29 - Tier I	Part 29 with 10-15 occupants	717	8	1	2020
Part 29 - Tier II	Part 29 with 16 or more occupants	41	4	2	2020, 2027
14 CFR 29.631	Per § 29.631	202	8	--	--

The benefit data must be scaled to match the future production levels predicted for all manufacturers over the entire 2020-2029 timeframe. Rotorcraft hours flown have grown over time, and the FAA estimates that they will continue to grow throughout the forecast period. This projected increase in hours-flown is accompanied by an increase in the risk of future accidents. To incorporate the effect of forecasted growth on the number of future injuries prevented by proposed bird strike regulations and the resulting economic benefits, we used an assumption of 2.5% growth in flight hours per year going forward as projected by the FAA Aerospace Forecast FY2017-2037[11] for the 10-year period of 2020-2029. This accounted for the effects of projected increase in overall flight activity on the reduction in future fatalities, injuries, damages expected to result from adopting proposed bird strike requirements. The future fleet size is calculated for each group through 2029 in accordance with the original assumptions that:

- The proposed bird strike protection regulations will not go into effect until 2020 following rulemaking process including the NPRM and attendant comment period, and
- The study assesses the cost benefit analysis over the 10-year period following implementation of the new proposed bird strike airworthiness standards.

Table B-2 provides the fleet growth projections for each rotorcraft group used for the cost benefit analyses.

BENEFIT ANALYSIS

The FAA's NWSD was used to review past bird strike events. The database was filtered to provide only rotorcraft strike events from January 2009 through the end of February 2016, which is when the data was first provided to the RBSWG. The data was then categorized as Part 27 or Part 29 and the number of maximum occupants for each type of rotorcraft were added to the database to facilitate risk grouping and subsequent cost benefit analyses. All bird strikes were reviewed and categorized as bird strike with damage, and additionally any bird strike with windshield penetration was identified.

In estimating benefit values for avoided fatalities and injuries, we used cost values provided by the Office of Aviation Policy and Plans published in the U.S. Department of Transportation's (DOT) 2016 Revised Value of a Statistical Life Guidance. This document estimates the value for preventing a fatality in 2016 at $9.9 million (in 2016 dollars), while preventing a serious injury in 2016 is valued at $2,504,700 (assumed to be the average of economic costs for severe, serious, and moderate injuries), and preventing a minor injury in 2016 is estimated to have an economic value of $29,700. As recommended in the DOT guidance document, these values are diminished at a rate of 7% per year to reflect net present value of an increasing future cost as shown in Table 7. These values are utilized for the benefit calculations in this report unless otherwise noted.

[11] FAA AEROSPACE FORECAST Fiscal Years 2017-2037.

Table 7. Valuation of a Statistical Life.

NTSB Classification	Valuation of Statistical Life	
	Fractional Values of Life	Dollar Value (2016 USD)
Fatalities	1.000	$ 9,900,000.00
Serious Injuries	0.253	$ 2,504,700.00
Minor Injuries	0.003	$ 29,700.00

Fatality, serious injury, and near fatal/serious injury events are the primary drivers for the benefit analysis. Cost of component repair/replacement and out-of-service are negligible in comparison and therefore not included.

As shown in Table 1, 263 penetrations out of 782 windshield strikes (34%) occurred on Part 27 rotorcraft, and 45 penetrations out of 151 windshield strikes (30%) occurred on Part 29 rotorcraft that were *not* certified to 14 CFR § 29.631. While not all of these windshield penetrations resulted in injury or fatality, the occupants on board were exposed to risk of injury or death. Therefore, bird strikes that resulted in windshield penetrations in the NWSD are assessed with a risk factor applied to a portion of the occupancy to quantify fatality and serious injury costs. This factor is calculated as follows. Half of the total number of seats in rotorcraft that reported windshield penetrations in the NWSD is summed and normalized by the rotorcraft population percentage within the tier in relation to all Parts 27 and 29 rotorcraft operating in the U.S. This normalized factor, shown in Table 8, is then multiplied by the sum of 11% (1 ÷ 9) of the statistical life valuation for a fatality and 25% of the statistical life valuation for a serious injury, as discussed in the sixth assumption in the **Introduction** – **Assumptions** section and shown below in equation format, to produce the cost per penetrating event.

$$\frac{Cost}{Penetrating\ Event} = \left[\frac{Fatality\ Cost}{9} + \frac{Injury\ Cost}{4}\right]\left[\frac{Seats\ in\ WS\ Pentration\ (normalized)}{2}\right]$$

Table 8. Scale Factor for Benefits.

RBSWG Group	Percentage of Population of both Part 27 & 29	Seats in WS Penetration (Normalized)	Ratio of Benefit Model to Actuals
Part 27 - Tier I	14.9%	9	1.6
Part 27 - Tier II	39.3%	83	2.3
Part 27 - Tier III	37.0%	366	4.1
Part 29 - Tier I	6.7%	403	4.2
Part 29 - Tier II	0.4%	263	No injuries or fatalities, only damage
14 CFR 29.631	1.9%	0	--

For events in the FAA's NWSD in which a bird strike resulted in windshield penetration, a consistent risk-based cost assessment is assigned even though injury may or may not have occurred or been reported. Accordingly, the estimated benefit has been adjusted as described for the projected probability of effectiveness of the rule. The use of this risk-based model increases the estimated benefits above that which would be calculated using only the actual injuries and death. This increase is shown in Table 8, ranging from 1.6 to 4.2. Recall from assumption (3) in the **Introduction-Assumptions** section that the cost of total loss of the rotorcraft was not included in the projected benefits (had BSR features been integrated), meaning the ratios shown in Table 8 would be slightly higher had this cost been included. There were no fatalities or injuries with Part 29 Tier II rotorcraft (that were not 14 CFR § 29.631-compliant) in the NWSD and hence the ratio of benefits to actuals is not calculated.

The actual data was compiled for the 86-month period (January 2009-February 2016, which is 7.17 year) and averaged to reflect a per year benefit for each of the rotorcraft groups. Table B-3 and Table B-4 reflect the benefit analysis for each of the groups.

Cost Analysis

The cost analysis of the proposed airworthiness standards summarized in Task 7 will vary by the ARAC tasks assigned and therefore will be discussed separately for Tasks 1 – 6. The estimated costs can be divided into two categories:

- Original Equipment Manufacturer (OEM) costs consisting of non-recurring costs for design, testing and certification of the BSR features and the additional per unit costs associated with manufacturing the BSR features. Non-recurring costs varied between rotorcraft types (i.e., models) due to differences in certification basis (starting point) and differences in OEM design standards/practices. Future newly type certificated rotorcraft include costs that can be estimated as an additional cost to future certification efforts.

- Operator costs related to increased maintenance requirements, increased fuel consumption, and decreased utility of the rotorcraft as a result of the BSR features. This was shown to be negligible

OEM Costs

The RBSWG included representatives from all major OEMs, foreign and domestic, that manufacture Parts 27 and 29 rotorcraft for the U.S. market. Each OEM provided estimates of the non-recurring costs required for the certification efforts of compliant newly type certificated and newly manufactured rotorcraft. The non-recurring costs are defined as the expenses incurred for design, testing, certification, and retooling to comply with the proposed Task 7 bird strike airworthiness standards.

The costs are defined for two requirements:

- Improvement of windshield only, and
- Improvement of windshield and flight critical equipment/components forward of the main rotor mast that could prevent CSFL for Category A and SL for Category B.

<u>Costs Associated with Bird Strike Resistant Windshield</u>

A non-recurring cost example including the engineering costs plus development and certification costs for an improved BSR windshield for a Part 27 Tier II rotorcraft is provided in Table B-5. The corresponding non-recurring costs for a new BSR windshield for each of the rotorcraft grouping are listed in Table B-6.

The recurring costs associated with labor and materials to support an improved BSR windshield for a Part 27 Tier II rotorcraft and a Part 29 Tier II are listed in Table B-7 and Table B-8. The corresponding recurring costs for the improved BSR windshield are listed by rotorcraft grouping in Table B-9.

<u>Costs Associated with Bird Strike Resistant Windshield and Critical Equipment</u>

A non-recurring cost example including the engineering costs plus development and certification costs for an improved BSR windshield and critical equipment that if damaged could prevent SL is listed in Table B-10. The critical equipment identified is located forward of the main rotor mast. The corresponding non-recurring costs for a new BSR windshield and critical equipment for each of the rotorcraft grouping are listed in Table B-11.

The recurring costs associated with labor and materials to support an improved BSR windshield and critical equipment for a Part 27 Tier II rotorcraft is listed in Table B-12. The corresponding recurring costs for the improved BSR windshield and critical equipment are listed by rotorcraft grouping in Table B-13.

These recurring costs have been added with the distributed OEM non-recurring costs to develop a per-unit cost increase per rotorcraft. The total 10-year cost to the industry is found by multiplying the total per-unit cost increase by the projected number of rotorcraft to be manufactured over the next 10 years.

Operator Costs

The RBSWG examined the effects of bird strike mitigation on operating cost across the rotorcraft fleet. In addition to the fixed costs of hardening for bird strikes, there is an assumed cost increase for fuel burn due to added weight (and possibly drag) for complying with proposed bird strike airworthiness standards.

While all rotorcraft are sensitive to weight changes, smaller aircraft are more sensitive than larger aircraft. This is primarily because the same weight change is a larger percentage of the useful load for a small rotorcraft than it would be for a large rotorcraft. For example, increasing empty weight by 20 lb will reduce the useful load of a Leonardo A109 by 0.64%, but the same addition to a Robinson R22 decreases the useful load by 5.1%; this is an order of magnitude larger. The same relationship holds true for other aspects of the rotorcraft.

In addition, the windshield makes up a much higher proportion of the frontal area in smaller rotorcraft than larger rotorcraft as evidenced in Figure 22. For the economic analysis, the RBSWG generalized the area of a windshield of a Part 27 Tier I rotorcraft as being similar to that of a Part 29 Tier II rotorcraft. However, a smaller rotorcraft generally has less structure to support a BSR windshield, which will require more reinforcement to handle the loads imparted during a bird strike. The need for an estimated 20 lb of extra reinforcement on an already weight sensitive rotorcraft increases the disadvantage further.

Figure 22. Comparison of windshields on R22 (Part 27 Tier I), EC120 (Part 27 Tier II), A109 (Part 27 Tier III), AW-189 (29.631), and S-92A (29.631).

The limited center of gravity envelope of small rotorcraft only compounds the problem. In the case of a BSR windshield, the additional weight of the windshield and structural reinforcement will be far forward in the rotorcraft, ahead of everything including the occupants. This can move the empty weight CG so far forward that normal loadings now put the rotorcraft out of operating limits resulting in limitations on passenger (crew) size, cockpit weight, and optional equipment weight. In response, manufacturers may need to develop aft ballast provisions and redesign critical tail components, increasing the design and implementation costs and reducing the useful load further.

Rotorcraft lose utility as the empty weight increases and the useful load decreases. This change can force operators to reduce passengers or fuel resulting in reduced revenue and shortened available mission times, range, and endurance.

There are a limited number of ways that manufacturers can retain useful load. Increasing the gross weight involves significant component testing and decreasing the service life of fatigue critical parts. This may not be feasible if the rotorcraft is already operating near the practical limits of its performance envelope. In that case, the manufacturer would be forced to develop a new model with a larger engine and/or rotor. In either case, this would require certifying a new model type.

The costs corresponding to the small rotorcraft limitations outlined above are difficult to quantify and have not been accounted for in this report's economic analysis. These limitations pose a significant problem to small rotorcraft and must be considered when deciding on the implementation of new bird strike regulations.

Conklin & de Decker Aviation Consultants[12] provide an online "Aircraft Cost Evaluator" for variable costs, which include fuel ($4.17/gal–Jet A, $4.74/gal–Avgas), airframe maintenance, labor ($85/hr) and parts, engine restoration and miscellaneous costs. Using these costs across the fleet, an example analysis was performed using sample costs for a Leonardo Helicopters A109 windshield upgrade to a BSR windshield.

- Basic windshield: 21.3 lb (4.84 kg) times 2 for left/right
- BSR windshield: 23.8 lb (5.4 kg) times 2 for left/right
- Weight increase: 2.5 lb
- Rotorcraft gross weight: 6985 lb
- Weight increase: 0.035%

Using the Conklin data, an average variable cost increase for an A109, which is in Part 27 Tier III, is $8,893 per year. Applying the 0.035% increase from the weight calculation to average of 139 annual flight hours per helicopter, the cost per flight hour for the A109 with the additional weight of a BSR windshield increases by only $0.023. From this calculation, we conclude that for the purposes of this study, any weight increase due to hardening for bird strikes on larger rotorcraft would result in a negligible increase to the operating costs.

[12] https://www.conklindd.com/cdalibrary/accostsummary.aspx

Economic Assessment for Task 1 Proposed Part 27 Airworthiness Standards for Newly Type Certificated Rotorcraft

This section provides the estimated cost and cost-benefit analysis that will result from implementing regulations and policies proposed under Task 1 for newly type certificated Part 27 rotorcraft. These are listed below.

- Part 27 Tier I, 1-3 occupants – § 27.631 same as Tier III but applied only to windshield.
- Part 27 Tier II, 4-6 occupants – § 27.631 same as Tier III but applied only to windshield and flight critical equipment/components in forward portion of fuselage that could prevent a SL.
- Part 27 Tier III, 7-9 occupants – § 27.631 same as § 29.631 Category B (SL).

Cost-Benefit Analysis for Newly Type Certificated Part 27 Rotorcraft

The projected benefits for implementing the proposed bird strike airworthiness standards for newly type certificated Part 27 rotorcraft are shown in Table 9. The fleet wide annual benefit values come from Table B-3. The values for percent of fleet that are newly type certificated (TC'd) are calculated from Table B-2 by determining the number of newly manufactured rotorcraft within a tier in each year normalized by the total quantity of rotorcraft within the tier.

The sum of newly TC'd in Table 9 and newly manufactured in Table 14 equal the annual fleet growth from Table B-2. The shaded cells in Table 9 are years in which a new TC is assumed. The columns with New TC Annual Benefit lists the product of the fleet wide benefit and percent of fleet that is newly TC'd.

The number of newly TC'd rotorcraft manufactured are calculated by determining the number of newly manufactured rotorcraft within a tier in each year then multiplied by the ratio of the number of new TCs to the total type certificates active that year for the tier (c.f., Table 6). For example, from Table B-2 in 2020 there are 1767 rotorcraft in Part 27 Tier I. This is a growth of 43 rotorcraft from the previous year. From Table 6 we see there is expected to be one new TC in 2020, which is one out of four TCs for this tier. Of the 43 new rotorcraft in 2020 within Part 27 Tier I, 25% (11 rotorcraft) are assumed to be under the new TC, and correspondingly 75% (32 rotorcraft) will be assumed to be newly manufactured (Task 2) under the three existing TCs. The 11 rotorcraft normalized by the fleet size of 1767 rotorcraft results in 0.61% of the Part 27 Tier I fleet (note, the number 11 is not treated here as an integer but rather a real number for 43 ÷ 4).

The columns in Table 9 labeled *New TC Annual Benefit* are the product of the *Fleet Wide Annual Benefit* and the *% of Fleet is New TC*. The columns labeled *Benefits with 2.5% Growth* are the product of *Fleet Growth Factor* and *New TC Annual Benefit*. The *Present Value Benefits at 7%* is the quotient of *Benefits with 2.5% Growth* and *Present Value at 7%*.

Table 9. Future Benefits for Newly TC'd Part 27 Rotorcraft (Task 1).

			Part 27 - Tier I					Part 27 - Tier II					Part 27 - Tier III				
Year	Fleet Growth Factor	Present Value at 7%	Fleet Wide Annual Benefit	% Of Fleet Is New TC	New TC Annual Benefit	Benefits with 2.5% Growth	Present Value Benefits at 7%	Fleet Wide Annual Benefit	% Of Fleet Is New TC.	New MFG. Annual Benefit	Benefits with 2.5% Growth	Present Value Benefits at 7%	Fleet Wide Annual Benefit	% Of Fleet Is New TC.	New MFG. Annual Benefit	Benefits with 2.5% Growth	Present Value Benefits at 7%
2016	1.000	1.000	1,127,391					9,933,730					43,783,471				
2017	1.025	1.070	1,127,391					9,933,730					43,783,471				
2018	1.051	1.145	1,127,391					9,933,730					43,783,471				
2019	1.077	1.225	1,127,391					9,933,730					43,783,471				
2020	1.104	1.311	1,127,391	0.61%	6,874	7,588	5,789	9,933,730	0.20%	20,191	22,287	17,002	43,783,471	0.17%	76,278	84,196	64,233
2021	1.131	1.403	1,127,391	1.20%	13,581	15,366	10,956	9,933,730	0.40%	39,889	45,130	32,177	43,783,471	0.34%	150,695	170,498	121,563
2022	1.160	1.501	1,127,391	1.79%	20,124	23,338	15,551	9,933,730	0.60%	59,106	68,545	45,674	43,783,471	0.51%	223,298	258,957	172,554
2023	1.189	1.606	1,127,391	2.35%	26,508	31,509	19,622	9,933,730	0.78%	77,855	92,545	57,633	43,783,471	0.67%	294,129	349,627	217,730
2024	1.218	1.718	1,127,391	4.65%	52,377	63,816	37,141	9,933,730	0.97%	96,147	117,145	68,180	43,783,471	0.83%	363,233	442,564	257,576
2025	1.249	1.838	1,127,391	5.51%	62,098	77,552	42,183	9,933,730	1.15%	113,992	142,361	77,435	43,783,471	0.98%	430,652	537,825	292,541
2026	1.280	1.967	1,127,391	6.35%	71,582	91,632	46,581	9,933,730	1.32%	131,402	168,206	85,507	43,783,471	1.13%	496,426	635,467	323,039
2027	1.312	2.105	1,127,391	7.17%	80,835	106,063	50,390	9,933,730	1.49%	148,388	194,698	92,500	43,783,471	2.39%	1,046,445	1,373,026	652,315
2028	1.345	2.252	1,127,391	9.96%	112,328	151,069	67,077	9,933,730	1.66%	164,959	221,852	98,505	43,783,471	2.66%	1,163,307	1,564,519	694,665
2029	1.379	2.410	1,127,391	10.94%	123,337	170,022	70,553	9,933,730	1.82%	181,126	249,685	103,610	43,783,471	2.92%	1,277,319	1,760,799	730,669
	Total					737,955	365,843				1,322,453	678,223				7,177,478	3,526,885

The total costs associated with recommended airworthiness standards from Task 1 are developed in Table 10. The costs for anticipated new TCs shown in Table 6 and as shaded cells in Table 10 are listed in the non-recurring cost columns. These non-recurring costs are assumed to be amortized over 10 years. For this analysis, the cost of newly type certificated rotorcraft are assumed to be equal to the corresponding cost of newly manufactured rotorcraft.

