ROTORCRAFT OCCUPANT PROTECTION WORKING GROUP

TASKS 1 AND 2

COST-BENEFIT ANALYSIS REPORT TO THE AVIATION RULEMAKING ADVISORY COMMITTEE (ARAC)

Submitted: November 10, 2016

EXECUTIVE SUMMARY

BACKGROUND

In the 1980's and 1990's, the FAA amended rotorcraft regulations related to emergency landing conditions and fuel system crash resistance (14 CFR 27/29.561, .562, .785, and .952) to incorporate occupant protection rules in newly certificated rotorcraft. However, as is the case with almost any new regulation, newly manufactured rotorcraft with older certification bases were excluded from the requirements of the new rules. Thus, by the end of 2014 only 16% of the U.S. rotorcraft fleet were fully compliant with the upgraded fuel system requirements, and only 10% were fully compliant with the upgraded emergency landing requirements.

The Rotorcraft Occupant Protection Working Group (ROPWG) was formed to study a wide range of issues related to compliance with the current upgraded rules. The initial task, the result of which is presented in this document, was to perform a cost-benefit analysis for incorporating the existing protection standards (14 CFR 27/29.561, .562, .785, and .952) in newly manufactured rotorcraft.

COST METHODOLOGY

The ROPWG estimated the cost of the proposed regulatory changes by dividing the cost into two categories:

- Manufacturer costs, including:
    - Non-recurring costs: Expenses incurred for design, testing, certification, and retooling to meet compliance with the applicable regulations. This is the expense associated with the effort to develop and certify a fully-compliant aircraft.
    - Unit costs: Increased expenses incurred for parts and labor required for the installation of mandated features on each aircraft produced.

- Operator costs, which arise from the design changes required to comply with the applicable regulations, as follows:
    - Reduced passenger and/or cargo capacity and greater fuel burn due to an increase in empty weight.
    - Reduced range due to a decrease in fuel capacity.

The cost of Crash Resistant Seat and Structure regulations (CRSS; 27/29.561, .562, .785) and Crash Resistant Fuel System regulations (CRFS; 27/29.952) were calculated separately.

BENEFIT METHODOLOGY

The benefit of the proposed regulatory changes was calculated by examining crashes for rotorcraft manufactured over the past ten years and determining the injuries and fatalities that would have been avoided had those aircraft been compliant with the applicable regulations. A monetary benefit for these avoided injuries and fatalities was then calculated based on data from the Federal Aviation Administration (FAA) Office of Aviation Policy and Plans (APO).

The CRSS (Crash Resistant Seat and Structure) and CRFS (Crash Resistant Fuel System) benefits were determined separately, as follows:

- Crash Resistant Seat and Structure (CRSS; 27/29.561, .562, .785)
  - In the absence of conclusive accident data from helicopters certified to the latest design standards, the FAA Office of Accident Investigation and Prevention (AVP) provided an estimate for the expected reduction in injuries and fatalities.

- Crash Resistant Fuel System (CRFS; 27/29.952)
  - To determine the effectiveness of the applicable regulations, the ROPWG examined the incidence of post-crash fires and thermal injuries for helicopters fully compliant with 27/29.952. The data indicate that fully-complaint CRFS are extremely effective at preventing post-crash fires and thermal injuries.
  - The ROPWG examined accidents from the previous 10 years in which a post-crash fire occurred following an accident with a non-fully-compliant CRFS-equipped helicopter, and used the effectiveness data from the previous step to estimate the reduction in injuries and fatalities that would have occurred had a fully-compliant CRFS been installed.

RESULTS

The resulting cost and benefit estimates are shown in the table below, presented as the present-day value of the total costs over a 10-year period starting with an assumed compliance start date of January 1, 2020. The data indicates that the costs exceed the benefits.

Cost-Benefit Summary, Present Day Value at 7% Annual Discount				
Cost Category	CRSS (.561, .562, .785)		CRFS (.952)	
	Part 27	Part 29	Part 27	Part 29
Total 10-year OEM Costs	$200,467,906	$91,290,090	$29,050,137	$65,864,022
Total 10-year Operator Costs	$63,151,996	$20,225,009	$14,801,527	$7,328,821
Total 10-year Costs	$263,619,903	$111,515,099	$43,851,665	$73,192,843
Total 10-year Benefit	$64,026,666	$0*	$17,142,135	$0*
Net (Cost) or Benefit	$(199,593,237)	N/A*	$(26,709,530)	N/A*

*The working group was unable to estimate the benefit for Part 29 aircraft due to the small number of Part 29 accidents available for study.

DISCUSSION AND CONCLUSIONS

1. While compliance with 27.952 was found to be extremely effective at preventing post-crash fires and thermal injuries, the calculated benefit is lower than what otherwise might be expected due the following considerations:
   a. This analysis is limited to studying the benefit for future production only, which limits the reach of CRFS to a relatively small percentage of the future fleet.
   b. Several manufacturers have already started to voluntarily include partially compliant CRFS in newly produced aircraft, thereby lessening the effect of a future mandate

A much greater benefit (but also a much greater cost) is likely to be seen when the working group studies the effectiveness of retrofitting fielded aircraft with CRFS.

2. The proposed regulatory changes will likely lead to the elimination of some rotorcraft currently in production. Four OEMs participating in the ROPWG reported that the resulting aircraft performance impacts required for full compliance with the four proposed regulations would be so great that several models of aircraft would likely be discontinued.

3. It is the opinion of the working group that partial implementation of the subject regulations may provide a significant portion of the benefits while avoiding much of the costs. Further study during the next task phases of the ROPWG is expected and warranted.

4. The estimated benefits for compliance with 14 CFR 27/29.561, .562, and .785 (CRSS) have a high degree of uncertainty due to the lack of CRSS-compliant accident data.

5. There were only two Part 29 crashes included in the study dataset, both of which had indeterminate potential benefit from integration of the new rules. However, long term benefits for Part 29 rotorcraft are expected to be proportionate to the calculated Part 27 benefits when considering the different accident rates, accident severity, production rate, and occupancy load factors. The appropriate conversion factor was not determined during the current task.

6. In the opinion of some members of the ROPWG, the empty weight and fuel capacity/range penalties outlined in the OEM Performance Data section (Appendix C) could potentially increase the accident rate for the following reasons:
    a. Operation at higher gross weights (GWs), even when still under max gross take-off weight (MGTOW), will reduce power margins, thereby increasing potential for loss of tail rotor effectiveness, settling with power, catastrophic rotor stall, and the inability to prevent collision with obstacles in power-limited situations.

    b. As a result of the decrease in fuel capacity, pilots may experience pressure (self-induced and/or external) to operate closer to established fuel reserves as part of task completion, leading to a greater incidence of accidents due to fuel starvation.

    c. Operating at higher gross weights will increase mechanical stress on affected aircraft, increasing component fatigue damage, maintenance costs, and the probability of premature component failure.

   Unfortunately, it was not possible to provide a meaningful dollar estimate for the cost of the accident rate concerns outlined above.

7. In the opinion of some members of the ROPWG, the current FAA methodology for calculating economic costs of fatal and serious injuries significantly underestimates the actual societal costs of these injuries.

8. In the opinion of the ROPWG, the current FAA standard methodology does not accurately consider the practical costs of aircraft modification. The ROPWG sought to correct this by using a methodology that it feels more accurately predicts actual industry costs.

9. The cost-benefit analysis was greatly inhibited by the fact that neither NTSB nor FAA determine impact conditions in an accident investigation nor injuries for the involved occupants. Lack of these data render occupant protection analysis almost impossible. If such data were available in a database similar to the National Highway Traffic Administration, National Accident Sampling System (NASS), rulemaking related to occupant protection in aircraft accidents would be greatly facilitated by allowing more detailed and reliable determinations of injury causation and the relationship of injuries to the crash environment and aircraft crashworthiness capabilities. The ROPWG recommends that NTSB establish a system similar to NASS for aircraft crashes.

TABLE OF CONTENTS

TABLE OF FIGURES

<u>Appendices</u>

This page intentionally left blank

INTRODUCTION

Based upon recent crashes of non-compliant rotorcraft resulting in severe and fatal thermal and blunt force trauma as well as a recent FAA fatal injury study showing that the upgraded rules would have been effective in saving lives in rotorcraft crashes, the FAA tasked the Aviation Rulemaking Advisory Committee (ARAC) to consider the effect of requiring compliance with the current rules for all newly manufactured rotorcraft regardless of certification basis.

To explore these issues, the Rotorcraft Occupant Protection Working Group (ROPWG) was formed to study a wide range of issues related to full compliance with the current, upgraded rules. The first two tasks for the ROPWG were to: 1) perform a cost-benefit analysis for incorporating the existing protection standards (14 CFR 27/29.561, .562, .785, and .952) in newly manufactured rotorcraft, and 2) develop a cost-benefit report to be presented to ARAC. In performing this analysis, the ROPWG was tasked to:

1. Estimate what the regulated parties would do differently as a result of the proposed regulation and how much it would cost.
2. Estimate the improvement in survivability of future accidents.
3. Estimate any other benefits (e.g., reduced administrative burden) or costs that would result from implementation of the occupant protection standards identified above.