The associated cost-benefit analysis shown in Table 11 uses benefits from Table 9 and costs from Table 10 to calculate the difference shown in the columns labeled *Delta*. For all tiers, the costs exceed the benefits for implementing the recommended regulation and policy. As a result, the cost of implementing only a BSR windshield on all tiers of newly TC'd Part 27 rotorcraft is calculated in Table 12 and the corresponding cost-benefit analysis shown in Table 13 reveals that only Part 27 Tier III becomes economically viable. For Part 27 Tiers I and II, the cost of implementing a BSR windshield on newly TC'd rotorcraft still exceed the benefits.

Table 10. Future Costs Associated with Recommended Policy (Task 1).

	Part 27 - Tier I, Windshield Only					Part 27 - Tier II, Windshield + Critical Equipment					Part 27 - Tier III, Windshield + Critical Equipment				
Year	New TC Aircraft mfg'd♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	New TC Aircraft mfg'd♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	New TC Aircraft mfg'd♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%
2016															
2017															
2018															
2019															
2020	11	103,000	22,500	345,452	263,544	9	217,313	56,214	750,918	572,872	8	266,607	64,000	757,300	577,741
2021	11	103,000	22,500	351,513	250,624	10	217,313	56,214	764,258	544,905	8	266,607	64,000	769,567	548,691
2022	11	103,000	22,500	357,726	238,368	10	217,313	56,214	777,931	518,369	8	266,607	64,000	782,141	521,174
2023	12	103,000	22,500	364,094	226,740	10	217,313	56,214	791,947	493,185	8	266,607	64,000	795,030	495,105
2024	19	103,000	22,500	531,194	309,160	10	217,313	56,214	806,313	469,281	8	266,607	64,000	808,240	470,403
2025	20	103,000	22,500	541,899	294,757	11	217,313	56,214	821,038	446,590	9	266,607	64,000	821,781	446,994
2026	20	103,000	22,500	552,872	281,052	11	217,313	56,214	836,131	425,047	9	266,607	64,000	835,660	424,807
2027	20	103,000	22,500	564,118	268,009	11	217,313	56,214	851,601	404,590	17	533,214	64,000	1,622,003	770,602
2028	26	103,000	22,500	693,808	308,059	12	217,313	56,214	867,459	385,162	17	533,214	64,000	1,649,223	732,275
2029	27	103,000	22,500	708,578	294,035	12	217,313	56,214	883,712	366,709	18	533,214	64,000	1,677,123	695,946
Total				**5,011,255**	**2,734,347**				**8,151,308**	**4,626,709**				**10,518,069**	**5,683,738**

♦ Assume 2.5% increase per year per FAA Aerospace Forecast & only aircraft manufactured under new TC are counted (normalized by total TC's within tier).

♦♦ Assumes new TC in shaded cells. Each TC amortized for 10 years.

Table 11. Cost-Benefit Analysis for Newly Type Certificated Part 27 Rotorcraft (Task 1).

Task 1 - Newly Type Certificated Part 27 Rotorcraft							
RBSWG Group	**Task 1 Policy**	**2016$**			**7% Present Value**		
		Benefit	**Cost**	**Delta**	**Benefit**	**Cost**	**Delta**
Part 27 - Tier I	1-3 occupants: § 27.631 same as Tier III but applied only to windshield	$ 737,955	$ 5,011,255	$ (4,273,300)	$ 365,843	$ 2,734,347	$ (2,368,504)
Part 27 - Tier II	4 to 6 occupants: only the windshield (with supporting structure) and flight critical equipment/ components forward of the main rotor mast including the main rotor blades and rotating components must be shown to comply.	$ 1,322,453	$ 8,151,308	$ (6,828,855)	$ 678,223	$ 4,626,709	$ (3,948,486)
Part 27 - Tier III	7-9 occupants: § 27.631 same as § 29.631 Category B (safe landing)	$ 7,177,478	$ 10,518,069	$ (3,340,592)	$ 3,526,885	$ 5,683,738	$ (2,156,853)

Table 12. Future Costs Associated with Recommended Policy (Task 1).

	Part 27 - Tier I, Windshield Only					Part 27 - Tier II, Windshield Only					Part 27 - Tier III, Windshield Only				
Year	New TC Aircraft mfg'd♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	New TC Aircraft mfg'd♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	New TC Aircraft mfg'd♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%
2016															
2017															
2018															
2019															
2020	11	103,000	22,500	345,452	263,544	9	163,625	27,500	424,664	556,648	8	187,692	36,214	465,350	355,013
2021	11	103,000	22,500	351,513	250,624	10	163,625	27,500	431,190	604,767	8	187,692	36,214	472,291	336,737
2022	11	103,000	22,500	357,726	238,368	10	163,625	27,500	437,880	657,139	8	187,692	36,214	479,406	319,449
2023	12	103,000	22,500	364,094	226,740	10	163,625	27,500	444,736	714,149	8	187,692	36,214	486,699	303,092
2024	19	103,000	22,500	531,194	309,160	10	163,625	27,500	451,764	776,214	8	187,692	36,214	494,174	287,614
2025	20	103,000	22,500	541,899	294,757	11	163,625	27,500	458,967	843,792	9	187,692	36,214	501,837	272,966
2026	20	103,000	22,500	552,872	281,052	11	163,625	27,500	466,351	917,382	9	187,692	36,214	509,690	259,101
2027	20	103,000	22,500	564,118	268,009	11	163,625	27,500	473,919	997,529	17	375,385	36,214	991,474	471,042
2028	26	103,000	22,500	693,808	308,059	12	163,625	27,500	481,676	1,084,827	17	375,385	36,214	1,006,876	447,065
2029	27	103,000	22,500	708,578	294,035	12	163,625	27,500	489,627	1,179,926	18	375,385	36,214	1,022,663	424,369
Total				**5,011,255**	**2,734,347**				**4,560,774**	**8,332,374**				**6,430,461**	**3,476,448**

♦ Assume 2.5% increase per year per FAA Aerospace Forecast & only aircraft manufactured under new TC are counted (normalized by total TC's within tier).

♦♦ Assumes new TC in shaded cells. Each TC amortized for 10 years.

Table 13. Cost-Benefit Analysis for Newly Type Certificated Part 27 Rotorcraft (Task 1).

Newly Type Certificated Part 27 Rotorcraft with Windshield Only							
RBSWG Group	Task 1 Policy	2016$			7% Present Value		
		Benefit	Cost	Delta	Benefit	Cost	Delta
Part 27 - Tier I	1-3 occupants: § 27.631 same as § 29.631 Category B (safe landing) but applied only to windshield	$ 737,955	$ 5,011,255	$ (4,273,300)	$ 365,843	$ 2,734,347	$ (2,368,504)
Part 27 - Tier II	4-6 occ: § 27.631 same as § 29.631 Category B (safe landing) but applied only to windshield	$ 1,322,453	$ 4,560,774	$ (3,238,321)	$ 678,223	$ 8,332,374	$ (7,654,151)
Part 27 - Tier III	7-9 occupants: § 27.631 same as § 29.631 Category B (safe landing) but applied only to windshield	$ 7,177,478	$ 6,430,461	$ 747,016	$ 3,526,885	$ 3,476,448	$ 50,437

Economic Assessment for Task 2 Proposed Part 27 Airworthiness Standards for Newly Manufactured Rotorcraft

This section provides the estimated cost and cost-benefit analysis that will result from implementing regulations and policies to be proposed under Task 2 for newly manufactured Part 27 rotorcraft. While non-traditional means will be recommended, this economic assessment presumes the means will be enacted; hence mandatory terminology (e.g., *must* or *required*) is used for this assessment. Only the airspeed-altitude limitation and helmet-visor means are assessed. These are listed below.

- Part 27 Tier I, 1-3 occupants – must implement one or more of the recommended non-traditional means of bird strike protection.

- Part 27 Tier II, 4-6 occupants – must meet the same requirements as Part 27 Tier III Newly Manufactured but applied only to the windshield, or alternatively, one or more of the recommended non-traditional means of bird strike protection are implemented.
- Part 27 Tier III, 7-9 occupants – must meet the same level of proposed bird strike airworthiness standard § 27.631 but only for the windshield and flight critical equipment/components forward of the main rotor mast that could prevent a SL. Alternatively, the bird strike requirement may be applied only to the windshield with implementation of one or more of the recommended non-traditional means of bird strike protection

Cost-Benefit Analysis for Newly Manufactured Part 27 Rotorcraft

The projected benefits for implementing the proposed bird strike airworthiness standards for newly manufactured Part 27 rotorcraft are shown in Table 14. The fleet wide annual benefit values come from Table B-3. The values for percent of fleet that are newly manufactured are calculated from Table B-2 by determining the number of newly manufactured rotorcraft within a tier in each year normalized by the total quantity of rotorcraft within the tier. The sum of newly TC'd in Table 9 and newly manufactured in Table 14 equal the annual fleet growth from Table B-2.

As discussed previously, in 2020 there is estimated to be a growth of 43 rotorcraft, bringing the Part 27 Tier I fleet to 1767 rotorcraft per Table B-2. Of these, 32 rotorcraft (75%) are estimated to be newly manufactured to existing TCs. Hence the column labeled *% of Fleet is New MFG* is the quotient of the newly manufactured rotorcraft to existing TCs (i.e., 32 rotorcraft for Tier I in 2020) and the tier fleet size (i.e., 1767 for Tier I in 2020). In 2020, this results in 1.81% of the Tier I fleet (32 ÷ 1767). The columns with *New MFG Annual Benefit* lists the product of the *Fleet Wide Annual Benefit* and percent of fleet that is newly manufactured.

Table 14. Future Benefits for Newly Manufactured Part 27 Rotorcraft (Task 2).

			Part 27 - Tier I					Part 27 - Tier II					Part 27 - Tier III				
Year	Fleet Growth Factor	Present Value at 7%	Fleet Wide Annual Benefit	% of Fleet Is New MFG	New MFG Annual Benefit	Benefits with 2.5% Growth	Present Value Benefits at 7%	Fleet Wide Annual Benefit	% of Fleet Is New MFG	New MFG Annual Benefit	Benefits with 2.5% Growth	Present Value Benefits at 7%	Fleet Wide Annual Benefit	% of Fleet Is New MFG	New MFG Annual Benefit	Benefits with 2.5% Growth	Present Value Benefits at 7%
2016	1.000	1.000	1,127,391					9,933,730					43,783,471				
2017	1.025	1.070	1,127,391					9,933,730					43,783,471				
2018	1.051	1.145	1,127,391					9,933,730					43,783,471				
2019	1.077	1.225	1,127,391					9,933,730					43,783,471				
2020	1.104	1.311	1,127,391	1.81%	20,414	22,534	17,191	9,933,730	2.23%	221,211	244,176	186,281	43,783,471	2.25%	984,926	1,087,174	829,400
2021	1.131	1.403	1,127,391	1.82%	20,539	23,238	16,568	9,933,730	2.24%	222,041	251,219	179,116	43,783,471	2.26%	990,022	1,120,119	798,629
2022	1.160	1.501	1,127,391	1.78%	20,038	23,238	15,484	9,933,730	2.22%	220,675	255,915	170,527	43,783,471	2.25%	984,814	1,142,082	761,017
2023	1.189	1.606	1,127,391	1.79%	20,142	23,942	14,910	9,933,730	2.23%	221,218	262,959	163,757	43,783,471	2.26%	988,509	1,175,027	731,748
2024	1.218	1.718	1,127,391	1.44%	16,183	19,717	11,475	9,933,730	2.23%	221,603	270,002	157,144	43,783,471	2.26%	991,438	1,207,971	703,050
2025	1.249	1.838	1,127,391	1.45%	16,352	20,421	11,108	9,933,730	2.23%	221,838	277,046	150,694	43,783,471	2.25%	984,843	1,229,934	669,003
2026	1.280	1.967	1,127,391	1.42%	15,953	20,421	10,381	9,933,730	2.23%	221,930	284,089	144,417	43,783,471	2.25%	986,559	1,262,879	641,984
2027	1.312	2.105	1,127,391	1.43%	16,101	21,125	10,037	9,933,730	2.23%	221,885	291,133	138,315	43,783,471	2.10%	920,649	1,207,971	573,898
2028	1.345	2.252	1,127,391	1.21%	13,614	18,309	8,129	9,933,730	2.23%	221,711	298,176	132,394	43,783,471	2.11%	922,690	1,240,916	550,982
2029	1.379	2.410	1,127,391	1.18%	13,281	18,309	7,597	9,933,730	2.23%	221,413	305,220	126,655	43,783,471	2.11%	924,085	1,273,861	528,607
	Total					**211,254**	**122,881**				**2,739,934**	**1,549,300**				**11,947,935**	**6,788,318**

The recommended non-traditional means proposed in Task 6 include airspeed-altitude operational envelope and wearing helmet-visor PPE by at least the Part 27 pilot. The airspeed-altitude limitation is estimated to increase operational costs by 30% in direct proportion to the 30% increase in flight hours as discussed in the Economic Assessment for Task 6 section. These costs are based on estimated annual fleet flight hours (c.f. Table 30) and used to project operational costs derived from Conklin and de Decker[13].

Each helmet-visor costs approximately $2,000 in 2017 USD (which is $2,450 in 2020 inflated at 7% per annum). Only one pilot is required for Part 27 rotorcraft; however, each pilot should have his/her own helmet individually sized. Since there are generally two to four pilots on staff for each helicopter, the cost for a helmet and visor is multiplied by three (3). These costs are developed in Table 15 – Table 17.

Implementing the helmet and visor in conjunction with a BSR windshield for Part 27 Tier III at first glance appears to be redundant protection for the crew. However, recall that as shown in Table 17, the helmet and visor costs recur annually beginning in 2020 until the BSR windshield is implemented in 2025 (an early assumed date to bring the costs within the 10-year evaluation period). Helmet and visor costs cease with implementation of the BSR windshield.

For Part 27 Tiers I and II, the airspeed-altitude limitation costs continue annually since for these tiers this option presumes a BSR windshield will not be implemented. For Part 27 Tier III, the cost of implementing airspeed-altitude limitations continues annually after implementing the BSR windshield in 2025 since this non-traditional means remains a substitute for protecting critical components forward of the main rotor mast.

Table 15. Future Costs Associated with Recommended Policy for Part 27 Tier I (Task 2).

	Part 27 - Tier I, Windshield					Part 27 - Tier I, Pilot Helmet-Visor					Part 27 - Tier I, Airspeed Restriction				
Year	New MFG Fleet Growth♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	New MFG Fleet Growth♦	Non-Recurring Cost	Recurring Cost	Costs	Present Value Costs at 7%	New MFG Fleet Growth♦	Non-Recurring Cost	Recurring Cost	Costs	Present Value Costs at 7%
2016															
2017															
2018															
2019															
2020	32	309,000	22,500	1,029,000	785,019	32		7,350	235,208	179,439	32		14,673	469,524	358,198
2021	33	309,000	22,500	1,051,500	749,705	33		7,865	259,538	185,047	33		14,673	484,197	345,226
2022	33	309,000	22,500	1,051,500	700,659	33		8,415	277,705	185,047	33		14,673	484,197	322,641
2023	34	309,000	22,500	1,074,000	668,833	34		9,004	306,149	190,654	34		14,673	498,869	310,671
2024	28	309,000	22,500	939,000	546,507	28		9,635	269,771	157,009	28		14,673	410,834	239,109
2025	29	309,000	22,500	961,500	522,992	29		10,309	298,964	162,617	29		14,673	425,506	231,447
2026	29	309,000	22,500	961,500	488,778	29		11,031	319,892	162,617	29		14,673	425,506	216,306
2027	30	309,000	22,500	984,000	467,491	30		11,803	354,087	168,224	30		14,673	440,179	209,126
2028	26	309,000	22,500	894,000	396,947	26		12,629	328,357	145,794	26		14,673	381,488	169,385
2029	26	309,000	22,500	894,000	370,978	26		13,513	351,342	145,794	26		14,673	381,488	158,304
Total				**9,840,000**	**5,697,909**				**3,001,014**	**1,682,243**				**4,401,789**	**2,560,412**

♦ Assume 2.5% increase per year per FAA Aerospace Forecast & only aircraft manufactured under new TC are counted (normalized by total TC's within tier).

♦♦ NR costs incurred in 2020 are amortized for 10 years.

[13] https://www.conklindd.com/cdalibrary/accostsummary.aspx

Table 16. Future Costs Associated with Recommended Policy for Part 27 Tier II (Task 2).