The ROPWG was formed in response to an announcement published in the Federal Register on November 5, 2015. The announcement requested interested parties with appropriate expertise to apply to the FAA for membership on the ROPWG. From the list of respondents, a Chairman was selected and he, along with the FAA Advisor to the working group, selected a committee consisting of nineteen voting members and three non-voting advisors (including the FAA Advisor). The list of members is included in Appendix A. To accomplish Tasks 1 and 2, the working group was divided into two task groups, the Cost Task Group and the Benefits Task Group. Each task group elected a Chair who reported to the ROPWG Chairman and was tasked to produce a separate report with cross-collaboration between both task group members. The general content of each Task Group report was discussed and modified at a ROPWG meeting on March 1, 2016. The ROPWG Chairman then combined the two reports and submitted the final report to the entire membership for final approval.

The initial report for Tasks 1 and 2 was submitted to the ARAC on March 13, 2016. Due to the short time period available to the working group to write this initial report, the initial report was not as detailed or thorough as desired, and the cost-benefit analysis results were limited. The working group thought that with additional time, a much more through, accurate, detailed, and useful analysis of Tasks 1 and 2 could be performed. The ARAC agreed, and granted the working group an additional 9 months to perform a more detailed analysis, and to submit a revised report for Tasks 1 and 2. This present document is that revised report; this report supersedes and replaces the initial draft submitted on March 13, 2016.

This report is organized by first presenting the cost to the industry (manufacturers and operators) of the proposed regulatory changes, following by a discussion of the benefits both in terms of injuries and fatalities prevented and the standard monetary valuation applied to these injuries/fatalities. There is then a discussion of the cost and benefit results, several conclusions, and followed by appendices that provide details of some of the analysis presented in the main body of the report.

COST ANALYSIS

The estimated cost of the proposed regulatory changes is best understood by dividing the costs into two categories:

- Original Equipment Manufacturer (OEM) costs consisting of non-recurring design costs and recurring manufacturing costs.
- Operator costs related to the reduction in payload, the reduction in fuel load/range, and the increase in the fuel burn rate caused by the required design changes.

Each of these cost categories are discussed in detail below.

SUMMARY OF OEM COST DATA

The ROPWG included representatives from all major OEMs, foreign and domestic, who still manufacture Part 27/29 rotorcraft for the U.S. market. For each of their currently produced aircraft models that are not currently fully compliant with 14 CFR 27/29.561, 27/29.562, 27/29.785, and 27/29.952, each OEM provided estimates of the Non-Recurring Costs and Unit Costs (defined below) that would be required to become fully compliant with these regulations.

- **Non-recurring costs:** The expenses incurred for design, testing, certification, and retooling to meet compliance with the applicable regulations. This is the expense associated with the effort to develop and certify a fully-compliant aircraft.
- **Unit costs:** The increased expenses incurred for parts and labor required for installation of mandated features on each aircraft produced.

Non-Recurring Costs

On the following page, Table 1 details the OEM estimated non-recurring costs required to bring non-compliant rotorcraft models still in production into compliance with current occupant protection regulations (27/29.561, 27/29.562, 27/29.785, and 27/29.952). Note that Part 27 rotorcraft were broken into three sub-categories to better represent the wide range of Part 27 helicopter types. Regulations were also divided into two groups:

- Parts 27/29.561, 27/29.562, and 27/29.785 represents regulations primarily pertaining to structure
- Part 27/29.952 relates to fuel systems

For convenience, we refer to the regulations pertaining to structure as Crash Resistant Seats and Structure (CRSS) and those pertaining to fuel systems as Crash Resistant Fuel Systems (CRFS).

Table 1. Industry Total Non-Recurring Costs (USD) of Compliance for Models Still in Production			
Rotorcraft Groups	**Non-recurring Cost, CRSS (.561,.562, and .785)**	**Non-recurring Cost, CRFS (.952)**	**Total Non-Recurring Costs (.561, .562, .785, .952)**
Part 27 - Single Piston	$19,150,000	$4,700,000	$23,850,000
Part 27 - Single Turbine	$165,600,000	$10,410,000	$176,010,000
Part 27 - Twin Turbine	$300,000	$0	$300,000
Part 29	$72,700,000	$75,580,000	$148,280,000
All Groups Combined	**$257,750,000**	**$90,690,000**	**$348,440,000**

Unit Costs

Table 2 summarizes OEM-provided estimates of the unit costs required to bring Part 27 and Part 29 rotorcraft currently in production into compliance with current occupant protection regulations (27/29.561, 27/29.562, 27/29.785, and 27/29.952). Note that Table 2 is divided so that unit costs for Part 27 helicopters and Part 29 helicopters, and costs for CRSS and CRFS, can be determined separately. Also, note that the costs presented in Table 2 and subsequent tables are (as applicable) weighted averages based on the estimated number of helicopters of each model within the category expected to be produced.

Table 2. Unit Costs (USD) to Bring Models Still in Production Up to Standard								
Rotorcraft Groups	**Estimated Annual Production**	**Weighted Average Unit Costs (.561, .562, and .785) (per aircraft)**	**Total Annual Unit Costs (.561, .562, .785)**	**Weighted Average Unit Costs (.952) (per aircraft)**	**Total Annual Unit Costs (.952)**	**Combined Weighted Average Unit Costs (.561, 562, .785, .952) (per aircraft)**	**Combined Total Annual Unit Cost (.561, .562, .785, .952)**	**10-Year Total Unit Cost Increase**
Part 27 - Single Piston	85	$12,753	$1,084,000	$6,559	$557,500	$19,312	$1,641,520	$16,415,200
Part 27 - Single Turbine Models	84	$110,179	$9,255,000	$29,748	$2,498,800	$139,927	$11,753,868	$117,538,680
Part 27 - Twin Turbine	3	$1,000	$3,000	$0	$0	$1,000	$3,000	$30,000
All Part 27	172	N/A	$10,342,000	N/A	$3,056,300	N/A	$13,398,388	$133,983,880
Part 29	13	$480,692	$6,249,000	$110,077	$1,431,000	$590,769	$7,679,997	$76,799,970
Total Parts 27 & 29	**185**	**N/A**	**$16,591,000**	**N/A**	**$4,487,300**	**N/A**	**$21,078,385**	**$210,783,850**

Discussion
Non-recurring and unit costs varied widely between aircraft models due to differences in certification basis (starting point) and differences in OEM design standards. Also, it should be noted that the values in Table 2 reflect the broader OEM estimates for specific aircraft in production, while the fuel systems data in Appendix D represents the costs for components to outfit generic, non-specific Part 27/29 aircraft. Lastly, note that these costs only apply to newly manufactured aircraft; retrofitting of fielded aircraft would likely be far costlier, and will be the subject of further study by the ROPWG.

International Cost Considerations
While OEMs were asked to discern costs specific to the U.S. market vs. the international market, OEMs working in international operations reported a dispersion of engineering and manufacturing costs across different countries, making specific demarcations of U.S. costs vs. international costs unfeasible for this report. Airbus provided the following statement:

> "*Airbus Helicopters is a global company. Engineering activities are performed in Europe and/or in Customer Centers Design Offices (including AHI and Vector Design Offices in the US) and wherever the NRC are spent, they impact product cost of sales worldwide.*
>
> *Allocation of engineering activities is performed on a case-by-case basis for each project depending on competences/resources availability. Considering the maturity of the potential modifications required, it is premature to assess the workload distribution between US and the rest of the world."*

SUMMARY OF OPERATOR COST DATA

As detailed in the Summary of Rotorcraft Performance Data below, revising older airframe designs to fully comply with the applicable regulations generally requires an increase in empty weight, reduced fuel capacity, and a resulting reduced range, and/or reduced seating capacity of the affected rotorcraft. These changes in the aircraft will result in significant monetary costs to operators by requiring affected operators to make any or all the following changes to their operations:

- Reducing the number of passengers and/or cargo capacity
- Reducing the fuel load and therefore reducing the range of the aircraft
- Experiencing an increase in fuel burn rate due to greater empty weight

To estimate the cost due to the reduction in passengers and cargo, the following methodology was used:

Total Yearly Cost to Industry = N * C * H * P

where,

N =The number of helicopters in the US fleet that are subject to the regulatory changes under consideration

C = Average baseline cost (before the regulatory changes take effect) to operate a single helicopter, in USD per flight hour

H = Average number of flight hours per year per aircraft

P = Average percentage increase in costs/reduction in revenue per flight hour

The average percentage increase in costs for the operators due to payload loss was assumed to be a percentage of the baseline direct operating cost equal to the percentage loss of payload (Appendix B).

The cost to operators of reduced fuel capacity/reduced range assumed that for a percentage of flights equal to the percentage reduction in fuel capacity/range, operators would have to use a different helicopter at an additional cost of 20% per flight hour (Appendix B).

The increased fuel consumption was assumed to be 0.005 gallons per flight hour per extra lb. of empty weight (Appendix B). The cost was calculated by assuming an affected fleet size, average flight hours per year, and average cost of fuel.

For the helicopters manufactured in the first year after the proposed changes are required, the total yearly cost to operators from these considerations is shown in Table 3 (calculation of the individual parameters defined above are detailed in Appendix B). Consistent with other sections of this report, data is summarized for four different classes of helicopter and was determined using weighted averages based upon the estimated annual production of each model of helicopter. Thus, giving appropriate weight to each helicopter model based upon the quantity expected to be produced.

Table 3. Total Increase in Operator Costs/Decrease in Operator Revenue Due to Changes in Payload, Fuel Capacity, and Range, Per Year

Aircraft Type	CRSS: .561, .562, .785	CRFS: .952	Combined
Single Engine Piston	$421,605	$85,719	$507,324
Single Engine Turbine	$1,805,391	$436,243	$2,241,635
Twin Turbine (Part 27)	$0	$0	$0
Part 29	$713,216	$258,444	$971,660
Total	**$2,940,213**	**$780,406**	**$3,720,618**

While this total yearly cost to operators is relatively small in comparison to the non-recurring OEM costs, this is an annual recurring cost for the operator, which grows at an accelerated pace as more affected helicopters enter the fleet. Helicopters that are manufactured in Year 1 incur this annual increase in cost of operation each year in Year 1 through Year 10 (and all subsequent years), helicopters manufactured in Year 2 incur this annual increase cost of operation each year in Year 2 through Year 10, and so forth. As a result, in the first 10 years after the proposed regulations take effect, the total cumulative additional operator cost is:

Cumulative cost = Additional operator cost for Year 1 * (10 + 9 + 8 + ... + 2 + 1)

or

Cumulative cost = Additional operator cost for Year 1 * 55

Table 4. Cumulative Increase in Operator Costs/Decrease in Operator Revenue Due to Changes in Payload, Fuel Capacity, and Range, First 10 Years After Regulatory Changes			
Aircraft Type	**CRSS: .561, .562, .785**	**CRFS: .952**	**Combined**
Single Engine Piston	$23,188,281	$4,714,519	$27,902,800
Single Engine Turbine	$99,296,532	$23,993,382	$123,289,914
Twin Turbine (Part 27)	$0	$0	$0
Part 29	$39,226,895	$14,214,404	$53,441,299
Total	**$161,711,709**	**$42,922,305**	**$204,634,014**

Note that this 10-year cost analysis simply adds together the costs for each of the first ten years of affected helicopters (Table 4). It does not account for interest nor use any other more sophisticated financial analysis.

Additional Monetary Considerations

Older airframes revised to meet the applicable regulations may not meet an operator's existing contract requirements due to the performance penalties discussed above, forcing the operators to renegotiate contracts or purchase a different model helicopter. Unfortunately, it was not possible to provide a meaningful dollar estimate for this cost.

SUMMARY OF ROTORCRAFT PERFORMANCE DATA

This section presents estimates of OEM performance penalties, which are used in the Operator Cost sections, including Appendix B, of this report.

Aircraft performance was evaluated consistent with the methods used to evaluate OEM Costs. The aircraft models were separated by Parts 27 and 29; then Part 27 was broken into three subcategories. Costs for the four categories were determined using weighted averages based upon the estimated annual production of each model of helicopter, thus giving appropriate weight to each helicopter model based upon the quantity expected to be produced. From there, performance was evaluated based on the following criteria:

- Reduction in payload
- Reduction in fuel capacity
- Increase in fuel consumption

Reduction in Payload

Table 5 outlines the weighted average reduction in payload for each of the four aircraft categories due to the increase in basic empty weight required to comply with the applicable regulations. The increase in basic empty weight is required due to:

- The incorporation of fuel bladders.
- The increase in strength required by incorporation of the structural requirements required in 27/29.952(b).
- The increased weight of crashworthy seats.
- The increased fuselage strength required to properly support the new seats.

In addition to these factors, for some helicopter models, compliance with 27/29.562 would reduce the number of passengers due to the inability to install complaint seats; in those instances, it was assumed that the "effective" loss of payload due to the loss of a passenger was equal to 85 pounds per lost passenger (see Appendix B).

Table 5. Weighted Average Reduction in Effective Payload

Subcategory	Avg. Payload Δ (lbs.) CRSS: (.561, .562, .785)	Avg. Payload Δ (lbs.) CRFS: (.952)	Total Avg. Payload Δ (lbs.)
Part 27 – Single Piston	50.0	8.5	58.5
Part 27 – Single Turbine	140.5	15.6	156.1
Part 27 – Twin Turbine	0.0	0.0	0
Part 29	271.8	72.4	344.2

<u>Reduction in Fuel Capacity</u>

Fuel capacity reductions varied widely because they differed in root cause. Large reductions in fuel capacities originated from aircraft models where energy absorbing (EA) seats required structural changes that impact fuel storage. Small decreases in fuel capacity generally resulted from the addition of fuel cell bladders and the volume they consume. Table 6 outlines the average fuel capacity reduction by aircraft category.

Table 6. Weighted Average Reduction in Fuel Capacity

Subcategory	Total Avg. Fuel Capacity Δ (lbs.)
Part 27 – Single Piston	3.1
Part 27 – Single Turbine	67.8
Part 27 – Twin Turbine	0
Part 29	79.6

<u>Increase in Fuel Consumption</u>

In general, engine fuel consumption increases as aircraft weight increases, however the impact is platform dependent and is often influenced by several variables. The FAA has previously used 0.005 gallon per pound per hour; since this value was within the range that each OEM provided for their respective models, for consistency this FAA accepted value was selected for this study[1]. This value was used by the operators to determine additional fuel costs per year based on their operations.

[1] Castedo, J. (2014). *Regulatory Evaluation: Air Ambulance and Commercial Helicopter Operations, Part 91 Helicopter Operations, and Part 135 Aircraft Operations; Safety Initiatives and Miscellaneous Amendments.* Washington, DC: US Dept. of Transportation, FAA, Office of Aviation Policy and Plans, Operations Regulatory Analysis Branch, APO-310

SUMMARY OF ESTIMATED COSTS TO INDUSTRY FOR COMPLIANCE WITH CURRENT REGULATIONS

Non-recurring costs, ten-year anticipated unit cost increase, and ten-year operator cost increases caused by compliance with 27/29. 561, .562, .785, and .952 are combined and are summarized in Table 7. All costs are shown in 2016 dollars. The costs are broken down by Part 27 and Part 29 helicopters as well as by regulation type (CRSS or CRFS). Note that the total estimated ten-year increased industry costs were estimated at approximately $764M.

Table 7. Summary of 10-Year Industry Costs (USD) of Compliance for Models Still in Production

Cost Category	Part 27	Part 29	Combined Costs Parts 27 & 29
Non-Recurring Cost (.561,.562, and .785)	$185,050,000	$72,700,000	$257,750,000
Non-recurring Cost (.952)	$15,110,000	$75,580,000	$90,690,000
Total Non-Recurring Costs (.561, .562, .785, .952)	$200,160,000	$148,280,000	$348,440,000
10-Year Unit Cost Increase (.561, .562, .785)	$103,420,000	$62,490,000	$165,910,000
10-Year Unit Cost Increase (.952)	$30,563,000	$14,310,000	$44,873,000
10-Year Total Unit Cost Increase	133,983,000	$76,800,000	$210,783,000
Total 10-Year OEM Costs	$334,143,000	$225,080,000	$559,223,000
10-Year Operator Cost Increase	$151,192,715	$53,441,299	$204,634,014
Total 10-Year Estimated Industry Cost	**$485,335,715**	**$278,521,299**	**$763,857,014**

Table 8 breaks down the projected ten-year OEM costs by CRSS and CRFS to better demonstrate the relative costs of the two groups of regulations. Note that for Part 27 rotorcraft the total OEM cost for CRSS is projected to be approximately $288M or more than six times that of implementation of CRFS, which is estimated to be approximately $46M. For Part 29 rotorcraft, the costs for CRSS implementation are about 1.5 times the costs of CRFS implementation.

Table 8. OEM Cost Summary

Cost Category	CRSS (.561, .562, .785)		CRFS (.952)	
	Part 27	Part 29	Part 27	Part 29
Non-Recurring costs	$185,050,000	$72,700,000	$15,110,000	$75,580,000
Unit Costs	$103,420,000	$62,490,000	$30,563,000	$14,310,000
Total OEM Costs	**$288,470,000**	**$135,190,000**	**$45,673,000**	**$89,900,000**

Table 9 shows projected costs and present value costs discounted at an annual 7% for OEMs over a ten-year period if current rules are applied to new production rotorcraft, both Part 27 and Part 29, in 2020. 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 costs for year 2020 include non-recurring costs plus annual unit costs. For the remaining years, only annual unit costs are included based on the assumption that unit costs are paid in the first year.

Table 9. Costs and Present Value Costs for OEMs over 10-years

Calendar Year	Costs in 2016 Dollars	Present Value Costs at 7%
2015		
2016		
2017		
2018		
2019		
2020	$369,518,300	$281,903,742
2021	$21,078,300	$15,028,537
2022	$21,078,300	$14,045,361
2023	$21,078,300	$13,126,506
2024	$21,078,300	$12,267,763
2025	$21,078,300	$11,465,199
2026	$21,078,300	$10,715,139
2027	$21,078,300	$10,014,148
2028	$21,078,300	$9,359,017
2029	$21,078,300	$8,746,745
	$559,223,000	**$386,672,156**

Table 10 shows projected 2016 costs and present value costs discounted at 7% for both OEMs and operators over a ten-year period if current rules are applied to new production rotorcraft, both Part 27 and Part 29, in 2020. Table 11 provides a comparison of this data.