	Part 27 - Tier II, Windshield					Part 27 - Tier II, Pilot Helmet-Visor					Part 27 - Tier II, Airspeed Restriction				
Year	New MFG Fleet Growth♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	New MFG Fleet Growth♦	Non-Recurring Cost	Recurring Cost	Costs	Present Value Costs at 7%	Cumu-lative Fleet Size♦	Non-Recurring Cost	Recurring Cost	Costs	Present Value Costs at 7%
2016															
2017															
2018															
2019															
2020	104	1,799,875	27,500	4,659,875	3,554,996	104		7,350	764,427	583,178	104		60,761	6,319,184	4,820,875
2021	107	1,799,875	27,500	4,742,375	3,381,248	107		7,865	841,531	600,000	211		60,761	12,820,652	9,140,948
2022	109	1,799,875	27,500	4,797,375	3,196,694	109		8,415	917,269	611,215	320		60,761	19,443,643	12,956,120
2023	112	1,799,875	27,500	4,879,875	3,038,941	112		9,004	1,008,491	628,037	432		60,761	26,248,918	16,346,507
2024	115	1,799,875	27,500	4,962,375	2,888,147	115		9,635	1,107,989	644,860	547		60,761	33,236,477	19,343,932
2025	118	1,799,875	27,500	5,044,875	2,744,078	118		10,309	1,216,476	661,682	665		60,761	40,406,321	21,978,361
2026	121	1,799,875	27,500	5,127,375	2,606,497	121		11,031	1,334,721	678,505	786		60,761	47,758,448	24,277,973
2027	124	1,799,875	27,500	5,209,875	2,475,174	124		11,803	1,463,561	695,327	910		60,761	55,292,860	26,269,239
2028	127	1,799,875	27,500	5,292,375	2,349,878	127		12,629	1,603,897	712,150	1,037		60,761	63,009,556	27,976,996
2029	130	1,799,875	27,500	5,374,875	2,230,382	130		13,513	1,756,709	728,972	1,167		60,761	70,908,536	29,424,521
Total				**50,091,250**	**28,466,035**				**12,015,071**	**6,543,925**				**375,444,594**	**192,535,474**

♦ Assume 2.5% increase per year per FAA Aerospace Forecast

♦♦ NR costs incurred in 2020 are amortized for 10 years.

Table 17. Future Costs Associated with Recommendations for Part 27 Tier III (Task 2).

	Part 27 - Tier III, Windshield + Critical Equipment					Part 27 - Tier III, Windshield + Helmet-Visor					Part 27 - Tier III, Windshield + Airspeed Restriction				
Year	New MFG Fleet Growth♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	New MFG Fleet Growth♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	Cumu-lative Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%
2016															
2017															
2018															
2019															
2020	99	3,465,893	64,000	9,801,893	7,477,817	99		4,410	436,605	333,084	99		90,619	8,971,276	6,844,144
2021	102	3,465,893	64,000	9,993,893	7,125,507	102		4,719	481,324	343,178	201		90,619	18,214,409	12,986,622
2022	104	3,465,893	64,000	10,121,893	6,744,645	104		5,049	525,115	349,907	305		90,619	27,638,780	18,416,886
2023	107	3,465,893	64,000	10,313,893	6,422,974	107		5,403	578,081	360,000	412		90,619	37,335,008	23,250,367
2024	110	3,465,893	64,000	10,505,893	6,114,525	110		5,781	635,889	370,093	522		90,619	47,303,093	27,530,831
2025	112	3,465,893	64,000	10,633,893	5,784,133	112	2,440,000	36,214	6,496,000	3,533,394	634	2,440,000	90,619	59,892,415	32,577,505
2026	115	3,465,893	64,000	10,825,893	5,503,335	115	2,440,000	36,214	6,604,643	3,357,466	749	2,440,000	90,619	70,313,594	35,743,866
2027	110	3,465,893	64,000	10,505,893	4,991,274	110	2,440,000	36,214	6,423,571	3,051,793	859	2,440,000	90,619	80,281,679	38,141,247
2028	113	3,465,893	64,000	10,697,893	4,749,992	113	2,440,000	36,214	6,532,214	2,900,381	972	2,440,000	90,619	90,521,621	40,192,682
2029	116	3,465,893	64,000	10,889,893	4,518,918	116	2,440,000	36,214	6,640,857	2,755,720	1,088	2,440,000	90,619	101,033,419	41,925,277
Total				**104,290,929**	**59,433,121**				**35,354,301**	**17,355,014**				**541,505,294**	**277,609,427**

♦ Assume 2.5% increase per year per FAA Aerospace Forecast

♦♦ NR costs incurred in 2020 are amortized for 10 years.

In Table 18, the costs and benefits are compared for each of the tiers evaluating both the traditional and non-traditional means. The cost exceeds the benefits for installing BSR windshields for all tiers. In addition, the costs exceed benefits for all tiers for implementing helmet and visor PPE and for implementing airspeed-altitude limitation.

Table 18. Cost-Benefit Analysis for Newly Manufactured Part 27 Rotorcraft (Task 2).

Task 2 - Newly Manufactured Part 27 Rotorcraft							
RBSWG Group	Task 2 Policy	2016$			7% Present Value		
		Benefit	Cost	Delta	Benefit	Cost	Delta
Part 27 - Tier I	1-3 occupants must meet the same level of proposed bird strike airworthiness standard § 27.631 but only for the windshield	$ 211,254	$ 9,840,000	$ (9,628,746)	$ 122,881	$ 5,697,909	$ (5,575,028)
Part 27 - Tier I	... or alternatively, 1-3 occupants, pilot wears a helmet-visor.	$ 211,254	$ 3,001,014	$ (2,789,760)	$ 122,881	$ 1,682,243	$ (1,559,362)
Part 27 - Tier I	... or alternatively, 1-3 occupants, airspeed-altitude restriction are implemented.	$ 211,254	$ 4,401,789	$ (4,190,535)	$ 122,881	$ 2,560,412	$ (2,437,531)
Part 27 - Tier II	4-6 occupants must meet the same level of proposed bird strike airworthiness standard § 27.631 but only for the windshield	$ 2,739,934	$ 50,091,250	$ (47,351,316)	$ 1,549,300	$ 28,466,035	$ (26,916,735)
Part 27 - Tier II	... or alternatively, 4-6 occupants, pilot wears a helmet-visor.	$ 2,739,934	$ 12,015,071	$ (9,275,137)	$ 1,549,300	$ 6,543,925	$ (4,994,625)
Part 27 - Tier II	... or alternatively, 4-6 occupants, airspeed-altitude restriction are implemented.	$ 2,739,934	$ 375,444,594	$ (372,704,659)	$ 1,549,300	$ 192,535,474	$ (190,986,174)
Part 27 - Tier III	7-9 occupants must meet the same level of proposed bird strike airworthiness standard § 27.631 but only for the windshield and flight critical equipment/components forward of the main rotor mast that could prevent a safe landing,	$ 11,947,935	$ 104,290,929	$ (92,342,994)	$ 6,788,318	$ 59,433,121	$ (52,644,803)
Part 27 - Tier III	... or alternatively, 7-9 occupants, the bird strike requirement may be applied only to the windshield with the pilot wearing a helmet-visor.	$ 11,947,935	$ 35,354,301	$ (23,406,367)	$ 6,788,318	$ 17,355,014	$ (10,566,696)
Part 27 - Tier III	... or alternatively, 7-9 occupants, the bird strike requirement may be applied only to the windshield with implementation of airspeed-altitude restriction.	$ 11,947,935	$ 541,505,294	$ (529,557,359)	$ 6,788,318	$ 277,609,427	$ (270,821,108)

Economic Assessment for Task 3 Proposed Retention of Existing 14 CFR § 29.631 Bird Strike Regulation

Because the RBSWG does not recommend a change in 14 CFR § 29.631, correspondingly there is no associated cost and hence no cost-benefit analysis.

Economic Assessment for Task 4 Proposed Regulation for Newly Manufactured Part 29 Rotorcraft

This section provides the estimated cost and cost-benefit analysis that will result from implementing regulations and policies to be proposed under Task 4 for newly manufactured Part 29 rotorcraft. This change is not applicable to Part 29.631 so this grouping is not listed. While non-traditional means will be recommended, this economic assessment presumes the means will be enacted; hence mandatory terminology (e.g., *must* or *required*) is used for this assessment. Only the airspeed-altitude limitation and helmet-visor means are assessed. These are listed below.

- Part 29 Tier I, 10-15 occupants – must meet the requirements of § 29.631 but applied only to the windshield and flight critical equipment/components forward of the main rotor mast that could prevent CSFL for Category A or a SL for Category B rotorcraft. Alternatively, only the windshield must be shown to comply with § 29.631 if one or more of the recommended non-traditional means of bird strike protection is implemented.

- Part 29 Tier II, 16 or more occupants – must meet 14 CFR § 29.631 or alternatively, only the windshield and flight critical equipment/components forward of the main rotor mast that could prevent CSFL for Category A or a SL for Category B rotorcraft must be shown to comply with § 29.631 if one or more of the recommended non-traditional means of bird strike protection is implemented.

Cost-Benefit Analysis Newly Manufactured Part 29 Rotorcraft

The projected benefits for implementing the proposed bird strike airworthiness standards for newly manufactured Part 29 rotorcraft are shown in Table 19 with benefits beginning in 2020. The fleet wide annual benefit values come from Table B-4. The values for percent of fleet that are newly manufactured are calculated from Table B-4 by determining the number of newly manufactured rotorcraft within a tier in each year normalized by the fleet quantity within the tier. For example, for Part 29 Tier I in 2020 there are estimated to be 19 newly manufactured rotorcraft adding to a fleet of 791 per Table B-4. Hence for 2020 Tier I, the percent of newly manufactured of fleet is 2.44% (19 ÷ 791, note, these values are real numbers, not integers, that are calculated based on the 2.5% assumed annual growth[14].). The columns with *New MFG Annual Benefit* lists the product of the fleet wide annual benefit and percent of fleet that is newly manufactured.

Table 19. Benefit Analysis for Newly Manufactured Part 29 Rotorcraft (Task 4).

			Part 29 - Tier I					Part 29 - Tier II				
Year	Fleet Growth Factor	Present Value at 7%	Fleet Annual Benefit	% of Fleet Is New MFG	New MFG Annual Benefit	Benefits with 2.5% Growth	Value Benefits at 7%	Fleet Annual Benefit	% of Fleet Is New MFG	New MFG Annual Benefit	Benefits with 2.5% Growth	Value Benefits at 7%
2016	1.000	1.000	48,189,608					31,445,167				
2017	1.025	1.070	48,189,608					31,445,167				
2018	1.051	1.145	48,189,608					31,445,167				
2019	1.077	1.225	48,189,608					31,445,167				
2020	1.104	1.311	48,189,608	2.44%	1,175,356	1,297,373	989,760	31,445,167	2.44%	766,955	846,575	645,848
2021	1.131	1.403	48,189,608	4.82%	2,322,045	2,627,181	1,873,144	31,445,167	4.82%	1,515,204	1,714,315	1,222,283
2022	1.160	1.501	48,189,608	7.14%	3,440,766	3,990,234	2,658,862	31,445,167	7.14%	2,245,203	2,603,748	1,734,987
2023	1.189	1.606	48,189,608	9.40%	4,532,202	5,387,363	3,354,979	31,445,167	9.40%	2,957,398	3,515,416	2,189,225
2024	1.218	1.718	48,189,608	11.61%	5,597,016	6,819,421	3,968,965	31,445,167	11.61%	3,652,221	4,449,877	2,589,869
2025	1.249	1.838	48,189,608	13.77%	6,635,860	8,287,280	4,507,731	31,445,167	13.77%	4,330,098	5,407,699	2,941,430
2026	1.280	1.967	48,189,608	15.87%	7,649,366	9,791,835	4,977,673	31,445,167	15.87%	4,991,441	6,389,467	3,248,081
2027	1.312	2.105	48,189,608	17.93%	8,638,153	11,334,005	5,384,704	31,445,167	17.93%	5,636,654	7,395,778	3,513,681
2028	1.345	2.252	48,189,608	19.93%	9,602,822	12,914,728	5,734,294	31,445,167	19.93%	6,266,130	8,427,248	3,741,799
2029	1.379	2.410	48,189,608	21.88%	10,543,963	14,534,970	6,031,496	31,445,167	21.88%	6,880,253	9,484,504	3,935,732
	Total					**76,984,392**	**39,481,607**				**50,234,628**	**25,762,934**

The recommended non-traditional means proposed in Task 6 include airspeed-altitude limitations and wearing helmet-visor by at least the flight crew. As discussed under the Economic Assessment for Task 2 section, the airspeed-altitude limitation is estimated to increase operational costs by 30%

14 $A\ 2.5\%\ growth\ rate\ viewed\ from\ the\ current\ year\ is\ 2.44\%\ less\ than\ the\ subsequent\ year, i.e., \frac{1}{1.025} = 97.56\%$

and the cost of each helmet-visor is approximately $2,000 in 2017 USD (which is $2,450 in 2020 escalated at 7% per annum). Two flight crew are assumed to be required for Part 29 rotorcraft. Since there are generally three to four pilots on staff for each helicopter, the cost for a helmet and visor is multiplied by four (4). This cost is included in Table 20 and Table 21 beginning in 2020. In addition, the costs for BSR windshield and protection of critical equipment are assumed to be implemented in 2027 (multiplied by the delta fleet size) within this analysis. As summarized in Table 20 and Table 21, the costs associated with airspeed-altitude limitations continue (being multiplied by the cumulative fleet size) since this non-traditional means continues to provide protection for the critical equipment that remain unprotected. However, the cost of helmets and visors discontinue in 2027 when the BSR windshield is implemented, since the PPE combined with BSR windshields is redundant. All non-recurring costs incurred are presumed to be amortized over 10 years.

Table 20. Future Costs for Newly Manufactured Part 29 Tier I Rotorcraft (Task 4).

	Part 29 - Tier I, Windshield + Critical Equipment					Part 29 - Tier I, Windshield + Helmet-Visor					Part 29 - Tier I, Windshield + Airspeed Restriction					
Year	Delta Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	Delta Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	Cumu-lative Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Operational Cost	Costs	Present Value Costs at 7%
2016																
2017																
2018																
2019																
2020	19	1,634,667	113,750	3,795,917	2,895,887	19		9,800	186,207	142,056	19			173,182	3,290,455	2,510,272
2021	19	1,634,667	113,750	3,795,917	2,706,436	19		10,486	199,241	142,056	38			173,182	6,580,910	4,692,098
2022	20	1,634,667	113,750	3,909,667	2,605,176	20		11,220	224,408	149,533	58			173,182	10,044,546	6,693,105
2023	20	1,634,667	113,750	3,909,667	2,434,744	20		12,006	240,117	149,533	78			173,182	13,508,183	8,412,217
2024	21	1,634,667	113,750	4,023,417	2,341,665	21		12,846	269,771	157,009	99			173,182	17,145,002	9,978,547
2025	21	1,634,667	113,750	4,023,417	2,188,472	21		13,745	288,655	157,009	120			173,182	20,781,820	11,303,933
2026	22	1,634,667	113,750	4,137,167	2,103,126	22		14,708	323,569	164,486	142			173,182	24,591,820	12,501,234
2027	22	1,634,667	113,750	4,137,167	1,965,538	22	1,230,000	64,625	2,651,750	1,259,827	164	1,230,000	64,625	173,182	31,053,571	14,753,328
2028	23	1,634,667	113,750	4,250,917	1,887,458	23	1,230,000	64,625	2,716,375	1,206,103	187	1,230,000	64,625	173,182	35,101,378	15,585,432
2029	24	1,634,667	113,750	4,364,667	1,811,181	24	1,230,000	64,625	2,781,000	1,154,016	211	1,230,000	64,625	173,182	39,322,367	16,317,384
Total				**40,347,917**	**22,939,683**				**9,881,093**	**4,681,629**					**201,420,051**	**102,747,551**

♦ Assume 2.5% increase per year per FAA Aerospace Forecast

♦♦ NR costs incurred are amortized for 10 years.

Table 21. Future Costs for Newly Manufactured Part 29 Tier II Rotorcraft (Task 4).

	Part 29 - Tier II, Windshield + Critical Equipment					Part 29 - Tier II, Windshield + Helmet-Visor					Part 29 - Tier II, Windshield + Airspeed Restriction					
Year	Delta Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	Delta Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	Cumu-lative Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Operational Cost	Costs	Present Value Costs at 7%
2016																
2017																
2018																
2019																
2020	1	720,000	132,500	852,500	650,368	1		9,800	9,800	7,477	1			221,311	221,311	168,837
2021	1	720,000	132,500	852,500	607,821	1		10,486	10,486	7,477	2			221,311	442,622	315,584
2022	1	720,000	132,500	852,500	568,057	1		11,220	11,220	7,477	3			221,311	663,933	442,407
2023	1	720,000	132,500	852,500	530,894	1		12,006	12,006	7,477	4			221,311	885,245	551,286
2024	1	720,000	132,500	852,500	496,163	1		12,846	12,846	7,477	5			221,311	1,106,556	644,026
2025	1	720,000	132,500	852,500	463,704	1		13,745	13,745	7,477	6			221,311	1,327,867	722,272
2026	1	720,000	132,500	852,500	433,368	1		14,708	14,708	7,477	7			221,311	1,549,178	787,524
2027	1	720,000	132,500	852,500	405,017	1	600,000	71,667	671,667	319,104	8	600,000	71,667	221,311	2,442,156	1,160,251
2028	1	720,000	132,500	852,500	378,520	1	600,000	71,667	671,667	298,228	9	600,000	71,667	221,311	2,663,467	1,182,611
2029	1	720,000	132,500	852,500	353,757	1	600,000	71,667	671,667	278,718	10	600,000	71,667	221,311	2,884,778	1,197,080
Total				**8,525,000**	**4,887,668**				**2,099,812**	**948,386**					**14,187,113**	**7,171,877**

♦ Assume 2.5% increase per year per FAA Aerospace Forecast

♦♦ NR costs incurred are amortized for 10 years.