Table 10. Costs and Present Value Costs for OEMs and Operators Over 10-years		
Calendar Year	**Costs in 2016 Dollars**	**Present Value Costs at 7%**
2015		
2016		
2017		
2018		
2019		
2020	$373,239,003	$284,742,248
2021	$28,519,621	$20,334,096
2022	$32,240,239	$21,483,033
2023	$35,960,857	$22,394,614
2024	$39,681,475	$23,094,980
2025	$43,402,093	$23,607,863
2026	$47,122,711	$23,954,797
2027	$50,843,329	$24,155,299
2028	$54,563,947	$24,227,045
2029	$58,284,565	$24,186,022
	$763,857,840	**$492,179,997**

Table 11. 10-Year Total Projected Costs and Present Value Costs		
	2016 Costs	**Present Value Costs at 7%**
OEM Costs	$559,223,000	$386,672,156
Operator Costs	$204,634,010	$105,507,353
Total	**$763,857,010**	**$492,179,997**

Other Considerations

Note that opportunities likely exist to reduce associated costs while still achieving significant improvement in safety by considering alternative regulations or partial compliance with existing regulations, equivalent levels of safety, and alternate means of compliance. For example:

- Selecting subpart sections as opposed to entire subparts, e.g., installation of drop-tested bladders without modification to structural load requirements, structural load criteria focus on critical areas and Energy Attenuating Seats without 27/29.561 requirements.
- Assessment of service experience
- Acceptance of qualification testing not witnessed by FAA and/or substantiation by analysis where analysis is validated by prior testing results.

Further study of these issues by the ROPWG is warranted and will be accomplished in subsequent phases of the current study.

Non-Monetary Considerations

In addition to the monetary costs due to the factors listed above, the ROPWG cost-group members with aircraft engineering and operator expertise expressed cautionary concerns about the effects of the regulations on smaller Part 27 aircraft. The empty weight and fuel capacity/range penalties outlined in the OEM Performance Data section (Appendix C) could potentially increase the accident rate for the following reasons:

- Operation at higher gross weights (GWs), even when still under max gross take-off weight (MGTOW), will reduce power margins. This creates an increased potential for loss of tail rotor effectiveness, settling with power, catastrophic rotor stall, and the inability to prevent collision with obstacles in power-limited situations.
- Increased empty weight may be offset by decreasing fuel loads. Pilots may experience pressure (self-induced and/or external) to operate closer to established fuel reserves as part of task completion, leading to a greater incidence of accidents due to fuel starvation.
- Operation at higher GWs will increase mechanical stress on affected aircraft, increasing component fatigue damage, maintenance costs, and the probability of premature component failure.

Unfortunately, it was not possible to provide a meaningful dollar estimate for the cost of the accident rate concerns outlined above. However, the ROPWG believes these factors are significant, especially for smaller helicopters. It is left to the reader to decide how to include these concerns in the final cost-benefit analysis.

Lastly, it must be understood the proposed regulatory changes will likely lead to the elimination of some rotorcraft currently in production. Four OEMs participating in the ROPWG reported that the resulting aircraft performance impacts required for full compliance with the four proposed regulations would be so great that several models of aircraft would likely be discontinued. Unfortunately, it was not possible to provide a meaningful dollar estimate for this effect.

BENEFITS ANALYSIS

INTRODUCTION

The Benefits Task Group was tasked with determining the approximate benefits in dollars as well as other benefits of all newly manufactured rotorcraft complying with current 14 CFR Part 27 and Part 29 regulations for a ten-year production period. The general approach was to examine crashes for rotorcraft manufactured over the past ten years which are representative of future production, and determine the injuries and fatalities that would have been avoided had those aircraft been compliant with the applicable regulations. A monetary benefit for these avoided injuries and fatalities was then calculated based on data from the Federal Aviation Administration (FAA) Office of Aviation Policy and Plans (APO). The Crash Resistant Seat and Structure (CRSS) and Crash Resistant Fuel System (CRFS) benefits were determined separately.

Note that the calculations in the section reflect the benefit that would have been seen had the previous 10 years of production aircraft been compliant with the applicable regulations, whereas the calculations in the cost section are based on estimates of future production for the next 10 years. Ideally, the benefit data would be scaled to match the production levels predicted for the future; unfortunately, this was not possible due to the inability of the working group to obtain reliable production numbers for all manufacturers for the entire 2006-2015 timeframe. While the 2006-2015 production quantities likely do not perfectly match those forecast for the next 10 years, the resulting error was considered acceptable as it is likely relatively small in comparison to the uncertainties present in the cost and benefit calculations.

VALUATION OF INJURIES AND FATALITIES

The Federal Aviation Administration (FAA) Office of Aviation Policy and Plans (APO) estimates for the value of preventing serious injuries and fatalities are reported in Table 12. These values were utilized for the benefit calculations for this report unless otherwise noted. These values may be lower than the actual societal costs; additional discussion on the valuation of injuries is included in Appendix F.

Table 12. Recommended Injury Values Based on the NTSB Classification of injuries (2015 USD).

NTSB Classification	Fractional Values of Life	Dollar Value
Fatal	1.000	$9,600,000
Serious	0.253	$2,428,800
Minor	0.003	$28,800

DEVELOPMENT OF DATASET

The crash data was extracted from the NTSB's Microsoft Access database, current through June 1, 2015. The above query resulted in 1,445 accident records. The initial filter criteria were as follows:

- regis_no = N* (all U.S. registered only)
- acft_category = heli (helicopters only)
- ev_type = *acc* (accidents only, not incidents)
- ev_date = Between 1/1/2006 and 12/31/2015 (date of accident; most recent 10-year data available)
- homebuilt = *N* or is null (excludes homebuilt helicopters that were not type certificated and catches cases where NTSB inadvertently left the field unpopulated)

The dataset was then filtered to only retain crashes of rotorcraft manufactured between January 1, 2006 and December 31, 2015. Crashes involving rotorcraft that were manufactured fully compliant to current 14 CFR Part 27 and Part 29 regulations were also removed. In addition, only accidents which resulted in at least one occupant receiving serious or fatal injuries were retained. The injury filter eliminated minor accidents where CRSS and/or CRFS compliance would be expected to provide minimal benefit. This dataset filtering resulted in 56 Part 27 accidents as shown in Table 13, and two Part 29 accidents as shown in Table 14.

Table 13. Crashes of Non-compliant Part 27 Rotorcraft Manufactured from 2006-2015, CRSS Evaluation Dataset

NTSB ID No.	Make	Model	Registration	F	S	M	N
WPR14LA160	Agusta	AW109SP	N361CR		1		3
CEN11FA118	Airbus	AS350-B2	N549AM		3		
CEN13FA344	Airbus	AS350-B2	N935EM	1	1	2	
ERA13LA421	Airbus	AS350-B2	N810LE		1	3	
CEN15FA171	Airbus	AS350-B2	N919EM	1	2		
ERA10MA188	Airbus	AS350-B3	N855HW	3			
WPR10FA371	Airbus	AS350-B3	N509AM	3			
CEN14GA109	Airbus	AS350-B3	N3948A		1	2	
WPR14FA195	Airbus	AS350-B3	N840PA	1			
WPR16FA040	Airbus	AS350-B3	N74317	2	1		
CEN15FA290	Airbus	AS350-B3E	N390LG	1	2		
WPR16FA029	Airbus	AS350-B3E	N711BE	2			
WPR12GA106	Bell	407	N407HL	1	2		
ERA13FA014	Bell	407	N108MF	2	1		
CEN13FA122	Bell	407	N445MT	3			
DEN07LA142	Bell	206-L4	N1813		2	1	
CEN10CA138	Enstrom	280FX	N327TB		1	1	
CEN09WA390	Enstrom	480B	N878EE	1			
ERA11FA042	MDHI	369E	N765WH	1	1	2	
SEA08CA032	Robinson	R22 BETA	N463SH		1		1
LAX08FA052	Robinson	R22 BETA	N705JJ	1			
NYC08LA078	Robinson	R22 Beta	N179SH		1		
WPR09FA284	Robinson	R22 BETA	N149SH	1			
CEN10FA019	Robinson	R22 BETA	N3234G	2			
WPR12LA362	Robinson	R22 BETA	N208WM		1	1	
CEN12FA621	Robinson	R22 BETA	N281RG	2			
WPR14LA356	Robinson	R22 BETA	N4187W		1	1	
WPR09FA104	Robinson	R22 BETA II	N4160A	1			
CEN13LA148	Robinson	R22 BETA II	N3059Q		2		

Table 13 (Continued). Crashes of Non-compliant Part 27 Rotorcraft Manufactured from 2006-2015, CRSS Evaluation Dataset							
NTSB ID No.	**Make**	**Model**	**Registration**	**F**	**S**	**M**	**N**
SEA07FA006	Robinson	R44	N769RT	1	1		
ERA09FA497	Robinson	R44	N33PX	1	1		
ERA10LA019	Robinson	R44	N3038W		1	3	
ANC10LA053	Robinson	R44	N333DV	1			
ERA13FA186	Robinson	R44	N3101H	2			
DFW08FA218	Robinson	R44 II	N41411	2			
CHI08FA293	Robinson	R44 II	N999ZD	2			
WPR09FA076	Robinson	R44 II	N168SH		2		
WPR09LA460	Robinson	R44 II	N4174P		2		
ERA10FA403	Robinson	R44 II	N34JS	2			
ERA11CA180	Robinson	R44 II	N4168W		1		
CEN11FA468	Robinson	R44 II	N42333	1			
CEN12FA139	Robinson	R44 II	N369TL	2			
CEN13FA010	Robinson	R44 II	N474FA	3			
WPR13FA054	Robinson	R44 II	N4204A	1			
WPR13CA064	Robinson	R44 II	N557AC		1	2	
CEN13FA295	Robinson	R44 II	N569BC	2			
CEN13FA517	Robinson	R44 II	N3156U	3			
CEN14LA149	Robinson	R44 II	N360AH		1		2
ANC14FA030	Robinson	R44 II	N392GP	1			
WPR15FA051	Robinson	R44 II	N3234U	2			
ERA15FA164	Robinson	R44 II	N30242	3			
CEN15LA375	Robinson	R44 II	N445HS		2		
CEN15LA387	Robinson	R44 II	N440SA		3	3	
CEN16LA039	Robinson	R44 II	N449MC		2	1	1
ERA10FA283	Schweizer	269C-1	N73SJ	1	1		
LAX08CA138	Schweizer	300C	N1510A		1		1
Part 27 Total: 56 Accidents				**59**	**44**	**22**	**8**

Table 14. Crashes of Non-compliant Part 29 Rotorcraft Manufactured from 2006-2015, CRSS Evaluation Dataset							
NTSB ID No.	**Make**	**Model**	**Registration**	**F**	**S**	**M**	**N**
NYC08WA131	Bell	412EP	N417EV	10			
CEN09MA117	Sikorsky	S-76C	N748P	8	1		
Part 29 Total: 2 Accidents				**18**	**1**	**0**	**0**

No additional filtering was required for the CRSS benefit calculations. However, additional filters were required for the CRFS evaluation as only accidents with reported post-crash fire needed to be evaluated, and to ensure the dataset accurately represents future production rotorcraft. Additional details of the CRFS filter are contained in the CRFS benefit subsection.

BENEFITS OF IMPLEMENTING 14 CFR PARTS 27/29.561, .562 AND .785 (CRSS)

Ideally, accident data from helicopters that were fully compliant with the CRSS regulations would be used to show the effectiveness of these requirements. Unfortunately, as noted in the introduction, only 10% of the rotorcraft fleet is compliant with these regulations, and as a result, there was insufficient data to prove the effectiveness based on actual accident data.

Therefore, in the absence of conclusive accident data, the FAA Office of Accident Investigation and Prevention (AVP) was requested to evaluate the accident dataset and score the crashes for projected effect of implementing CRSS in rotorcraft involved in the crashes. Initially, the AVP assessed whether CRSS would have prevented the fatalities in the 58 crashes. To accomplish this, they evaluated only the 37 crashes with one or more fatalities (fatal accidents).

Seven accident reports lacked sufficient information for scoring, so they were not evaluated. This left 30 out of 37 fatal accident records available for scoring for projected effectiveness of rule changes. These accidents were scored as high, medium, low, or zero as follows:

- High – 2 accidents
- Medium – 6 accidents
- Low – 7 accidents
- Zero - 15 accidents

FAA APO then assigned the following effectiveness values:

- High effectiveness (84%)
- Medium effectiveness (50%)
- Low effectiveness (16%)
- Zero effectiveness (0%)

There were just two Part 29 rotorcraft accidents in the 58-accident dataset. One accident occurred in Peru and accident details were not available for scoring. The other was an extreme accident (non-survivable) which received a zero score. Therefore, there is insufficient data to independently determine the CRSS benefit for Part 29 rotorcraft.

Table 15 below shows the estimated benefits of preventing fatalities and injuries associated with the potential future recurrence of each of the 15 historical fatal accidents where it was determined that CRSS would have been of some benefit. These estimated benefits have been adjusted for the projected probability of effectiveness of the rule in preventing the recurrence of similar injury outcomes in the future. Only the CRSS applicability effectiveness is applied in the table. The following assumptions were applied:

- A Rotorcraft Occupant Protection (ROP) rule would take effect in 2020.
- The value of a statistical life (VSL) is $9.6M. [2]

---

[2]FAA Office of Aviation Policy and Plans, U.S. Federal Aviation Administration, "Economic Values for FAA Investment and Regulatory Decisions, a Guide Final Report," Updated September 2016.

- The value of a serious injury is $2,428,800. [3]
- The value of a minor injury is $28,800. [4]

Table 15. Benefits from Avoided Fatalities and Injuries by CRSS in Fatal Accidents, Part 27

No	NTSB ID	Injury			Fatality Costs	Serious Injury Costs	Minor Injury Costs	Total Casualty Cost	AVP Score	Benefits from Avoided Fatalities and Injuries
		F	S	M						
1	SEA07FA006	1	1	0	$9,600,000	$2,428,800	$0	$12,028,800	0.5	$6,014,400
2	WPR09FA284	1	0	0	$9,600,000	$0	$0	$9,600,000	0.16	$1,536,000
3	ERA09FA497	1	1	0	$9,600,000	$2,428,800	$0	$12,028,800	0.5	$6,014,400
4	ERA10FA283	1	1	0	$9,600,000	$2,428,800	$0	$12,028,800	0.16	$1,924,608
5	ANC10LA053	1	0	0	$9,600,000	$0	$0	$9,600,000	0.5	$4,800,000
6	WPR10FA371	3	0	0	$28,800,000	$0	$0	$28,800,000	0.16	$4,608,000
7	CEN11FA468	1	0	0	$9,600,000	$0	$0	$9,600,000	0.16	$1,536,000
8	WPR13FA054	1	0	0	$9,600,000	$0	$0	$9,600,000	0	$0
9	WPR12GA106	1	2	0	$9,600,000	$4,857,600	$0	$14,457,600	0.16	$2,313,216
10	CEN12FA621	2	0	0	$19,200,000	$0	$0	$19,200,000	0.25	$4,800,000
11	ERA13FA014	2	1	0	$19,200,000	$2,428,800	$0	$21,628,800	0.50	$10,814,400
12	CEN13FA295	2	0	0	$19,200,000	$0	$0	$19,200,000	0.42	$8,064,000
13	CEN13FA517	3	0	0	$28,800,000	$0	$0	$28,800,000	0.50	$14,400,000
14	CEN15FA171	1	2	0	$9,600,000	$4,857,600	$0	$14,457,600	0.16	$2,313,216
15	CEN15FA290	1	2	0	$9,600,000	$4,857,600	$0	$14,457,600	0.00	$0
						Total benefit over 10-year history				**$69,138,240**
						Per year benefit				**$6,913,824**

Among accidents with non-zero effectiveness, the average FAA AVP effectiveness score in Table 15 is 0.275. This average effectiveness score was applied to the serious and minor injuries occurring in the serious accidents shown in Table 16 below, which includes the remainder of the accidents from Table 13 (those accidents from where there were serious and minor injuries, but no fatalities). Accident WPR14LA160 was not rated as the injury was a hoisting accident (not CRSS related).

[3] Refer to prior section of this report.
[4] Refer to prior section of this report.

Table 16. Benefits for Serious and Minor Injuries from CRSS in Non-Fatal Accidents, Part 27											
Count	NTSB ID	Injury			Fatality Costs	Serious Injury Costs	Minor Injury Costs	Total Casualty Cost	Average AVP Score	Benefits from Avoided Fatalities and Injuries
		F	S	M						
1	CEN10CA138		1	1	$0	$2,428,800	$28,800	$2,457,600	0.275	$675,840
2	CEN11FA118		3		$0	$7,286,400	$0	$7,286,400	0.275	$2,003,760
3	CEN13LA148		2		$0	$4,857,600	$0	$4,857,600	0.275	$1,335,840
4	CEN14GA109		1	2	$0	$2,428,800	$57,600	$2,486,400	0.275	$683,760
5	CEN14LA149		1		$0	$2,428,800	$0	$2,428,800	0.275	$667,920
6	CEN15LA375		2		$0	$4,857,600	$0	$4,857,600	0.275	$1,335,840
7	CEN15LA387		3	3	$0	$7,286,400	$86,400	$7,372,800	0.275	$2,027,520
8	CEN16LA039		2	1	$0	$4,857,600	$28,800	$4,886,400	0.275	$1,343,760
9	DEN07LA142		2	1	$0	$4,857,600	$28,800	$4,886,400	0.275	$1,343,760
10	ERA10LA019		1	3	$0	$2,428,800	$86,400	$2,515,200	0.275	$691,680
11	ERA11CA180		1		$0	$2,428,800	$0	$2,428,800	0.275	$667,920
12	ERA13LA421		1	3	$0	$2,428,800	$86,400	$2,515,200	0.275	$691,680
13	LAX08CA138		1		$0	$2,428,800	$0	$2,428,800	0.275	$667,920
14	NYC08LA078		1		$0	$2,428,800	$0	$2,428,800	0.275	$667,920
15	SEA08CA032		1		$0	$2,428,800	$0	$2,428,800	0.275	$667,920
16	WPR09FA076		2		$0	$4,857,600	$0	$4,857,600	0.275	$1,335,840
17	WPR09LA460		2		$0	$4,857,600	$0	$4,857,600	0.275	$1,335,840
18	WPR12LA362		1	1	$0	$2,428,800	$28,800	$2,457,600	0.275	$675,840
19	WPR13CA064		1	2	$0	$2,428,800	$57,600	$2,486,400	0.275	$683,760
20	WPR14LA356		1	1	$0	$2,428,800	$28,800	$2,457,600	0.275	$675,840
						Total benefit over 10-year history				**$20,180,160**
						Per year benefit				**$2,018,016**