Table 22 provides the cost-benefits analysis for both tiers evaluating the traditional and non-traditional means. The costs are less than the benefits for both tiers with the BSR windshield and protected critical equipment and for the PPE helmets and visors. However, the costs exceed the benefits with the airspeed-altitude limitation for Tier I, while showing to be cost effective for Tier II. The recommended solution is implementation of the traditional means of BSR windshield and protection of critical equipment for both tiers.

Table 22. Cost-Benefit Analysis for Newly Manufactured Part 29 Rotorcraft (Task 4).

Task 4 - Newly Manufactured Part 29 Rotorcraft							
RBSWG Group	Task 4 Policy	2016$			7% Present Value		
		Benefit	Cost	Delta	Benefit	Cost	Delta
Part 29 - Tier I	10-15 occupants must meet the requirements of § 29.631 but applied only to the windshield and flight critical equipment/components forward of the main rotor mast that could prevent continued safe flight and landing for Category A or a safe landing for Category B rotorcraft.	$ 76,984,392	$ 40,347,917	$ 36,636,475	$ 39,481,607	$ 22,939,683	$ 16,541,924
Part 29 - Tier I	Alterantively, 10-15 occupants, only the windshield must be shown to comply with § 29.631 with the the pilot and copilot wearing helmet-visor.	$ 76,984,392	$ 9,881,093	$ 67,103,298	$ 39,481,607	$ 4,681,629	$ 34,799,978
Part 29 - Tier I	Alterantively, 10-15 occupants, only the windshield must be shown to comply with § 29.631 if airspeed-altitude restrictions are implemented.	$ 76,984,392	$ 201,420,051	$ (124,435,660)	$ 39,481,607	$ 102,747,551	$ (63,265,944)
Part 29 - Tier II	16 or more occupants must meet 14 CFR § 29.631	$ 50,234,628	$ 8,525,000	$ 41,709,628	$ 25,762,934	$ 4,887,668	$ 20,875,267
Part 29 - Tier II	Alternatively, 16 or more occupants, only the windshield and flight critical equipment / components forward of the main rotor mast that could prevent continued safe flight and landing for Category A or a safe landing for Category B rotorcraft must be shown to comply with § 29.631 with the pilot and copilot wearing helmet-visor.	$ 50,234,628	$ 2,099,812	$ 48,134,815	$ 25,762,934	$ 948,386	$ 24,814,548
Part 29 - Tier II	Alternatively, 16 or more occupants, only the windshield and flight critical equipment / components forward of the main rotor mast that could prevent continued safe flight and landing for Category A or a safe landing for Category B rotorcraft must be shown to comply with § 29.631 if airspeed-altitude restrictions are implemented.	$ 50,234,628	$ 14,187,113	$ 36,047,514	$ 25,762,934	$ 7,171,877	$ 18,591,058

Economic Assessment for Task 5 Proposed Bird Strike Airworthiness Standards for Existing Operating Rotorcraft

This section provides the estimated cost and cost-benefit analysis that will result from implementing regulations and policies to be proposed under Task 5 for existing Parts 27 and 29 rotorcraft. These are listed below. While non-traditional means will be recommended, this economic assessment presumes the means will be enacted; hence mandatory terminology (e.g., *must* or *required*) is used for this assessment. Only the airspeed-altitude limitation and helmet-visor means are assessed.

- Part 27 Tier I, 1-3 occupants – must implement one or more of the recommended non-traditional means of bird strike protection.
- Part 27 Tier II, 4-6 occupants – must implement one or more of the recommended non-traditional means of bird strike protection.
- Part 27 Tier III, 7-9 occupants – must meet the same level of proposed bird strike protection in § 27.631 (proposed in Task 1 for newly type certificated normal category rotorcraft) but only for the windshield plus implementation of one or more of the recommended non-traditional means of bird strike protection.
- Part 29 Tier I, 10-15 occupants – must meet the requirements of § 29.631 applied only to the windshield plus one or more of the recommended non-traditional means of bird strike protection must be implemented.
- Part 29 Tier II, 16 or more occupants – the windshield and flight critical equipment/components forward of the main rotor mast that could prevent CSFL for Category A or a SL for Category B rotorcraft must be shown to comply with § 29.631. Alternatively, only the windshield must be shown to comply with § 29.631 if one or more of the recommended non-traditional means of bird strike protection is implemented.

<u>Cost-Benefit Analysis for Existing Operating Parts 27 and 29 Rotorcraft</u>

The recommended implementation date for the traditional means such as BSR windshield is January 1st, 2030. However, to capture the benefits and costs within the 10-year assessment window in this economic analysis, the costs are incurred in 2020 with benefits continuing thereafter. The evaluation for non-traditional means proposed in Task 6, which includes airspeed-altitude limitations and wearing helmet-visor by at least the flight crew, is also assumed to begin in 2020 for this economic assessment. The fleet wide annual benefit values come from Table B-3 and Table B-4.

Table 23. Future Benefits for Existing Parts 27 and 29 Rotorcraft (Task 5).

			Part 27 - Tier I			Part 27 - Tier II			Part 27 - Tier III			Part 29 - Tier I			Part 29 - Tier II		
Year	Growth Factor	Present Value Benefits at 7%	Annual Benefit	Benefits with 2.5% Growth	Present Value Benefits at 7%	Annual Benefit	Benefits with 2.5% Growth	Present Value Benefits at 7%	Annual Benefit	Benefits with 2.5% Growth	Present Value Benefits at 7%	Annual Benefit	Benefits with 2.5% Growth	Present Value Benefits at 7%	Annual Benefit	Benefits with 2.5% Growth	Present Value Benefits at 7%
2016	1.000	1.000															
2017	1.025	1.070															
2018	1.051	1.145															
2019	1.077	1.225															
2020	1.104	1.311	1,127,391	1,244,428	949,368	9,933,730	10,964,979	8,365,130	43,783,471	48,328,760	36,869,779	48,189,608	53,192,311	40,580,159	31,445,167	34,709,580	26,479,773
2021	1.131	1.403	1,127,391	1,275,539	909,442	9,933,730	11,239,103	8,013,325	43,783,471	49,536,979	35,319,181	48,189,608	54,522,119	38,873,517	31,445,167	35,577,320	25,366,137
2022	1.160	1.501	1,127,391	1,307,428	871,194	9,933,730	11,520,081	7,676,316	43,783,471	50,775,403	33,833,795	48,189,608	55,885,172	37,238,650	31,445,167	36,466,753	24,299,337
2023	1.189	1.606	1,127,391	1,340,113	834,555	9,933,730	11,808,083	7,353,481	43,783,471	52,044,788	32,410,878	48,189,608	57,282,301	35,672,538	31,445,167	37,378,422	23,277,402
2024	1.218	1.718	1,127,391	1,373,616	799,457	9,933,730	12,103,285	7,044,222	43,783,471	53,345,908	31,047,804	48,189,608	58,714,358	34,172,291	31,445,167	38,312,882	22,298,446
2025	1.249	1.838	1,127,391	1,407,957	765,835	9,933,730	12,405,867	6,747,970	43,783,471	54,679,556	29,742,055	48,189,608	60,182,217	32,735,139	31,445,167	39,270,704	21,360,661
2026	1.280	1.967	1,127,391	1,443,155	733,627	9,933,730	12,716,014	6,464,177	43,783,471	56,046,544	28,491,221	48,189,608	61,686,773	31,358,427	31,445,167	40,252,472	20,462,316
2027	1.312	2.105	1,127,391	1,479,234	702,774	9,933,730	13,033,914	6,192,319	43,783,471	57,447,708	27,292,992	48,189,608	63,228,942	30,039,615	31,445,167	41,258,784	19,601,751
2028	1.345	2.252	1,127,391	1,516,215	673,218	9,933,730	13,359,762	5,931,894	43,783,471	58,883,901	26,145,156	48,189,608	64,809,666	28,776,267	31,445,167	42,290,253	18,777,378
2029	1.379	2.410	1,127,391	1,554,121	644,905	9,933,730	13,693,756	5,682,422	43,783,471	60,355,998	25,045,593	48,189,608	66,429,907	27,566,050	31,445,167	43,347,510	17,987,675
	Total			**13,941,807**	**7,884,375**		**122,844,843**	**69,471,255**		**541,445,544**	**306,198,456**		**595,933,766**	**337,012,653**		**388,864,680**	**219,910,877**

The airspeed-altitude limitation is estimated to result in 30% increased operational cost as discussed in the next section, while each helmet-visor cost approximately $2,000 in 2017 USD (which is $2,450 in 2020 escalated at 7% per annum). If this non-traditional approach is selected, only one pilot would be expected to wear a helmet-visor for Part 27 rotorcraft. Two flight crew are assumed to be required for Part 29 rotorcraft and both would be expected to wear a helmet-visor if this non-traditional approach is selected. Helmets must be fitted to each pilot. Since most pilot staffs have approximately three pilots for each Part 27 helicopter and four pilots for each Part 29 helicopter, the helmet-visor costs are multiplied accordingly. The helmet-visor approach is a one-time cost multiplied by the existing fleet and incurred in 2020. These costs are summarized in Table 24 through Table 28.

Table 24. Future Costs for Retrofitting Part 27 Tier I Rotorcraft (Task 5).

	Part 27 - Tier I, Windshield					Part 27 - Tier I, Pilot Helmet-Visor					Part 27 - Tier I, Airspeed Restriction				
Year	Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	Fleet Size♦	Non-Recurring Cost	Recurring Cost	Costs	Present Value Costs at 7%	Fleet Size♦	Non-Recurring Cost	Recurring Cost	Costs	Present Value Costs at 7%
2016	1,601														
2017	1,641														
2018	1,682														
2019	1,724														
2020	1,767	309,000	48,000	85,134,813	64,948,941	1,767		7,350	12,989,409	9,909,558	1,767		105,203	185,914,764	141,833,483
2021		309,000		309,000	220,313				0	0	1,767		105,203	185,914,764	132,554,657
2022		309,000		309,000	205,900				0	0	1,767		105,203	185,914,764	123,882,857
2023		309,000		309,000	192,430				0	0	1,767		105,203	185,914,764	115,778,371
2024		309,000		309,000	179,841				0	0	1,767		105,203	185,914,764	108,204,085
2025		309,000		309,000	168,076				0	0	1,767		105,203	185,914,764	101,125,313
2026		309,000		309,000	157,080				0	0	1,767		105,203	185,914,764	94,509,638
2027		309,000		309,000	146,804				0	0	1,767		105,203	185,914,764	88,326,765
2028		309,000		309,000	137,200				0	0	1,767		105,203	185,914,764	82,548,378
2029		309,000		309,000	128,224				0	0	1,767		105,203	185,914,764	77,148,017
Total				**87,915,813**	**66,484,807**				**12,989,409**	**9,909,558**				**1,859,147,636**	**1,065,911,566**

♦ Assume 2.5% increase per year per FAA Aerospace Forecast

♦♦ NR costs incurred in 2020 are amortized for 10 years.

Table 25. Future Costs for Retrofitting Part 27 Tier II Rotorcraft (Task 5).

	Part 27 - Tier II, Windshield					Part 27 - Tier II, Pilot Helmet-Visor					Part 27 - Tier II, Airspeed Restriction				
Year	Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	Fleet Size♦	Non-Recurring Cost	Recurring Cost	Costs	Present Value Costs at 7%	Fleet Size♦	Non-Recurring Cost	Operational Cost	Costs	Present Value Costs at 7%
2016	4,231										4,231				
2017	4,337										4,337				
2018	4,445										4,445				
2019	4,556										4,556				
2020	4,670	1,799,875	53,500	251,657,305	191,988,153	4,670		7,350	34,327,413	26,188,219	4,670		228,964	1,069,316,200	872,880,544
2021		1,799,875		1,799,875	1,283,286				0	0	4,670		228,964	1,069,316,200	815,776,209
2022		1,799,875		1,799,875	1,199,333				0	0	4,670		228,964	1,069,316,200	762,407,672
2023		1,799,875		1,799,875	1,120,872				0	0	4,670		228,964	1,069,316,200	712,530,535
2024		1,799,875		1,799,875	1,047,544				0	0	4,670		228,964	1,069,316,200	665,916,388
2025		1,799,875		1,799,875	979,013				0	0	4,670		228,964	1,069,316,200	622,351,764
2026		1,799,875		1,799,875	914,965				0	0	4,670		228,964	1,069,316,200	581,637,163
2027		1,799,875		1,799,875	855,108				0	0	4,670		228,964	1,069,316,200	543,586,133
2028		1,799,875		1,799,875	799,166				0	0	4,670		228,964	1,069,316,200	508,024,424
2029		1,799,875		1,799,875	746,884				0	0	4,670		228,964	1,069,316,200	474,789,181
Total				**267,856,180**	**200,934,323**				**34,327,413**	**26,188,219**				**10,693,162,000**	**6,559,900,012**

♦ Assume 2.5% increase per year per FAA Aerospace Forecast

♦♦ NR costs incurred in 2020 are amortized for 10 years.

Table 26. Future Costs for Retrofitting Part 27 Tier III Rotorcraft (Task 5).

	Part 27 - Tier III, Windshield				
Year	Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%
2016	3,987				
2017	4,087				
2018	4,189				
2019	4,294				
2020	4,401	2,440,000	48,571	216,198,097	164,936,493
2021		2,440,000		2,440,000	1,739,686
2022		2,440,000		2,440,000	1,625,875
2023		2,440,000		2,440,000	1,519,509
2024		2,440,000		2,440,000	1,420,102
2025		2,440,000		2,440,000	1,327,198
2026		2,440,000		2,440,000	1,240,372
2027		2,440,000		2,440,000	1,159,226
2028		2,440,000		2,440,000	1,083,389
2029		2,440,000		2,440,000	1,012,513
Total			0	**238,158,097**	**177,064,365**

♦ Assume 2.5% increase per year per FAA Aerospace Forecast

♦♦ NR costs incurred in 2020 are amortized for 10 years.

Table 27. Future Costs for Retrofitting Part 29 Tier I Rotorcraft (Task 5).

Year	Part 29 - Tier I, Windshield + Critical Equipment					Part 29 - Tier I, Windshield + Helmet-Visor					Part 29 - Tier I, Windshield + Airspeed Restriction					
	Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Operational Costs	Costs	Present Value Costs at 7%
2016	717										717					
2017	735										735					
2018	753										753					
2019	772										772					
2020	791	1,634,667	70,000	57,035,036	43,511,756	791		9,800	7,756,324	5,917,262	791		0	1,241,714	23,969,129	19,565,949
2021		1,634,667		1,634,667	1,165,495	811		9,800	193,908	138,254	811		0	1,241,714	24,568,357	18,743,082
2022		1,634,667		1,634,667	1,089,247	832		9,800	198,756	132,439	832		0	1,241,714	25,182,566	17,954,821
2023		1,634,667		1,634,667	1,017,988	852		9,800	203,725	126,870	852		0	1,241,714	25,812,130	17,199,712
2024		1,634,667		1,634,667	951,391	874		9,800	208,818	121,534	874		0	1,241,714	26,457,433	16,476,360
2025		1,634,667		1,634,667	889,150	895		9,800	214,038	116,423	895		0	1,241,714	27,118,869	15,783,429
2026		1,634,667		1,634,667	830,982	918		9,800	219,389	111,526	918		0	1,241,714	27,796,841	15,119,640
2027		1,634,667		1,634,667	776,618	941	1,093,333	64,625	61,890,345	29,403,657	941	1,093,333	64,625	1,241,714	90,382,107	45,945,680
2028		1,634,667		1,634,667	725,812	964	1,093,333		1,093,333	485,453	964	1,093,333	0	1,241,714	30,297,389	14,394,071
2029		1,634,667		1,634,667	678,329	988	1,093,333		1,093,333	453,694	988	1,093,333	0	1,241,714	31,027,491	13,776,577
Total				**71,747,036**	**51,636,767**				**73,071,969**	**37,007,112**					**332,612,312**	**194,959,321**

♦ Assume 2.5% increase per year per FAA Aerospace Forecast

♦♦ NR costs incurred are amortized for 10 years.

Table 28. Future Costs for Retrofitting Part 29 Tier II Rotorcraft (Task 5).

Year	Part 29 - Tier II, Windshield + Critical Equipment					Part 29 - Tier II, Windshield + Helmet-Visor					Part 29 - Tier II, Windshield + Airspeed Restriction					
	Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Costs	Present Value Costs at 7%	Fleet Size♦	Non-Recurring Cost♦♦	Recurring Cost	Operational Costs	Costs	Present Value Costs at 7%
2016	41										41					
2017	42										42					
2018	43										43					
2019	44										44					
2020	45	720,000	75,000	4,114,225	3,138,722	45		9,800	443,528	338,365	45	0	0	1,241,714	1,370,620	1,045,639
2021		720,000		720,000	513,350	46		9,800	454,616	324,135	46	0	0	1,241,714	1,404,885	1,001,664
2022		720,000		720,000	479,766	48		9,800	465,981	310,503	48	0	0	1,241,714	1,440,007	959,538
2023		720,000		720,000	448,380	49		9,800	477,631	297,444	49	0	0	1,241,714	1,476,007	919,183
2024		720,000		720,000	419,047	50		9,800	489,571	284,935	50	0	0	1,241,714	1,512,908	880,526
2025		720,000		720,000	391,632	51		9,800	501,811	272,952	51	0	0	1,241,714	1,550,730	843,495
2026		720,000		720,000	366,011	52		9,800	514,356	261,473	52	0	0	1,241,714	1,589,499	808,020
2027		720,000		720,000	342,067	54	400,000	71,667	4,255,348	2,021,685	54	400,000	71,667	1,241,714	5,884,584	2,795,723
2028		720,000		720,000	319,689	55	400,000		400,000	177,605	55	400,000	0	1,241,714	2,069,967	919,090
2029		720,000		720,000	298,774	57	400,000		400,000	165,986	57	400,000	0	1,241,714	2,111,716	876,287
Total				**10,594,225**	**6,717,439**				**8,402,841**	**4,455,082**					**20,410,923**	**11,049,165**

♦ Assume 2.5% increase per year per FAA Aerospace Forecast

♦♦ NR costs incurred are amortized for 10 years.

The cost-benefits are compared in Table 29 for each of the Parts 27 and 29 tiers including both the traditional and non-traditional means. It is not economically cost effective to implement the traditional means such as BSR windshield for existing Part 27 Tiers I and II rotorcraft, though it is for Part 27 Tier III and Part 29 Tiers I and II. It is cost effective to implement the helmet-visor PPE non-traditional means for Part 27 Tier II as well as for Part 29 Tiers I and II, and only marginally cost-effective for Part 27 Tier I in 2016 dollars.

While the airspeed-altitude limitation non-traditional means is only cost effective for Part 29 rotorcraft, the recommended approach remains the traditional means.

Table 29. Cost-Benefit Analysis for Retrofitting Parts 27 and 29 Rotorcraft (Task 5).

Task 5 - Existing Parts 27 & 29 Rotorcraft								
RBSWG Group	Task 5 Policy	2016$			7% Present Value			
		Benefit	Cost	Delta	Benefit	Cost	Delta
Part 27 - Tier I	1-3 occupants must meet the same level of proposed bird strike airworthiness standard § 27.631 but only for the windshield	$ 13,941,807	$ 87,915,813	$ (73,974,006)	$ 7,884,375	$ 66,484,807	$ (58,600,432)
Part 27 - Tier I	... or alternatively, 1-3 occupants, pilot wears helmet-visor.	$ 13,941,807	$ 12,989,409	$ 952,398	$ 7,884,375	$ 9,909,558	$ (2,025,183)
Part 27 - Tier I	... or alternatively, 1-3 occupants, airspeed-altitude restriction are implemented.	$ 13,941,807	$ 1,859,147,636	$ (1,845,205,830)	$ 7,884,375	$ 1,065,911,566	$ (1,058,027,191)
Part 27 - Tier II	4-6 occupants must meet the same level of proposed bird strike airworthiness standard § 27.631 but only for the windshield	$ 122,844,843	$ 267,856,180	$ (145,011,337)	$ 69,471,255	$ 200,934,323	$ (131,463,068)
Part 27 - Tier II	... or alternatively, 4-6 occupants, pilot wears helmet-visor.	$ 122,844,843	$ 34,327,413	$ 88,517,431	$ 69,471,255	$ 26,188,219	$ 43,283,036
Part 27 - Tier II	... or alternatively, 4-6 occupants, airspeed-altitude restriction are implmented.	$ 122,844,843	$ 10,693,162,000	$ (10,570,317,157)	$ 69,471,255	$ 6,559,900,012	$ (6,490,428,757)
Part 27 - Tier III	7-9 occupants must meet the same level of proposed bird strike airworthiness standard § 27.631 but only for the windshield.	$ 541,445,544	$ 238,158,097	$ 303,287,447	$ 306,198,456	$ 177,064,365	$ 129,134,091
Part 29 - Tier I	10-15 occupants must meet the requirements of § 29.631 applied only to the windshield and flight critical equipment/components forward of the main rotor mast that could prevent continued safe flight and landing for Category A or a safe landing for Category B rotorcraft.	$ 595,933,766	$ 71,747,036	$ 524,186,731	$ 337,012,653	$ 51,636,767	$ 285,375,885
Part 29 - Tier I	Alternatively, 10-15 occupants, only the windshield must be shown to comply with § 29.631 plus pilot and copilot wear helmet-visor.	$ 595,933,766	$ 73,071,969	$ 522,861,797	$ 337,012,653	$ 37,007,112	$ 300,005,540
Part 29 - Tier I	Alternatively, 10-15 occupants, only the windshield must be shown to comply with § 29.631 plus implementation of airspeed-altitude restriction.	$ 595,933,766	$ 332,612,312	$ 263,321,454	$ 337,012,653	$ 194,959,321	$ 142,053,332
Part 29 - Tier II	16 or more occupants the windshield and flight critical equipment / components forward of the main rotor mast that could prevent continued safe flight and landing for Category A or a safe landing for Category B rotorcraft must be shown to comply with § 29.631.	$ 388,864,680	$ 10,594,225	$ 378,270,455	$ 219,910,877	$ 6,717,439	$ 213,193,439
Part 29 - Tier II	Alternatively, 16 or more occupants, only the windshield must be shown to comply with § 29.631 plus pilot and copilot wear helmet-visor.	$ 388,864,680	$ 8,402,841	$ 380,461,839	$ 219,910,877	$ 4,455,082	$ 215,455,795
Part 29 - Tier II	Alternatively, 16 or more occupants, only the windshield must be shown to comply with § 29.631 plus implementation of airspeed-altitude restriction.	$ 388,864,680	$ 20,410,923	$ 368,453,757	$ 219,910,877	$ 11,049,165	$ 208,861,712

Economic Assessment for Task 6 Implementing Proposed Non-Traditional Means of Bird Strike Protection

The recommended non-traditional means proposed in Task 6 include airspeed-altitude operational limitations, wearing helmet-visor PPE by at least the flight crew, and operating with taxi and/or landing lights turned on in a continuous mode during sunny conditions and at night when practical, and using a 2-Hz pulsed mode during partly cloudy conditions. Only the costs for the airspeed-altitude operational limitations and helmet-visor options are estimated as follows.

The airspeed-altitude limitation is estimated to result in increased operational cost due to slower speeds resulting in increased mission duration and hence increased flight hours. Limiting airspeed to less than 80 knots below 1,300 ft AGL will reduce the operational speed of most rotorcraft by about 30%, that is, most rotorcraft will operate at or above 104 knots (a conservative speed), which is 130% of 80 knots. Thus, the mission duration will increase by 30%. The assumption is made that the reduction in operational cost (e.g., reduced fuel consumption) at 80 knots instead of 104 knots or higher is offset by the conservatively low operational velocity of 104 knots. Hence the operational costs are assumed to increase 30% in direct proportion to the 30% increase in flight hours.

Because fleet flight hours were not uniformly available across all rotorcraft types, estimates were made based on those for which flight hours were available. The flight hours shown in Table 30 were used to project operational costs derived from Conklin and de Decker[15].

Table 30. Estimated Annual Flight Hours per Rotorcraft by Tier.

RBSWG Group	Annual Flight Hours per Rotorcraft	30% of Average Variable Operating Cost ♦♦
Part 27 - Tier I	246	$60
Part 27 - Tier II	291♦	$209
Part 27 - Tier III	336	$270
Part 29 - Tier I	395	$438
Part 29 - Tier II	295	$749

♦ Based on mean of Part 27-Tier I & Part 27-Tier II

♦♦ Based on data from Conklin & de Decker

As noted previously, each helmet-visor costs approximately $2,000 in 2017 USD (which is $2,450 in 2020 escalated at 7% per annum). Helmets must be fitted for each individual pilot. For this

[15] https://www.conklindd.com/cdalibrary/accostsummary.aspx

economic analysis, the cost of three helmet-visors are assumed for Part 27 rotorcraft and four helmet-visors for Part 29 rotorcraft.

The economic analysis presumes a 100% compliance or in effect a mandatory application of the non-traditional means, (e.g., through RFM restrictions requiring either airspeed-altitude operational limitations or PPE consisting of helmet and visor for the Part 27 pilot and Part 29 pilot and copilot). However, this would adversely affect the operator and be difficult to implement through Parts 91 and 135 operating and flight rules. Therefore, the non-traditional means of bird strike protection are only recommended prior to implementation of traditional BSR means.

ANTICIPATED PROCEDURAL CHANGES FOR REGULATED PARTIES

The regulated parties can be evaluated as two different groups: rotorcraft manufacturers (OEMs) and operators. The anticipated procedural changes for OEMs consist primarily in developing BSR windshields and structure protecting critical equipment as appropriate for newly type certificated Part 27 rotorcraft and newly manufactured Parts 27 and 29 rotorcraft. In addition, OEMs (or PMAs) would be encouraged to develop BSR windshields and, as appropriate, structure to protect critical equipment for existing Part 27 and 29 rotorcraft. This includes rotorcraft that are no longer in production. For existing rotorcraft, these kits and associated modifications would be market-induced rather than regulatory.

The anticipated procedural changes for operators consists primarily in enhanced crew training providing preflight planning and briefings with the location of bird concentrations during seasonal migrations and the local bird nesting and roosting habitats. Air carriers and general aviation operators working with the FSDO Safety Programs and Flight Service Briefing should identify and publish the known locations and probability of bird concentrations. This information should be incorporated into alert bulletins, flight service Notice to Airmen (NOTAM) and other systems presently used to inform flight crews of the hazards of bird concentrations. Further, training should remind flight crews that most bird strikes (2 out of 3) occur during airspeeds greater than 80 knots and at lower altitudes. Bird strikes have not been reported for rotorcraft with airspeeds below 55 knots. Therefore, if flight operations allow slower airspeeds in areas known to have a high-density bird population, flight crews should reduce the airspeed to 80 knots or less. In addition, when practical and allowed by other flight variables, rotorcraft operators should fly at higher altitudes. Data shows bird strike threat is reduced by one-third for each 1,000-ft gain in altitude above the ground. Only 7% of bird strikes occur above 3,500 ft AGL.

In addition, anticipated procedural changes for operators will be operating with taxi and/or landing lights turned on in a continuous mode during sunny conditions and at night when practical, and using a 2-Hz pulsed mode during partly cloudy conditions.

ESTIMATED SAFETY IMPROVEMENTS

Adoption of bird strike safety procedures recommended in **Task 7 Proposed Policy and Guidance Material** is expected to reduce the potential for fatalities and injuries due to bird strikes.

Further, the safety improvements to be implemented by the recommendations provided in this study include enhanced bird strike threat information available for flight crews and operators, and BSR windshields for the following:

- Newly type certificated Part 27 Tier III rotorcraft
- Existing Part 27 Tier III rotorcraft
- Newly type certificated Part 29 rotorcraft (Tiers I and II)
- Newly manufactured Part 29 rotorcraft (Tiers I and II)
- Existing Part 29 rotorcraft (Tiers I and II).

Specifically, the following categories did not show benefits that exceeded costs.

- Newly type certificated Part 27 Tier I rotorcraft
- Newly type certificated Part 27 Tier II rotorcraft
- Newly manufactured Part 27 Tier I rotorcraft
- Newly manufactured Part 27 Tier II rotorcraft
- Newly manufactured Part 27 Tier III rotorcraft
- Existing Part 27 Tier I rotorcraft
- Existing Part 27 Tier II rotorcraft

OTHER POTENTIAL BENEFITS

Other potential benefits that would result from implementation of the recommendations include likely future reduction in insurance premiums as actuarial tables reflect realized benefits of rotorcraft bird strike regulations and operator-implemented bird strike safety procedures.

Accelerated research in non-traditional means of bird strike detection and protection is anticipated to result in additional benefits for safely operating rotorcraft in bird rich environments.

TASK 9 – FINDINGS AND RESULTS

TASK DESCRIPTION

As published in FR Doc. 2016–09781, Task 9 states:

> *Develop a report containing recommendations on the findings and results of the tasks explained above. The report should document:*
> *a. Both majority and dissenting positions on the findings and the rationale for each position.*
> *b. Any disagreements, including the rationale for each position and the reasons for the disagreement.*

MAJORITY AND DISSENTING POSITIONS

Bell Helicopter Textron Majority Position

Bell Helicopter Textron in general supports adoption of bird strike safety standards and associated guidance proposed by the RBSWG.

Airbus Helicopters Dissenting Position

As a general comment, Airbus wishes to point out that its own safety records of serious incidents/accidents due to bird strikes show that the analysis prepared by the ARAC group is very conservative. Although the statistics of number of bird penetrations used in this study are taken from the actual observations reported in the FAA bird strike incident database, potential consequences (injuries and fatalities) of such bird penetrations have been computed using a simple theoretical model, and not the real consequences of the observed bird strikes (although these data are available) which are much less significant. As a result, this provides a very conservative approach, as compared to the actual injuries/fatalities figures in this database, and consequently we believe that the benefits of improved bird strike protection systems are strongly overestimated (the ratio is up to 4 for Part 27 Tier III).

In addition, the reinforcements costs are average values on a group of helicopters, and do not reflect necessarily the specificity of particular models of rotorcraft. Only a detailed and dedicated study could provide the real effort to be performed and reveal the potential difficulties, especially for retrofit of the existing fleet.

Airbus therefore considers that the economic justification of bird strike protection systems is not fully demonstrated.

Nevertheless, in the framework of its Safety Improvement program, Airbus supports actions intended to improve the safety of helicopters against bird strikes:

- Airbus therefore fully supports the introduction of a bird strike requirement for any new Type Certificate (Task 1) with a short-term date of application as 2020, as proposed in the ARAC report.
- Airbus also supports the introduction of improvements for newly manufactured helicopters (Tasks 2 and 4), in the timeframe defined in the ARAC report:
  - Part 27 (Task 2): via safety procedures based on non-traditional means, after 2020;
  - Part 29 (Task 4): via compliance to 14 CFR § 29.631 (partial or total depending on the tier), after 2029.
- For helicopters in service (Task 5), Airbus is concerned that mandatory heavy retrofit will severely impact operators (recurring cost, loss of rotorcraft availability, parts availability, etc…), leading to significant revenue losses and/or rotorcraft loss of value which largely outweigh the expected safety benefits. This is the reason why Airbus insists that the ARAC recommendation remains limited to the use of non-traditional means for any model of Parts 27 and 29 helicopters already delivered (e.g. helmet mandatory for pilot, external lights when flying low altitude, etc) and that the decision to implement bird strike protection systems remains at the discretion of operators, based on optional solutions developed by the OEMs in the meantime. This implies that, in order to answer the need of operators willing to fit on their rotorcraft with an improved bird strike protection system, OEMs should do their best effort to have certified optional retrofit kits for their models to bring them to the equivalent level of protection as the corresponding new rotorcraft, with a target certification date by 2034 (5 years after application date for every new rotorcraft), and a coverage perimeter encompassing all rotorcraft delivered after 2009 (last 25 years).

Airbus is fully committed to improve the safety of helicopters against bird strikes and considers that these recommendations represent a good equilibrium.

Enstrom Position on the RWBSG Report of Recommendations to the ARAC

The Enstrom Helicopter Corporation generally supports the findings of the RBSWG report, particularly the recommended guidance and policy that provides operators with specific steps that can be taken, when practical, to greatly reduce the risk of serious injury from bird strikes. Enstrom has the following comments on this report:

1. Enstrom believes the economic analysis over reports the benefits of implementing bird strike resistant structure. Enstrom agrees with the RBSWG decision that the calculated benefits must be higher than the historical data has shown to account for the fact that penetrating bird strikes that resulted in minimal damage could have been significantly worse; there is no evidence that future bird strike penetrations will have the same minimal damage. For Part 27 Tier I and Tier II rotorcraft the benefits used are approximately 1.6-2.3 times larger than what the historical data supports. It is Enstrom's opinion that this level of conservatism is acceptable. However, for Part 27 Tier III and Part 29 Tier I the benefits are greater than 4 times larger than what the historical data supports. Enstrom believes this

is too conservative and does not provide an accurate comparison for the cost-benefit analysis.

2. Enstrom believes the economic analysis under reports the costs of implementing bird strike resistant structure. The bird strike resistant structure costs for the economic analysis are based only on the design, certification, and implementation costs. The operating costs associated with the implementation of traditional bird strike resistant features have not been fully considered and are not reflected in the cost analysis. While the operational costs were assumed to be minimal compared to the design, certification, and installation costs, that assumption was not fully proven. Enstrom believes that the under reported costs do no provide an accurate comparison for the cost-benefits analysis.

3. The report's final recommendation for traditional bird strike protection of Part 27 Tier III rotorcraft can be summarized as follows:
   - Newly Certificated: Must implement a BSR windshield
   - Newly Manufactured: No requirement for BSR windshield
   - Existing Rotorcraft: Must implement a BSR windshield

   It does not make sense to allow rotorcraft to be manufactured and sold, but then require an immediate upgrade before they can operate. If the economic analysis does not support requiring a BSR windshield on newly manufactured aircraft (which it does not), then it is very difficult to see how it would support implementation of a BSR windshield after it is fielded.

While Enstrom believes the industry should be encouraged to implement BSR structure, the cost-benefit analysis does not justify this for most rotorcraft. This cost-benefit relationship may change as technology matures or if certification costs can be reduced, but until such time that it does, the regulations should not be written to *require* implementation for BSR structure for all tiers of rotorcraft.

Era Helicopter's Position on the RWBSG Report of Recommendations to the ARAC

Era Helicopters generally supports the findings and recommendations of the RWSBG report. Most importantly that manufacturers, regulators and operators are in need of consolidated efforts to increase bird strike resistance and resiliency. Era also believes that regulation alone cannot provide all encompassing safety aspects for operators through operational or certification standards, but rather regulations provide minimum standards in which best practices are partnered for continued flight safety in the rotary-wing community.

As Era recognizes the cost-benefit analysis and recommendations in the report, these figures were not provided by Era and the report is illustrative of estimated costs using future values for feasibility of which Tiered decisions were made. Knowing that majority of operators utilizing Part 27 aircraft have the possibility of being impacted above or below the reports estimates, Era will only comment that each operator will need to review numerous aspects of this report's recommendations and submit comments as required if/when recommendations from this report are released for public comment.