The bottom two rows of Tables 15 and 16 show the total estimated benefits if CRSS had been in place during the full ten years of the accident history, and the estimated average annual benefit of the rule. The average yearly benefit in 2016 dollars is the sum of the annual benefits calculated in Tables 14 and 15 or:

Total Yearly Benefit from CRSS = $6,913,824 + $2,018,016 = $8,931,840

Helicopter hours flown have grown over time, and the FAA forecasts 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 CRSS and the resulting economic benefits, we applied the FAA forecast of 2.5%

annual growth in hours flown to the estimates of benefits from avoided fatalities and injuries.[5] This accounted for the effects of projected increase in overall flight activity on the reduction in future fatalities and injuries expected to result from adopting CRSS. Table 17 below shows how the benefits are projected to grow throughout the future analysis period accounting for projected growth in hours flown. The total estimated CRSS benefit over ten years is approximately $113M or $64M when discounted at 7% present value.

Table 17. Benefits and Present Value Benefits of CRSS, Part 27 Rotorcraft

Calendar Year	Activity Growth Factor	Benefits without 2.5% Growth, 2016 Dollars	Benefits with 2.5% Growth, 2016 Dollars	Present Value Benefits at 7%
2015	1			
2016	1.025			
2017	1.0506			
2018	1.0769			
2019	1.1038			
2020	1.1314	$8,931,840	$10,105,484	$7,709,425
2021	1.1597	$8,931,840	$10,358,255	$7,385,293
2022	1.1887	$8,931,840	$10,617,278	$7,074,741
2023	1.2184	$8,931,840	$10,882,554	$6,777,108
2024	1.2489	$8,931,840	$11,154,975	$6,492,297
2025	1.2801	$8,931,840	$11,433,648	$6,219,147
2026	1.3121	$8,931,840	$11,719,467	$5,957,583
2027	1.3449	$8,931,840	$12,012,432	$5,707,020
2028	1.3785	$8,931,840	$12,312,541	$5,466,916
2029	1.413	$8,931,840	$12,620,690	$5,237,138
		Total	**$113,217,324**	**$64,026,666**

BENEFITS OF IMPLEMENTING 14 CFR PART 27.952 (CRFS) COMPLIANCE

Effectiveness of CRFS Eliminating Post-Crash Fire

The first step in calculating CRFS benefit was to estimate how many post-crash fires would be prevented through compliance with Part 27/29.952. For this assessment, a new accident data-set (unrelated to the dataset in Table 13) was prepared consisting of accidents of CRFS equipped rotorcraft that were fully compliant with FAR 27/29.952. To increase the review sample size, a twenty-year (1996-2015) capture of NTSB accidents was reviewed. Rotorcraft that were compliant with some, but not all, of Part 27/29.952 (partial compliance) were excluded from the dataset to eliminate the effects of partial compliance on outcome.

[5] FAA Aerospace Forecasts 2016 - 2036, Table 29, Active General Aviation and Air Taxi Hours Flown.

A total of 58 accidents were found matching the search criteria. Coincidentally, this dataset is the same size as the previous dataset in Table 13 - 14, but includes different accidents. This sample size was considered large enough to be statistically significant, yet small enough to allow detailed review of each accident to evaluate the CRFS crash performance (ability to prevent post-crash fire and thermal injury).

When available, the accident docket for each accident was reviewed with attention given to accidents with "ground fire" noted in the corresponding NTSB data field. Each docket was also reviewed for any mention of fuel spillage, as this could also indicate suboptimal CRFS performance even though a fire was not reported. An accident severity rating from 0 to 4 was also assigned to each accident utilizing the criteria shown in Table 18. Details of the 58 accident reviews are contained in Appendix G.

Table 18. Definition of Accident Severity Levels Utilized for the CRFS Review

Severity	Description	Details/Example
0	Non-crash	Rotorcraft normal landing after damage to the rotorcraft.
1	Minor	Hard landing where the landing gear does not fully collapse and the rotorcraft remains upright. Most auto-rotations would fall in this category.
2	Moderate	Enough crash energy to fully collapse the landing gear and cause some fuselage crush, and/or any crash with a rollover or tipping on the side.
3	Severe	Significant impact energy and fuselage crush. Occupant living volume is maintained for at least one occupant.
4	Extreme	High energy impact where volume is compromised for all occupants. An example would be CFIT. This level of crash severity is often called "non-survivable."

Tables 19 and 20 show the Part 27 and Part 29 accidents sorted by crash severity. If fires were found, they were also categorized as contained in the engine compartment, ground foliage (i.e., grass), or related to fuel spillage. Only fires related to fuel spillage are an indicator of CRFS performance.

Table 19. CRFS Equipped Part 27 Rotorcraft Accidents, 20 Year Dataset, Sorted by Crash Severity

NTSB ID No.	Make	Model	Severity	Fire			
				None	Engine comp.	Foliage	Fuel spillage
CEN15LA395	Bell	429	0	X			
GAA16LA056	Airbus	EC 135-P2+	0	X			
LAX02LA016	MDHI	MD-600N	0	X			
ANC06LA038	MDHI	MD-900	0	X			
CEN15LA066	MDHI	MD-900	0	X			
SEA99LA016	MDHI	MD-900	0	X			
CEN15CA039	Robinson	R66	0	X			
WPR12WA327	Airbus	EC 120B	1	X			
FTW03LA186	Airbus	EC 120B	1	X			
ATL04LA070	Airbus	EC 120B	1	X			
SEA03LA019	Airbus	EC 135-P1	1	X			
MIA06CA096	Airbus	EC 135-T2	1	X			
ERA16CA060	Airbus	EC 135-T2	1	X			
DFW07CA065	MDHI	MD-600N	1	X			
CHI08CA098	MDHI	MD-600N	1	X			
WPR10TA016	MDHI	MD-600N	1	X			
LAX98LA076	MDHI	MD-600N	1	X			
LAX98TA202	MDHI	MD-600N	1	X			
LAX01TA092	MDHI	MD-600N	1	X			
ATL02LA095	MDHI	MD-600N	1	X			
LAX04LA333	MDHI	MD-900	1	X			
ERA15CA079	Robinson	R66	1	X			
DFW06LA118	Airbus	EC 120B	2	X			
DFW07LA043	Airbus	EC 120B	2	X			
ATL07CA037	Airbus	EC 120B	2	X			
CEN12TA004	Airbus	EC 120B	2	X			
NYC06MA131	Airbus	EC 135-P1	2	X			
CEN14LA048	Airbus	EC 135-P1	2	X			
NYC99FA032	Airbus	EC 135-P1	2		X		
NYC08FA198	Airbus	EC 135-P2+	2	X			
LAX05LA060	Airbus	EC 135-T1	2	X			
WPR09GA119	MDHI	MD-600N	2	X			
WPR14LA173	MDHI	MD-600N	2	X			
CEN16LA058	MDHI	MD-600N	2		X	X	
LAX99TA115	MDHI	MD-600N	2	X			
LAX97LA061	MDHI	MD-600N	2	X			
LAX97FA091	MDHI	MD-600N	2	X			
LAX98LA093	MDHI	MD-600N	2	X			
LAX01FA277	MDHI	MD-600N	2	X			
LAX03GA001	MDHI	MD-600N	2		X		
LAX04TA017	MDHI	MD-900	2	X			
LAX05GA231	Airbus	EC 120B	3		X	X	
NYC05MA039	Airbus	EC 135-P2	3	X			
ANC12FA084	MDHI	MD-600N	3	X			
CEN10WA016	Airbus	EC 120B	4	X			
CHI07FA069	Airbus	EC 120B	4	X			
CHI03FA179	Airbus	EC 120B	4	X			
WPR10FA133	Airbus	EC 135-T1	4				X
CHI08FA128	Airbus	EC 135-T2+	4	X			
MIA00FA102	MDHI	MD-600N	4				X
ERA11RA398	Robinson	R66	4	X			
CEN12FA001	Robinson	R66	4				X
ERA13FA336	Robinson	R66	4	X			
			Total	**44**	**4**	**2**	**3**

Table 20. CRFS Equipped Part 29 Rotorcraft Accidents, 20 Year Dataset, Sorted by Crash Severity							
NTSB ID No.	Make	Model	Severity	Fire			
				None	Engine comp.	Foliage	Fuel spillage
CEN11CA152	Airbus	BK 117-C2	0	X			
CEN12CA474	Airbus	BK 117-C2	0	X			
ERA13LA134	Airbus	BK 117-C2	0	X			
CEN13FA025	Agusta	AW139	1	X			
ERA11LA106	Airbus	BK 117-C2	1	X			
			Total	**5**	**0**	**0**	**0**

There were 53 Part 27 accidents that matched these criteria (fully compliant with 27.952, and involved in an accident between 1996 and 2015). A review of these accidents indicates that rotorcraft certificated to 14 CFR Part 27.952 are preventing post-crash fires up to the extreme crash severity level. Furthermore, even at the extreme crash level, six out of nine accidents resulted in no significant post-crash fire; additional details of the three extreme accidents which resulted in fuel spillage fire are shown in Table 21.