Era is grateful to be involved in this report and urges all operators to pursue a commitment to safe operations and through training, awareness and equipment in support of occupant safety and the general public.

Airborne Law Enforcement Association Position on the Rotorcraft Bird Strike Working Group Report of Recommendations to the Aviation Rulemaking Committee

The Airborne Law Enforcement Association (ALEA) generally supports the findings of the Rotorcraft Bird Strike Working Group (RBSWG) report, particularly the recommended guidance that provides operators with specific steps that can be taken to reduce the risk of serious injury from bird strikes. ALEA, however, has the following comments on this report:

1. ALEA is concerned that the cost basis assumptions used in the economic analysis for a damaging event are flawed resulting in an overstatement of the cost for these events, therefore, an overstatement of the benefits of implementing bird strike resistant structure. While ALEA agrees with the RBSWG decision that the calculated benefits must be higher than what the historical data has shown to account for (i.e., the fact that penetrating bird strikes that resulted in minimal damage could have been significantly worse), we have serious concerns with the assumption that 11% of bird strikes to the windshield would cause fatalities and an additional 25% would cause serious injuries. Percentages this high are arbitrary, not supported by historical data, and do not provide an accurate comparison for the cost-benefit analysis.

2. ALEA wants to emphasis that the non-traditional bird strike recommendations detailed in Task 6, specifically airspeed-altitude limitations, helmet and visor for flight crew, and the use of taxi and or landing lights in flight, are all qualified with the phrase, “when practical” and are not meant to be regulatory. While most public safety helicopter aircrews wear helmets and visors and ALEA endorses their use, any regulatory restriction on altitude-airspeed or regulatory mandate on the constant use of taxi or landing lights in flight would negatively impact the effectiveness and safety of some public safety aviation operations.

3. The report’s final recommendation for traditional bird strike protection of Part 27 Tier III rotorcraft can be summarized as follows:
    - Newly Certificated: Must implement a BSR windshield
    - Newly Manufactured: No requirement for BSR windshield
    - Existing Rotorcraft: Must implement a BSR windshield

    It is ALEA’s opinion that it does not make sense to allow rotorcraft to be manufactured and sold, but then require an immediate upgrade before they can operate. If the economic analysis does not support requiring a BSR windshield on newly manufactured aircraft (which it does not), then it is very difficult to see how it would support implementation of a BSR windshield after it is fielded.

Leonardo Helicopters Dissenting Position

Leonardo Helicopters Division supports the adoption of bird strike safety standards and associated guidance proposed by the RBSWG, with the exception of helicopters in service (Task 5).

Leonardo shares the concern raised by Airbus that mandatory heavy retrofit will severely impact operators (recurring cost, loss of rotorcraft availability, parts availability, etc.), leading to significant revenue losses and/or rotorcraft loss of value which largely outweigh the expected safety benefits. Leonardo joins Airbus in insisting that the ARAC recommendation remains limited to the use of non-traditional means for any model of Parts 27 and 29 helicopters already delivered (e.g. helmet mandatory for pilot, external lights when flying low altitude, etc.) and that the decision to implement bird strike protection systems remains at the discretion of operators, based on optional solutions developed by the OEMs in the meantime.

APPENDIX A – ACRONYMS AND DEFINITIONS

AC	Advisory Circular
AGL	Above ground level
ARAC	Aviation Rulemaking Advisory Committee
AMOC	Alternate means of compliance
BCAR	British Civil Airworthiness Requirements
BSR	Bird strike resistant
CFR	Code of Federal Regulations
CSFL	Continued safe flight and landing
FR	Federal Register
HID	High-Intensity Discharge
JAR	Joint Aviation Requirements
LED	Light Emitting Diode
NAS	National Airspace System
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board
NWSD	National Wildlife Strike Database
OEM	Original Equipment Manufacturer
PMA	Parts Manufacturer Approval
PPE	Personal Protective Equipment (e.g., helmet and visor)
RBSWG	Rotorcraft Bird Strike Working Group
RFM	Rotorcraft Flight Manual
SL	Safe landing
STC	Supplemental Type Certificate
TC	Type Certification
TCDS	Type Certification Data Sheet
USDA	United States Department of Agriculture
USDX	U.S. Dollar Index
V_H	Maximum horizontal velocity (airspeed)
V_{NE}	Never-to-exceed velocity (maximum airspeed)

APPENDIX B – COST ANALYSIS TABLES

Table B-1. Rotorcraft Used in Economic Assessment.

Group	Aircraft	Currently in Production?
Part 27 - Tier I	F-28F	Yes
Part 27 - Tier I	280FX	Yes
Part 27 - Tier I	R22	Yes
Part 27 - Tier II	EC120	Yes
Part 27 - Tier II	BO105	Yes
Part 27 - Tier II	SA313	No
Part 27 - Tier II	SA315	No
Part 27 - Tier II	SA341	No
Part 27 - Tier II	Bell 206	No
Part 27 - Tier II	480B	Yes
Part 27 - Tier II	Hughes 369	No
Part 27 - Tier II	Hughes 369 #2 (MD500)	No
Part 27 - Tier II	MD500	Yes
Part 27 - Tier II	R44	Yes
Part 27 - Tier II	R66	Yes
Part 27 - Tier III	AS350	Yes
Part 27 - Tier III	EC130	Yes
Part 27 - Tier III	AS355	Yes
Part 27 - Tier III	EC135	Yes
Part 27 - Tier III	Bell 230	No
Part 27 - Tier III	Bell 222	No
Part 27 - Tier III	Bell 206L Series	No
Part 27 - Tier III	Bell 407	Yes
Part 27 - Tier III	Bell 427	No
Part 27 - Tier III	Bell 429	Yes
Part 27 - Tier III	A109	Yes
Part 27 - Tier III	A119	Yes
Part 27 - Tier III	MD900	Yes
Part 27 - Tier III	MD600	Yes
Part 29 - Tier I	BK117	Yes
Part 29 - Tier I	AS365	Yes
Part 29 - Tier I	H155	Yes
Part 29 - Tier I	Bell 204	No
Part 29 - Tier I	Bell 205	No
Part 29 - Tier I	Bell 212	No
Part 29 - Tier I	Bell 412	Yes
Part 29 - Tier I	Bell 430	No
Part 29 - Tier I	S76	Yes
Part 29 - Tier II	H215	Yes
Part 29 - Tier II	SA321	No
Part 29 - Tier II	SA330	No
Part 29 - Tier II	AS332L1 (H215)	Yes
Part 29 - Tier II	Bell 214	No
Part 29 - Tier II	Bell 214ST	No
14 CFR 29.631	BK117 #2 (H145)	Yes
14 CFR 29.631	H225	Yes
14 CFR 29.631	AW139	Yes
14 CFR 29.631	AW189	Yes
14 CFR 29.631	S92A	Yes

Table B-2. Rotorcraft Fleet Growth Projections.

	Fleet Growth					
Year	Part 27 - Tier I	Part 27 - Tier II	Part 27 - Tier III	Part 29 - Tier I	Part 29 - Tier II	14 CFR 29.631
2016	1601	4231	3987	717	41	202
2017	1641	4337	4087	735	42	207
2018	1682	4445	4189	753	43	212
2019	1724	4556	4294	772	44	218
2020	1767	4670	4401	791	45	223
2021	1811	4787	4511	811	46	229
2022	1857	4907	4624	832	48	234
2023	1903	5029	4739	852	49	240
2024	1951	5155	4858	874	50	246
2025	1999	5284	4979	895	51	252
2026	2049	5416	5104	918	52	259
2027	2101	5551	5231	941	54	265
2028	2153	5690	5362	964	55	272
2029	2207	5832	5496	988	57	278

Assume 2.5% increase per year per FAA Aerospace Forecast

Table B-3. Part 27 Tiers I, II and III Annual Benefit Analysis.

Category	January 2009 - February 2016 - Risk assumption applied to any Windshield penetration								
	Part 27 - Tier I			Part 27 - Tier II			Part 27 - Tier III		
	Severity Factor	**Factor**	**Total w/Factor**	**Severity Factor**	**Factor**	**Total w/Factor**	**Severity Factor**	**Factor**	**Total w/Factor**
Fatalities	$ 1,089,000	4.7	$ 5,132,312	$ 1,089,000	41.5	$ 45,222,121	$ 1,089,000	183.0	$ 199,319,039
Serious Injuries	$ 626,175	4.7	$ 2,951,079	$ 626,175	41.5	$ 26,002,720	$ 626,175	183.0	$ 114,608,447
Average Cost for Repair		3.0	$ -	$ -	25.0	$ -	$ -	79.0	$ -
Total Benefit over 7.17 years			$ 8,083,392			$ 71,224,841			$ 313,927,487
Annual Benefit			**$ 1,127,391**			**$ 9,933,730**			**$ 43,783,471**

Table B-4. Part 29 Tiers I, II and 14 CFR § 29.631 Annual Benefit Analysis.

Category	January 2009 - February 2016 - Risk assumption applied to any Windshield penetration								
	Part 29 - Tier I			Part 29 - Tier II			14 CFR 29.631		
	Severity Factor	**Factor**	**Total w/Factor**	**Severity Factor**	**Factor**	**Total w/Factor**	**Severity Factor**	**Factor**	**Total w/Factor**
Fatalities	$ 1,089,000	201.4	$ 219,377,455	$ 1,089,000	131.5	$ 143,150,378	$ 1,089,000	0.0	$ -
Serious Injuries	$ 626,175	201.4	$ 126,142,037	$ 626,175	131.5	$ 82,311,467	$ 626,175	0.0	$ -
Average Cost for Repair	$ -	9.0	$ -	$ -	0.0	$ -	$ -	1.0	$ -
Total Benefit over 7.17 years			$ 345,519,492			$ 225,461,845			$ -
Annual Benefit			**$ 48,189,608**			**$ 31,445,167**			$ -

Table B-5. Nonrecurring Cost Basis – New Windshield.

Example of Required NR Costs - Part 27 Tier II				
Task	Hours	Materials / Supplier Costs	Travel Days	Cost
CAD/FEA Modeling/Design	320	$ -	$ -	$ 44,800
Run Analysis, Present Results, Determine Test Conditions	320	$ -	$ -	$ 44,800
Write/Approve Test Plan	235	$ -	$ -	$ 32,950
Design/Build Test Fixture	450	$ 50,000	$ -	$ 113,000
Surrounding Structure Specimen (2 sets)	0	$ 150,000		$ 150,000
Windshield Specimens (3 minimum plus a spare)	0	$ 120,000	$ -	$ 120,000
Testing (assume 3 shots and 2 weeks)	600	$ 60,000	$ 78	$ 163,500
Write/Approve Test Report	480	$ -	$ -	$ 67,200
New Tooling	0	$ 120,000	$ -	$ 120,000
Design Modifications to Component Parts	0	$ 80,000	$ -	$ 80,000
Engineering Cost of Integration	5000	$ -	$ -	$ 700,000
Total	7405	$ 580,000	$ 78	$ 1,636,250

Table B-6. Nonrecurring Cost by Rotorcraft Grouping – New Windshield.

Non-Recurring Costs for New Windshield	
Part 27 - Tier I	$ 1,030,000
Part 27 - Tier II	$ 1,636,250
Part 27 - Tier III	$ 1,876,923
Part 29 - Tier I	$ 1,366,667
Part 29 - Tier II	$ 1,000,000
14 CFR 29.631	N/A

Table B-7. Recurring Cost Basis – New Windshield for Part 27 Tier II.

Example of Required Recurring Costs - Part 27 Tier II	
Task	Materials / Supplier Costs
New Windshield Cost	$ 15,000
Components (i.e. edge attachment, bushings, fasteners, etc.)	$ 4,000
Structural change costs	$ 4,000
Cost to retrofit	$ 4,500
Total	$ 27,500

Table B-8. Recurring Cost Basis – New Windshield for Part 29 Tier II.

Example of Required Costs - Part 29 Tier II	
Task	Materials / Supplier Costs
New Windshield Cost	$ 20,000
Components (i.e. edge attachment, bushings, fasteners, etc.)	$ 10,667
Structural change costs	$ 11,000
Cost to retrofit	$ 30,000
Total	$ 71,667

Table B-9. Recurring Cost by Rotorcraft Grouping – New Windshield.

Recurring Costs for New Windshield	
Part 27 - Tier I	$ 22,500
Part 27 - Tier II	$ 27,500
Part 27 - Tier III	$ 36,214
Part 29 - Tier I	$ 64,625
Part 29 - Tier II	$ 71,667
14 CFR 29.631	N/A

Table B-10. Nonrecurring Cost Basis – New Windshield and Critical Equipment.

Example of Required NR Costs - Part 27 Tier II				
Task	Hours	Materials / Supplier Costs	Travel Days	Cost
CAD/FEA Modeling/Design	400	$ -	$ -	$ 56,000
Run Analysis, Present Results, Determine Test Cond	400	$ -	$ -	$ 56,000
Write/Approve Test Plan	260	$ -	$ -	$ 36,400
Design/Build Test Fixture	580	$ 50,000	$ -	$ 131,265
Testing (assume 3 shots and 2 weeks)	774	$ 60,000	$ 78	$ 187,854
Windshield Specimens (3 minimum plus a spare)	0	$ 120,000	$ -	$ 120,000
Write/Approve Test Report	230	$ -	$ -	$ 32,200
New Tooling	0	$ 120,000	$ -	$ 120,000
Design Modifications to Component Parts	0	$ 150,000	$ -	$ 150,000
Engineering Analysis and Design for Post/Radome	525	$ -	$ -	$ 73,500
Engineering Analysis and Design for Engine Inlets	450	$ -	$ -	$ 63,000
Engineering Analysis and Design for Upper Fairing	440	$ -	$ -	$ 61,600
Engineering Analysis and Design for M/R Blades	557	$ -	$ -	$ 77,917
Engineering Analysis and Design for T/R Blades	700	$ -	$ -	$ 98,000
Engineering Analysis and Design for Pylon Covers	440	$ -	$ -	$ 61,600
Testing (6 Components, assume 2 shots each)	1290	$ 120,000	$ 156	$ 339,589
Write/Approve Test Report (6 Components)	930	$ -	$ -	$ 130,200
Engineering Cost of Integration	2700	$ -	$ -	$ 378,000
Total	10676	$ 620,000	$ 234	$ 2,173,125

Table B-11. Nonrecurring Cost by Rotorcraft Grouping – New Windshield and Critical Equipment.

Non-Recurring Costs for New Windshield & Critical Equipment	
Part 27 - Tier I	$ 1,854,000
Part 27 - Tier II	$ 2,173,125
Part 27 - Tier III	$ 2,666,071
Part 29 - Tier I	$ 2,043,333
Part 29 - Tier II	$ 1,800,000
14 CFR 29.631	$ -

**Table B-12. Recurring Cost Basis –
New Windshield and Critical Equipment.**

Example of Required Costs - Part 29 Tier II	
Task	Materials / Supplier Costs
New Windshield Cost	$ 20,000
Post/Radome	$ 3,000
Engine Inlets	$ 3,000
Upper Fairing	$ 6,000
M/R Blades	$ 15,000
M/R Pitch Link	$ 1,500
Structural change costs	$ 20,000
Cost to retrofit	$ 64,000
Total	$ 132,500

**Table B-13. Recurring Cost by Rotorcraft Grouping –
New Windshield and Critical Equipment.**

Recurring Costs for New Windshield & Critical Equipment	
Part 27 - Tier I	$ 40,500
Part 27 - Tier II	$ 56,214
Part 27 - Tier III	$ 64,000
Part 29 - Tier I	$ 113,750
Part 29 - Tier II	$ 132,500
14 CFR 29.631	$ -

APPENDIX C – POPULATION INCREASES OF LARGE BIRDS

Dr. Richard A. Dolbeer reports in Dolbeer, Seubert, & Begier, 2014, and Dolbeer, 2015, that for fixed wing airplanes, damaging strikes and multi-bird strikes have shown significant increases between 1990-2012. Large birds are those greater than 4 lb, which include snow geese at 6.1 lb, brown pelicans at 8.2 lb, and sandhill cranes at 10.6 lb. Medium birds weighing between 2.5 – 3.9 lb include red-tailed hawks at 2.7 lb and brants at 3.0 lb.

Dr. Dolbeer writes: *The bottom line is that it appears (through 2015) that the resident (non-migratory) Canada goose population is stabilizing after a dramatic increase in 1980s and especially 1990s. Snow goose populations also appear to be stabilizing. But most of the other large (>4 lb) bird species appear to be still increasing. See attached spreadsheet which shows.* Figures C-1 through C-14, all from Dr. Richard A. Dolbeer, document trends in estimated population numbers for Canada geese and snow geese (from U.S. Fish and Wildlife Service [USFWS] surveys) and estimated population indices for 12 other large species mostly based on Breeding Bird Survey results.

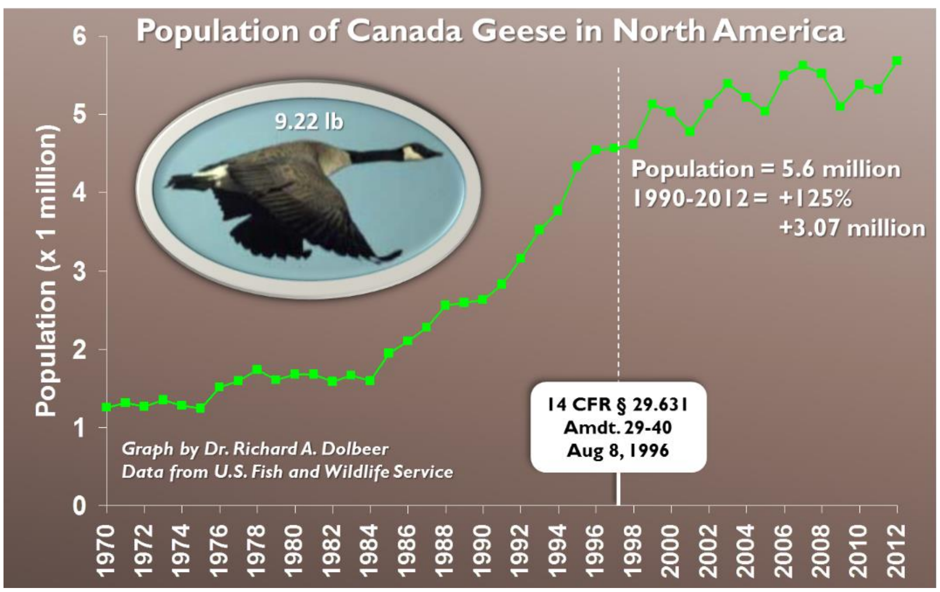
Why have resident Canada goose numbers stabilized? *First of all, until the mid 1950s there were no resident (non-migratory or year round) nesting Canada geese in the USA outside of a small population in Minnesota. State wildlife agencies in Ohio and other eastern states, in cooperation with the USFWS, began taking some of these birds from Minnesota and releasing them (with clipped wings) into state wildlife refuges. These birds nested and young produced imprinted to area and soon we had these resident goose populations popping up everywhere and perpetuating themselves. More relocations occurred (everybody wanted Canada geese!) and by the 1980s, populations of these "introduced" Canada geese were everywhere. They thrived because of minimal predation in urban areas, huge expanses of high quality forage in the form of corn fields, golf courses, corporate lawns, parks etc. The traditional migratory population from Canada intermingled with these resident birds during winter.*

Dolbeer, Seubert, & Begier, state in their 2014 journal article: *We hypothesize that the stabilization of the resident Canada goose population in the past decade and the decline in reported strikes and damaging strikes between aircraft and resident Canada geese from 1998 to 2012 is related to aggressive management programs at airports and other areas throughout the USA that have targeted resident Canada geese (e.g., Smith et al. 1999, Dolbeer et al. 2000, Wenning et al. 2004, Woodruff et al. 2004, U.S. Fish and Wildlife Service 2005, Dolbeer and Franklin 2013). For example, a special, early Canada goose hunting season has been phased in over the past 21 years in the USA to target resident birds before the Canadian migrants arrive.* ***About 450,000 to 650,000 resident Canada geese were taken each year by hunters in 38 U.S. states during the 2001 to 2011 early (September) seasons (Raftovich et al. 2012).*** *As another example, biologists from the U.S. Department of Agriculture, Wildlife Services (WS) provided assistance at 772 to 838 airports nationwide in 2010 to 2012 to mitigate wildlife risks to aviation, compared to only 42 airports in 1991 and 193 airports in 1998 (Begier and Dolbeer 2013). The number of resident Canada geese euthanized by WS because of conflicts with humans (including aviation safety) increased from about 6,000 in 2001 to 24,000 in 2011 (U.S. Department of Agriculture 2013).*

These types of active management actions to reduce goose populations have not been taken with most of the other large species (except double-crested cormorants).

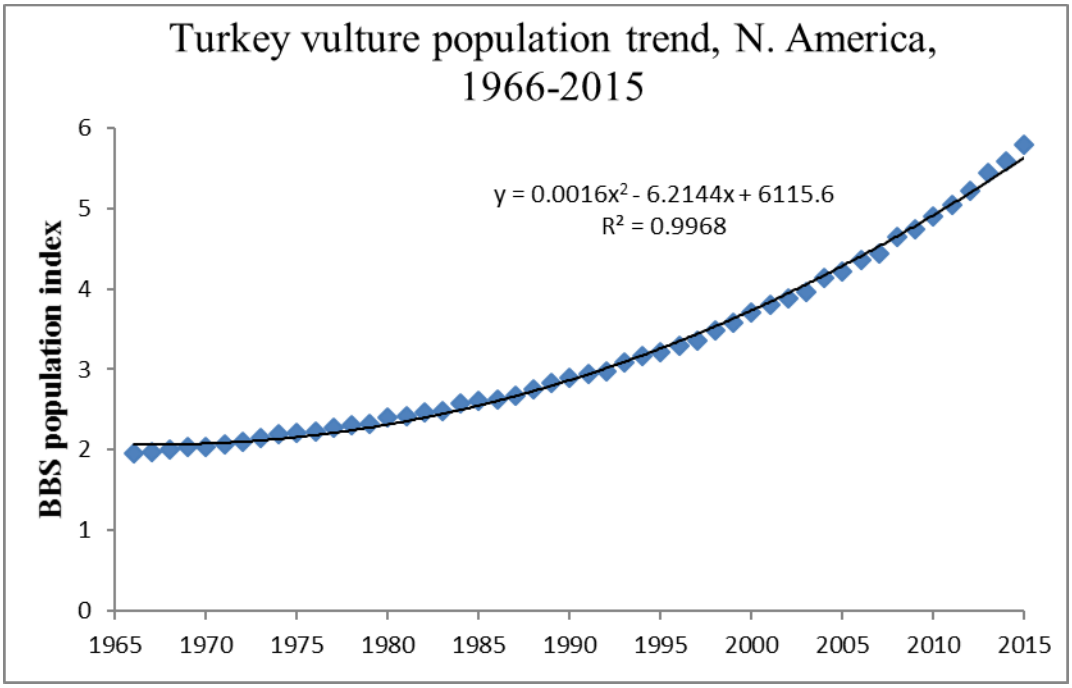
Dr. Dolbeer's recommendations related to fixed-wing aircraft include:

1. Management actions to reduce populations of resident Canada geese around airports should be continued and strongly supported by the aviation industry.
2. Management actions to reduce populations of resident Canada geese around airports should be continued and strongly supported by the aviation industry.
3. ARAC needs to consider the following:
    a. There are a lot more large and medium birds, especially large-flocking birds, today than 20 years ago,
    b. The overall trend of increase has not yet abated, and
    c. Traditional wildlife management actions to abate risks are limited for many of these species.
4. These facts should be considered in revisions to standards and advisory material for *engine* design and certification.



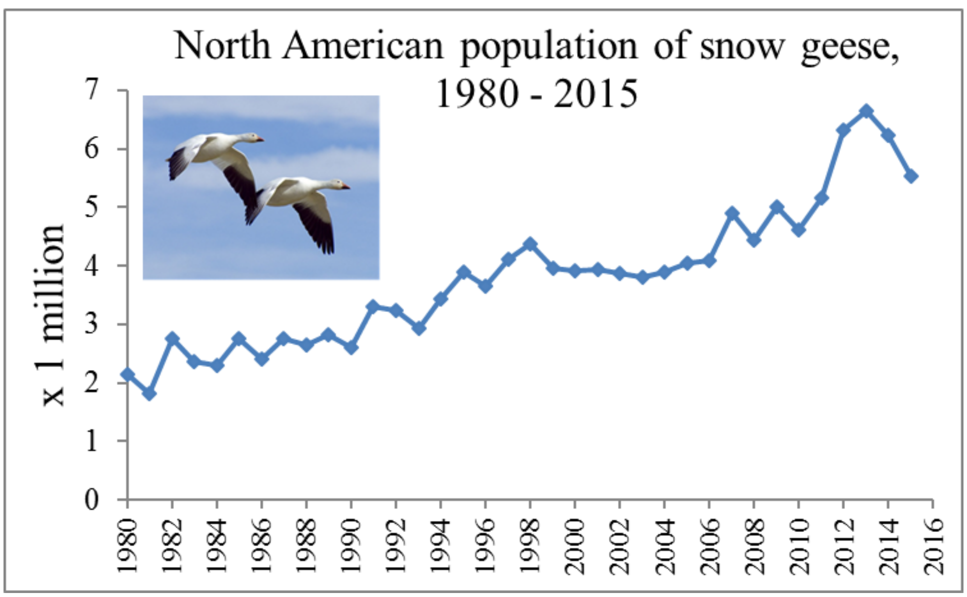
Adapted by R. A. Dolbeer from U.S. Fish and Wildlife Service. 2015. Waterfowl population status, 2015. U.S. Department of the Interior, Washington, D.C. USA. 75

Figure C-1. Population of Canada geese (4.2 kg mean body mass) in North America.



Graphs by R. A. Dolbeer based on data from North American Breeding Bird Survey

Figure C-2. Population of turkey vultures (2.0 kg mean body mass) in North America.



Adapted by R. A. Dolbeer from U.S. Fish and Wildlife Service. 2015. Waterfowl population status, 2015. U.S. Department of the Interior, Washington, D.C. USA. 75

Figure C-3. Population of snow goose (2.7 kg mean body mass) in Greater, Mid-continent and Western regions.

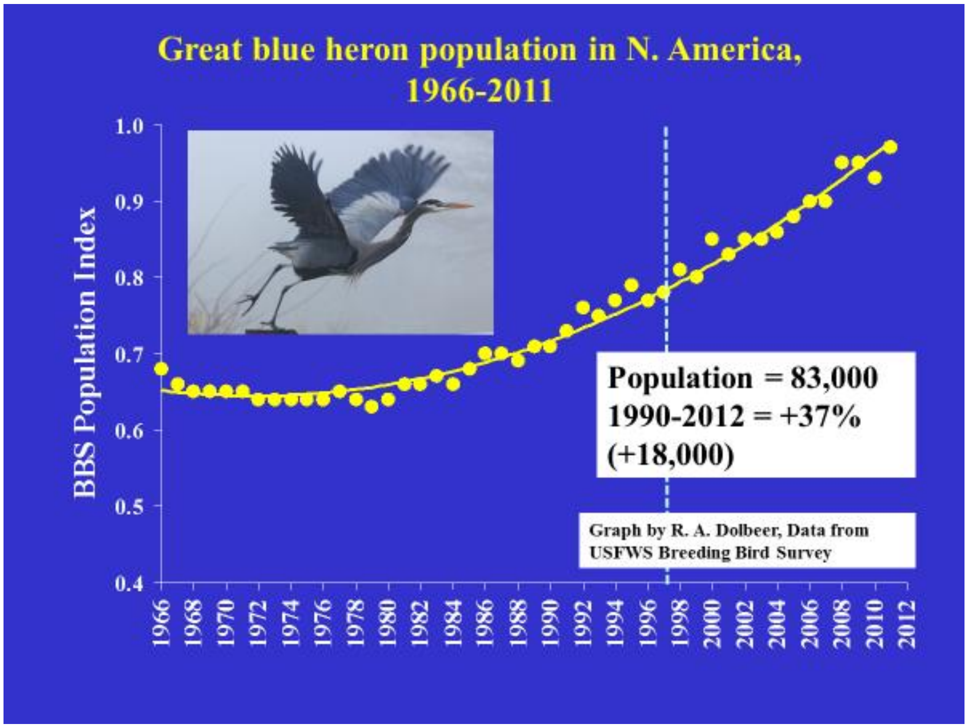
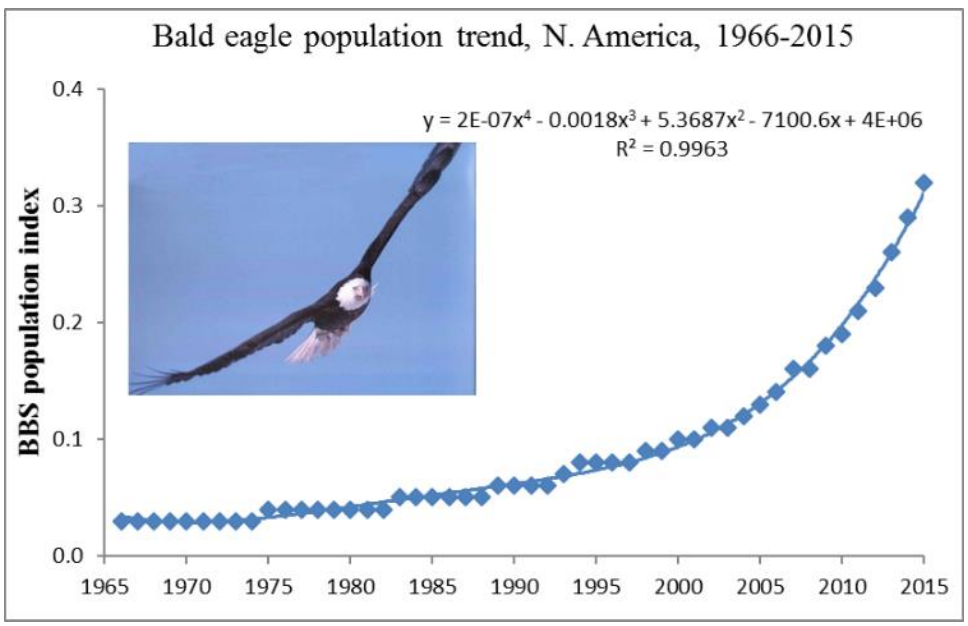
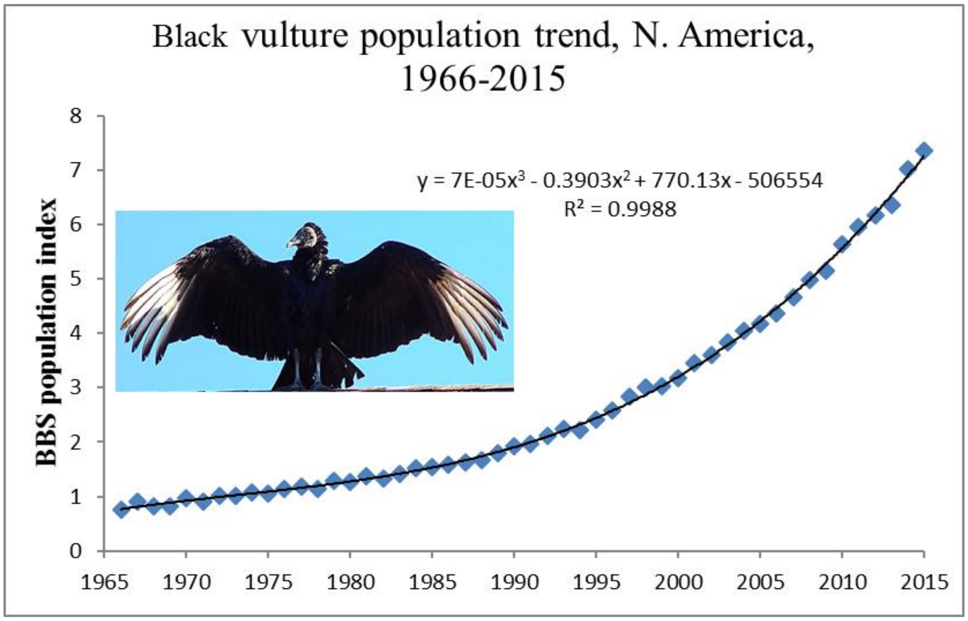


Figure C-4. Population of great blue heron (2.3-2.7 kg) in North America.



Graphs by R. A. Dolbeer based on data from North American Breeding Bird Survey

Figure C-5. Population of bald eagle (5.4 kg mean body mass) in North America.



Graphs by R. A. Dolbeer based on data from North American Breeding Bird Survey

Figure C-6. Population of black vulture (2.2 kg mean body mass) in North America.

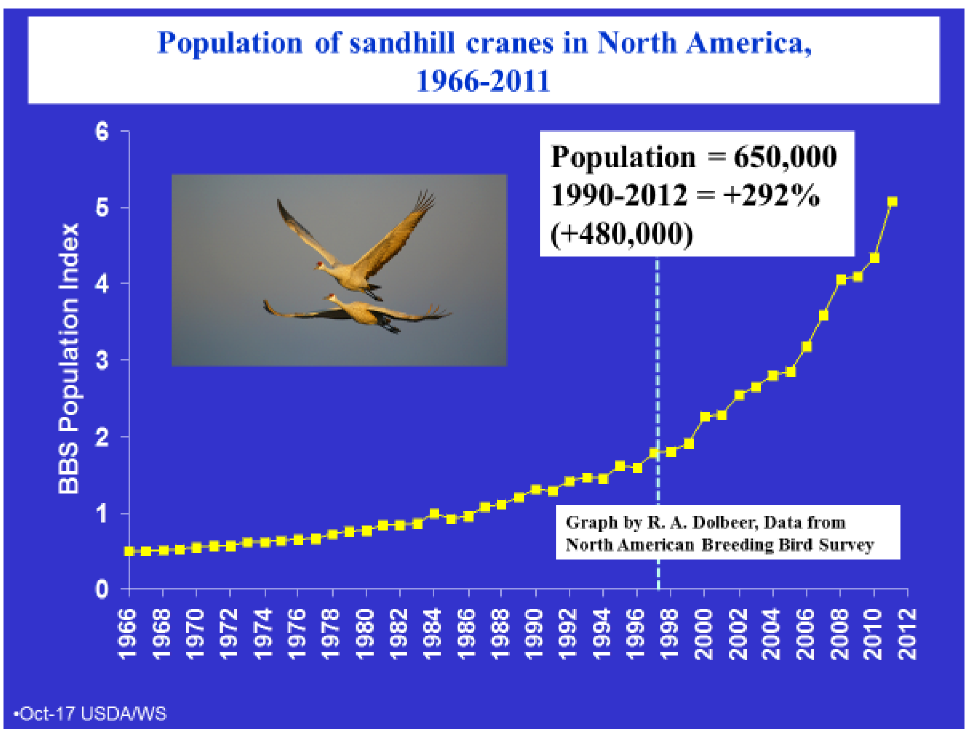
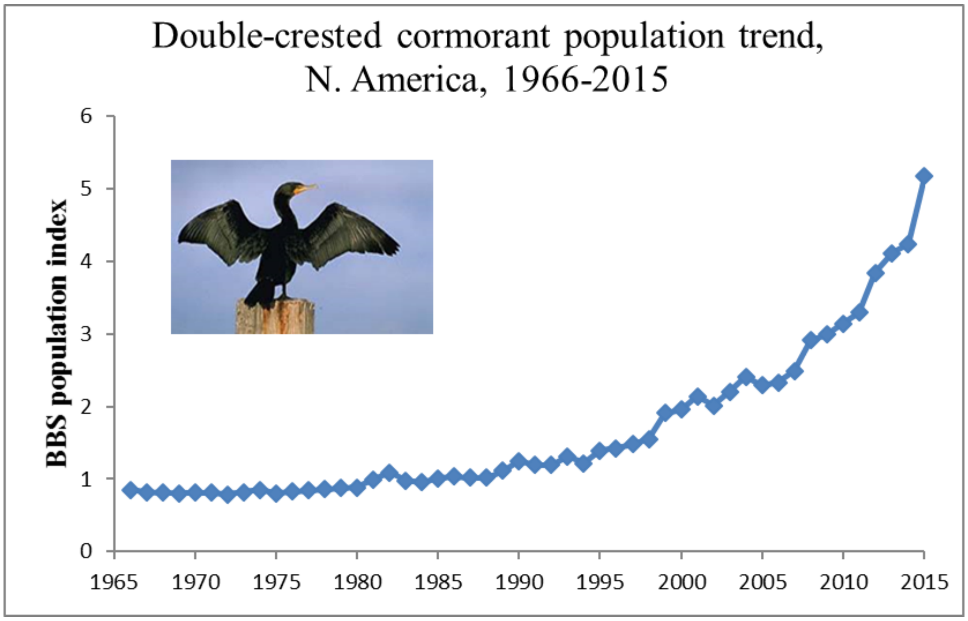


Figure C-7. Population of sandhill cranes (2.7-6.7 kg) in North America.