Table 21. Accident Details for Three Accidents with Fuel Fire (from the 20 Year CRFS Compliant Dataset), all Part 27 Rotorcraft			
NTSB ID No./ Registration	Make	Model	Description
WPR10FA133 N127TS	Airbus	EC 135-T1	Main rotor tail boom strike during cruise after abrupt full-down collective input. The crash wreckage path was approximately 1/3-mile long.
MIA00FA102 N611BC	MDHI	MD-600N	Tail boom separation during aerobatic maneuver. Docket not available for detailed review. The Miami-Dade Medical Examiner office was contacted who reviewed the autopsies of both occupants. Both occupants received massive internal injuries including lacerations that essentially cut through the heart/aorta (fire was not the cause of death).
CEN12FA001 N266CY	Robinson	R66	Main rotor separation during cruise flight. The wreckage debris were scattered over an area approximately 1,500 ft. long by 600 ft. wide.

Based on these results, nearly all thermal injuries in survivable accidents would be expected to be eliminated through compliance to the current 14 CFR Part 27.952 regulation up to the extreme crash severity level as defined in Table 18.

There were only five Part 29 accidents; three considered non-crashes, and two minor. Due to the small sample size and low severity of the accidents, the CRFS performance for Part 29 rotorcraft cannot be determined from the Part 29 crash data. However, while the presented Part 29 data does not confirm Part 29 CRFS performance, similar results to Part 27 would be expected as the CRFS performance requirements are identical for both Part 27 and 29 rotorcraft.

BENEFIT VALUATION FOR 14 CFR PART 27.952 COMPLIANCE

Dataset Preparation for CRFS Evaluation

The dataset used for CRFS evaluation was generated by starting with the same dataset used for CRSS evaluation (Table 13: Non-CRFS-fully compliant helicopters that were manufactured and involved in a serious injury or fatal accident between 2006 and 2015), and applying the following additional filters:

- Limiting the dataset to accidents with a post-crash fire
- Limiting the dataset to helicopters that are representative of what is currently being manufactured. This resulted in removal of most Robinson R22/R44 helicopters from the dataset, as described below.

Prior to 2009, Robinson R22 and R44 helicopters were equipped with aluminum sheet metal fuel tanks which did not incorporate most of the current requirements of 27.952. However, starting in April 2009 (R44) and March 2013 (R22), all newly produced Robinson R22 and R44 series helicopters have included crash resistant fuel tank bladders and other CRFS features. While the complete system has not been fully certified to 14 CFR Part 27.952, it has been changed significantly to address post-crash fire concerns. Since the non-bladder configuration is no longer available, all non-CRFS R22s and R44s were removed from the Benefits Analysis as they do not represent currently produced aircraft. Inclusion of the non-upgraded Robinson helicopters would significantly inflate the benefit valuations and would not be representative of future benefit. Table 22 shows the remaining Part 27 and Part 29 rotorcraft after applying all filters.

Table 22. Occupant Injuries for Accidents with Reported Ground Fire, Rotorcraft Manufactured from 2006-2015 Representative of Current Production Design

NTSB ID	Make	Model	Registration	Injury Level		
				Fatal	**Serious**	**Minor**
CEN13FA344	Airbus	AS350-B2	N935EM	1	1	2
ERA10MA188	Airbus	AS350-B3	N855HW	3		
WPR10FA371	Airbus	AS350-B3	N509AM	3		
CEN14GA109	Airbus	AS350-B3	N3948A		1	2
CEN15FA290	Airbus	AS350-B3E	N390LG	1	2	
WPR16FA029	Airbus	AS350-B3E	N711BE	2		
CEN13FA122	Bell	407	N445MT	3		
CEN09WA390	Enstrom	480B	N878EE	1		
WPR15FA051	Robinson	R44 II	N3234U	2		
			Part 27, 9 Accidents Total	**16**	**4**	**4**
NYC08WA131	**Bell**	**412EP**	**N417EV**	**10**		
			Part 29, 1 Accident Total	**10**	**0**	**0**
			Total Part 27/29	**26**	**4**	**4**

There was only one Part 29 rotorcraft accident with ground fire. In addition, this accident occurred in Peru, and there is minimal accident data readily available. Part 29.952 benefit cannot be calculated with reasonable confidence based on this single accident and will not be presented in this report.

INJURY REDUCTION FOR 14 CFR PART 27.952 COMPLIANCE

Since our study shows that most post-crash fires are expected to be prevented in survivable accidents with the introduction of Part 27.952 compliance, it follows that most CRFS-related thermal injuries should also be eliminated in these accidents. Therefore, to determine the monetary benefit of mandating 27.952 for future production, a detailed review of each of the nine accidents with reported ground fire (Table 23) was performed to determine what injuries and fatalities were thermally related. Details of the analysis are contained in Appendix H, and are summarized in Table 23 below.

Table 23. Occupant Thermal Injuries and Fatalities Expected to be prevented by Introduction of CRFS, Part 27 Rotorcraft Manufactured from 2006-2015 Representative of Current Production Design

NTSB ID	Crash Severity(1)	Extent of Fire	Preventable Injury by Introduction of CRFS	Reported Injury			Projected Injury with CRFS Introduction		
				F	S	M	F	S	M
CEN13FA344	Moderate	Engine area	No	1	1	2	1	1	2
ERA10MA188	Extreme	Extensive fuel fire	No	3			3		
WPR10FA371	Severe	Extensive fuel fire	Yes	3			1	2	
CEN14GA109	Moderate	Engine area	No		1	2		1	2
CEN15FA290	Severe	Extensive fuel fire	Yes	1	2			2	1
WPR16FA029	Minor	Engine area	No	2			2		
CEN13FA122	Extreme	Unknown(3)	No	3			3		
CEN09WA390	Unknown(2)	Unknown(2)	Unknown(2)	1			1		
WPR15FA051	Extreme	Unknown(4)	No	2			2		
			Totals	**16**	**4**	**4**	**13**	**6**	**5**

(1) As previously defined in Table 17
(2) Crash in the Dominican Republic. No crash details available
(3) Extensive impact damage. Fire damage appears to be minimal
(4) Accident photographs not available to determine extent of fire.

There were only two crashes where the introduction of CRFS would have altered the injury outcome. The remaining seven crashes were either extreme (3 accidents), had fire contained to the engine compartment that would not cause thermal injury and were not CRFS related (3 accidents), or data were not available to determine the benefit (1 accident).

For accident CEN15FA290, the pilot received fatal thermal injuries and serious blunt trauma injuries. Had there been no fire, he may have survived with serious injuries. One passenger received serious thermal injuries and minor blunt trauma injuries, so his injuries would have been reduced to minor had there been no fire. The third passenger received serious blunt trauma injuries and no thermal injuries, so there would have been no change in injury outcome for this occupant had there been no fire.

For accident WPR10FA371, the pilot and one passenger received fatal thermal injuries and serious blunt trauma injuries. Had there been no fire, both may have survived with serious blunt trauma injuries. A third occupant received fatal injuries, but there was insufficient data available to indicate potential survivability without the fire.

CRFS BENEFIT CALCULATIONS

As shown in Table 24, the net calculated cost benefit for the implementation of CRFS for the ten-year period from 2006-2015 is approximately $23.9 million. Adjusting for the FAA projected 2.5 percent annual flight hour growth factor, and calculating the present value benefits discounted at a 7% annual rate (assuming the new rules take effect in 2020), the benefit is approximately $30.3 million and $17.1 million respectively as shown in Table 25.