Graphs by R. A. Dolbeer based on data from North American Breeding Bird Survey

Figure C-8. Population of double-crested cormorants (2.1 kg mean body mass) in North America.

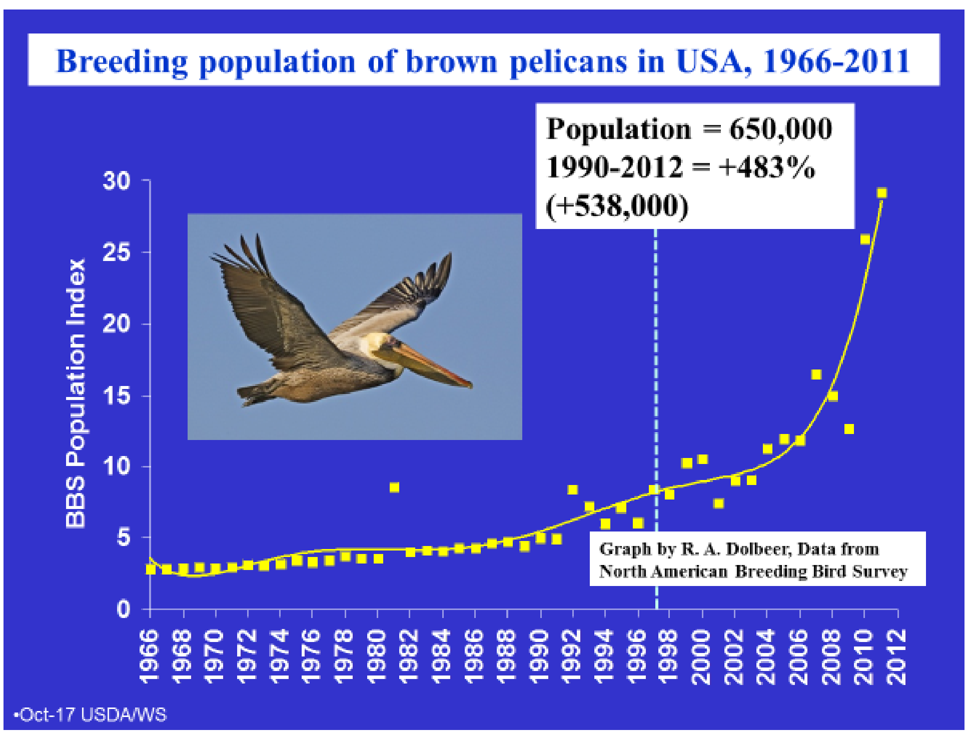


Figure C-9. Population of brown pelicans (2-5 kg) in USA.

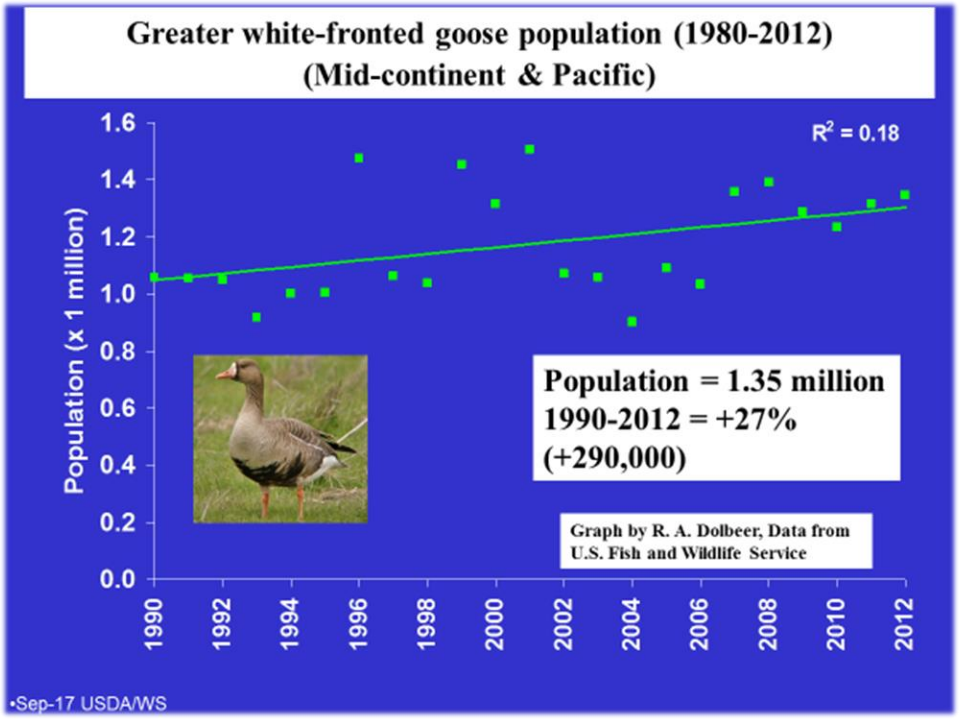


Figure C-10. Population of greater white-fronted goose (1.9-3.3 kg) in Mid-continent and Pacific regions.

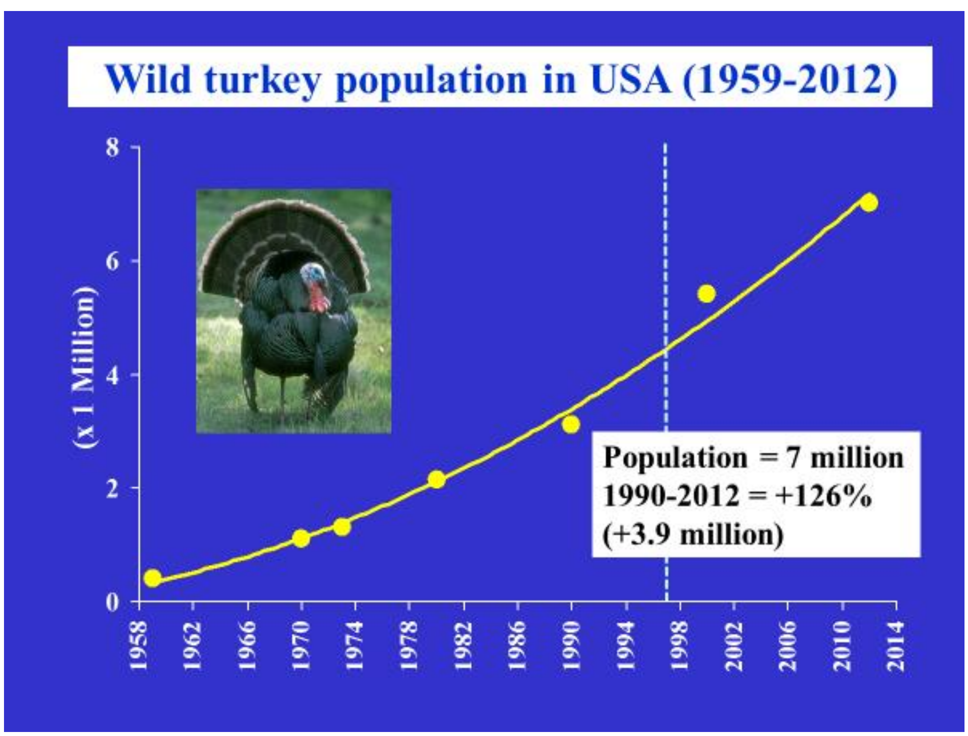


Figure C-11. Population of wild turkey (4.3-7.6 kg) in USA.

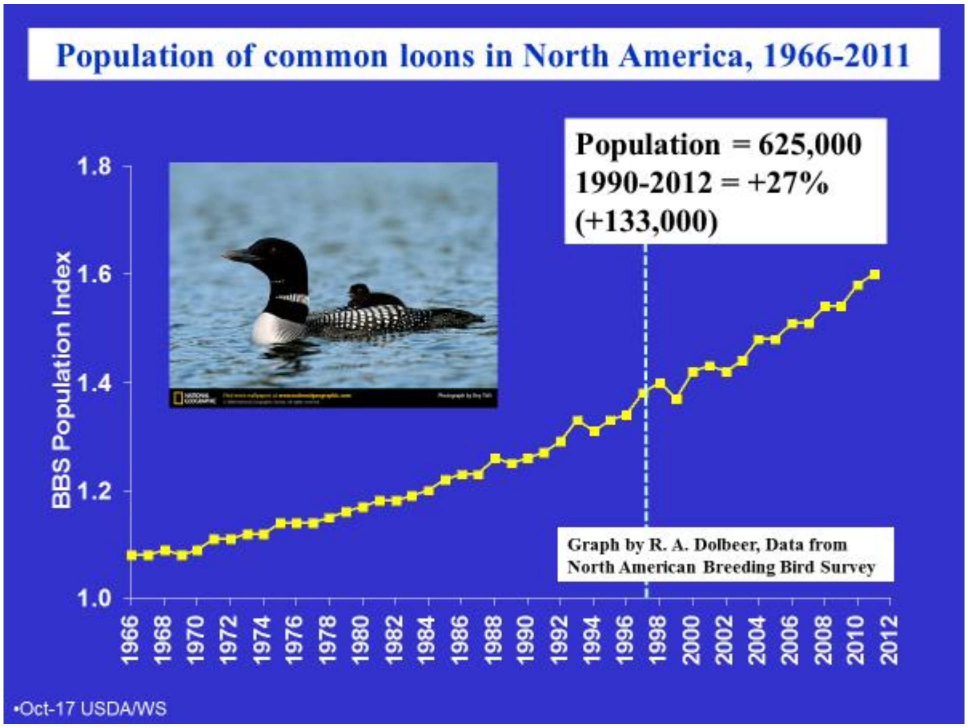


Figure C-12. Population of common loons (3.2-4.1 kg) in North America.

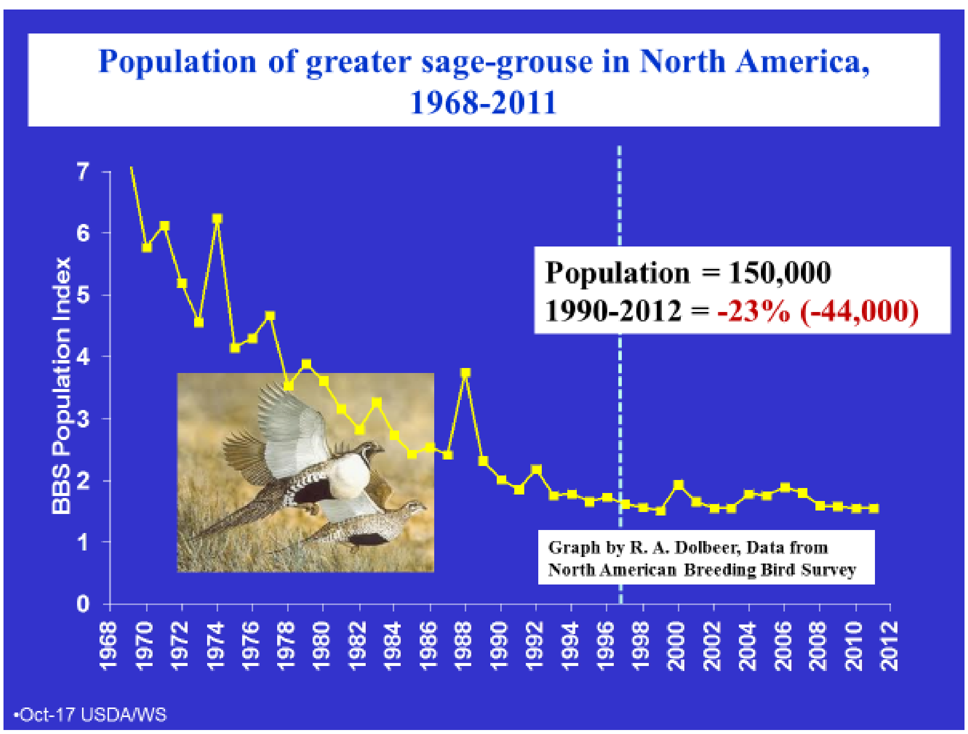
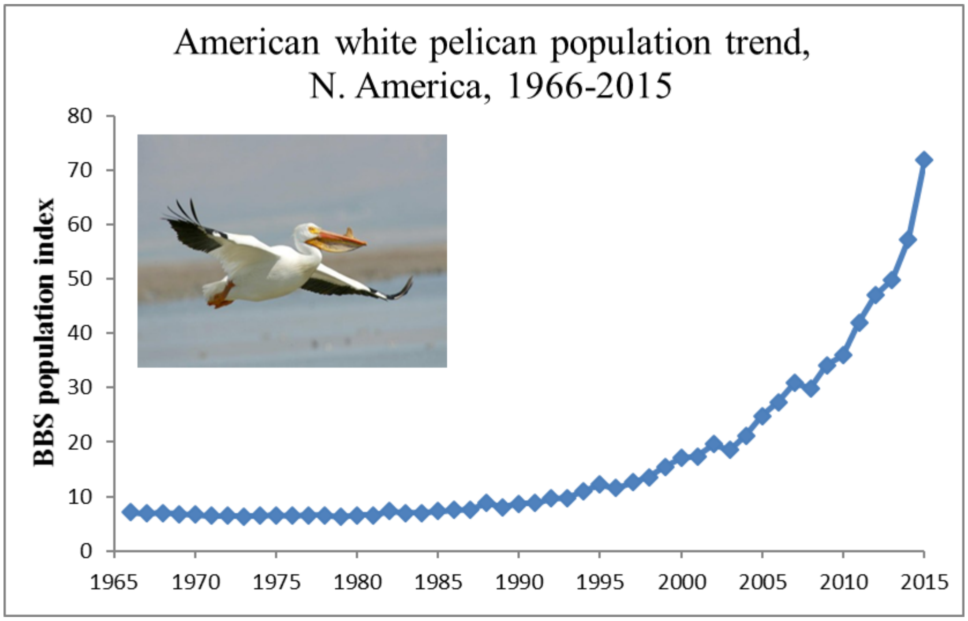


Figure C-13. Population of greater sage-grouse (1.3-2.7 kg) in North America.



Graphs by R. A. Dolbeer based on data from North American Breeding Bird Survey

Figure C-14. Population of white pelicans (6.3 kg mean body mass) in North America.

APPENDIX D –ARAC ROTORCRAFT BIRD STRIKE WORKING GROUP MEMBERS

- Cory Cummins, Co-Chair, Air Methods Corporation
- Michael Smith, Co-Chair, Bell Helicopter Textron
- Ken Furnes, Voting Member, Sikorsky Aircraft
- Joan Gregoire, Voting Member, MD Helicopters
- Chris Jenkins, Voting Member, Robinson Helicopters
- Eric Lincoln, Voting Member, Blue Hawaiian Helicopters
- Bernard Tagliana, Voting Member, Airbus Helicopters
- Tony Salerno, Voting Member, GKN Transparency Group
- Dan Schwarzbach, Voting Member, Airborne Law Enforcement Association
- Harold (Hal) L. Summers, Voting Member, Helicopter Association International
- William (Bill) Taylor, Voting Member, Enstrom Helicopter Corporation
- Phillip Woody, Voting Member, Leonardo Helicopters
- David Zaworski, Voting Member, Era Helicopters
- ▫ Tyson Daniel, Alternate Member, Airbus Helicopters
- ▫ Enrico Masiero, Alternate Member, Leonardo Helicopters
- ▫ Stephen Turnour, Alternate Member, Robinson Helicopters
- ▫ Jesse Vos, Alternate Member, Enstrom Helicopter Corporation
- ⦿ Michael (Mike) Begier, Non-Voting Member, USDA
- ⦿ Dr. Bradley Blackwell, Non-Voting Member, USDA
- ⦿ Dr. Travis DeVault, Non-Voting Member, USDA
- ⦿ Herdrice Hereson, Non-Voting Member, EASA
- ⦿ Laurent Pinsard, Non-Voting Member, EASA
- ⦿ Gary Roach, Non-Voting Member, FAA
- ⦿ John Weller, Non-Voting Member, FAA
- ⦿ Phyllis Miller, Supporting Member, FAA NWSD, USDA/APHIS/Wildlife Services

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