Table 24. 10-Year Estimated Injury Cost Benefit for Implementation of CRFS, Part 27 Rotorcraft

Injury	W/O CRFS	With CRFS	Difference	Injury Value	Net Savings
Fatal	16	13	-3	$9,600,000	$28,800,000
Serious	4	6	+2	$2,428,800	($4,857,600)
Minor	4	5	+1	$28,800	($28,800)
None	0	0	0	$0-	$0
Total	24	24			**$23,913,600**
				Per Year Benefit	**$2,391,360**

Table 25. Benefits Including Growth Factor and Present Value Benefits for Implementation of CRFS, Part 27 Rotorcraft

Calendar Year	Activity Growth Factor	Benefits Without 2.5% Growth (2016 Dollars)	Benefits With 2.5% Growth (2016 Dollars)	Present Value Benefits at 7%
2015	1			
2016	1.025			
2017	1.0506			
2018	1.0769			
2019	1.1038			
2020	1.1314	$2,391,360	$2,705,585	$2,064,078
2021	1.1597	$2,391,360	$2,773,260	$1,977,296
2022	1.1887	$2,391,360	$2,842,610	$1,894,151
2023	1.2184	$2,391,360	$2,913,633	$1,814,464
2024	1.2489	$2,391,360	$2,986,570	$1,738,211
2025	1.2801	$2,391,360	$3,061,180	$1,665,079
2026	1.3121	$2,391,360	$3,137,703	$1,595,049
2027	1.3449	$2,391,360	$3,216,140	$1,527,965
2028	1.3785	$2,391,360	$3,296,490	$1,463,681
2029	1.413	$2,391,360	$3,378,992	$1,402,161
		Total	**$30,312,162**	**$17,142,135**

Discussion of CRFS Benefit Calculations

There was only one serious thermal injury (CEN15FA290) in the nine accidents with ground fire, which resulted in a net benefit valuation of $2.4 million (for that individual). The medical expenses alone for this serious thermally injured survivor are expected to be more than the estimated value for a fatality since extensive thermal injuries are extremely painful, debilitating, and require numerous days or weeks of intensive care and subsequent rehabilitation and reconstructive surgery. For this reason, the net savings predicted in Tables 23 and 24 are considered extremely conservative.

The benefit calculated in the section above is proportional to the number of applicable thermal injuries and fatalities in the dataset. Since there were relatively few accidents in the dataset where it was determined that CRFS would have been of likely value for at least one occupant, the number of preventable thermal fatalities and injuries in the dataset, and the resulting benefit calculation, could by random chance, be higher or lower than what would be expected on average. For instance, a single additional accident could have doubled the expected benefit, while a single avoided accident could have reduced the calculated benefit by up to 60 percent.

In order to quantify this uncertainty and provide a range of likely benefit values, it is assumed that the number of accidents causing CRFS-preventable thermal injuries/fatalities, and the total number of CRFS-preventable fatalities and injuries, are random events, in which case it is appropriate to assume the number of these accidents/injuries/fatalities in a ten year period will each have their own Poisson distribution (a Poisson distribution is appropriate for applications that involve counting the number of times a random event occurs in a given amount of time, distance, area, etc.). With data for a single ten-year period in which two accidents with CRFS-preventable serious thermal injuries/fatalities occurred, the 25%-75% confidence interval for the expected number of such accidents is 0.96 to 3.92. Similarly, the 25%-75% confidence interval for the expected number of CRFS-preventable thermal fatalities is 1.73 to 5.11, and the interval for expected CRFS-preventable serious thermal injuries is 0.29 to 2.69. To calculate the 25%-75% confidence interval for the benefit of introducing CRFS that are fully compliant with the applicable regulations, the expected number of applicable accidents (0.96 to 3.92) is multiplied by the average benefit per accident in the dataset ($23,914,000/2 = $11,957,000), yielding a benefit confidence interval of $11,478,720 to $46,871,440.

Other Potential Benefits of CRFS

There are other significant potential benefits of implementing CRFS other than injury reduction for on-board occupants. Some examples, which include statements from actual crash narratives, include:

1. "*Many fixed-wing aircraft were parked on apron and 2 other helicopters were parked on grassy area at southern edge of asphalt apron.*"

   There is significant potential for additional destruction of property if a fuel fire is involved, depending on where the crash occurs, as in this example, at an airport. There was potential for multiple other aircraft and property to be involved with an uncontained post-crash fire.

2. *"The Aero-Med Sikorsky S-76 impacted the helipad atop the 11-story Spectrum Health Butterworth Hospital in downtown Grand Rapids. Patients on the seventh, eighth, and ninth floors were relocated to other floors due to damage from the fire, water runoff, and fuel leakage. There was also fuel that ran down a hospital elevator shaft."*

Many helicopters frequent rooftop helipads. The impact of fuel leakage and/or post-crash fire on a hospital or other occupied structure is an important consideration. Although significant effort has been put into establishing robust fire suppression systems on rooftop helipads, uncontained fire fed by the aircraft's fuel system can have profound consequence to the structure and its occupants.

3. Elimination of most post-crash fires will aid the accident investigation and could help identify accident causation factors and ultimately reduce accident rates.

BENEFIT SUMMARY FOR COMPLIANCE WITH ALL REGULATIONS (CRSS AND CRFS)

The projected benefit value was calculated for all non-compliant rotorcraft based on the expected net change in occupant injuries over a ten-year production time frame by implementation of full compliance to the current safety standards. The accidents and injuries of all non-compliant rotorcraft produced in the past ten years was utilized to estimate the benefits. Table 26 shows the estimated ten-year benefit of approximately $143.5M and the ten-year present value benefit of approximately $81.1M for Part 27 rotorcraft.

Table 26. Summary of Projected Benefits from CRSS and CRFS, Part 27 Rotorcraft

	Regulation	10-Year Benefit	10-Year Present Value Benefit at 7% Discount
Part 27	CRFS	$30,312,162	$17,142,135
	CRSS	$113,217,324	$64,026,666
	Part 27 Total	**$143,529,486**	**$81,168,801**

<u>Non-Economic Considerations</u>

Economic costs represent only one aspect of the consequences of helicopter crashes. People injured in these crashes often suffer physical pain and emotional anguish that is beyond any economic recompense. The permanent disability of burns, spinal cord damage, loss of mobility, and serious brain injury can profoundly limit a person's life, resulting in dependence on others for routine physical care and activities of daily life. More commonly, less serious injuries, can cause physical pain and limit a victim's physical activities for years after the crash. Serious burns or lacerations can lead to long-term discomfort and the emotional trauma associated with permanent disfigurement. For an individual, these non-monetary outcomes can be the most devastating aspect of surviving a helicopter crash.

The family and friends of the victim feel the psychological repercussions of the victim's injury acutely as well. Caring for an injured family member can be very demanding for others in the family, resulting in economic loss and emotional burdens for all parties concerned. It can change the very nature of their family life and the emotional difficulties of the victim can affect other family members and the cohesiveness of the family unit. When a crash leads to death, the emotional damage is even more intense, affecting family and friends for years afterward and sometimes leading to the breakup of previously stable family units.

Action taken by society to alleviate the individual suffering of its members can be justified in and of itself; to increase the overall quality-of-life for individual citizens. In this context, economic benefits from such actions are useful to determine the net cost to society of programs that are primarily based on humane considerations. If the focus of policy decisions was purely on the economic consequences of helicopter crashes, the most tragic, and, in both individual and societal terms, possibly the costliest aspect of such crashes would be overlooked.[6]

[6] The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised), pg. 1-21

DISCUSSION

The ROPWG approached the task of performing a cost-benefit analysis by assigning cost analysis and benefits to two separate task groups, referred to as the Cost Group and the Benefits Group. The Cost Group consisted primarily of OEM representatives and operator representatives, while the Benefits Group consisted of accident investigators, accident analysts, and safety experts. Participation across groups was encouraged through quarterly ROPWG meetings and frequent telephone conferences. Several members participated significantly in both task groups. Each task group produced a separate report approved by its membership and then the two reports were combined for comment/approval of the entire ROPWG.

OEM costs were determined based on data provided by OEMs marketing rotorcraft in the U.S. since they were considered the most reliable and readily available source of such data. Most are represented on the ROPWG. These estimates were based on current prices of parts and labor and did not consider potential volume discounts available based on increased demand once the regulations come into effect. Although it was recognized that operators of affected rotorcraft would probably incur significant costs if the current regulations were applied to all newly manufactured rotorcraft, particularly when either their operations or established contracts required specific performance capabilities of their aircraft, estimating these costs was complex and required making a number of assumptions as described above and in Appendix B.

As already discussed, reliable benefits estimates were hampered by the volume of crashes and the lack of impact and injury data in the NTSB database and accident dockets. Because the NTSB database lacks injury and impact information, the actual dockets of accidents had to be retrieved and reviewed. This is a very time-consuming process and, unfortunately, yielded little significant data. The lack of data in the database and dockets required numerous accidents to be excluded for lack of essential data required to perform an appropriate injury analysis. Nevertheless, two 58 accident datasets were produced. Since the crashes of Part 27/29.592 compliant rotorcraft included all accidents of these helicopters since inception of the requirement for CRFS, the analysis of these cases to determine efficacy of CRFS can be considered highly reliable. Determining the effectiveness of CRSS was much more problematic since impact conditions and resulting injuries were essential to determine effect of more crash-resistant structures or inclusion of energy absorbing seats. For this reason, we sought the assistance of the FAA (APO and AVP) in analyzing the 58-accident dataset of accidents occurring over the most recent ten-year period. Unfortunately, of the 58 accidents in the dataset, AVP determined that only 30 had sufficient data for scoring of projected effectiveness of CRSS, and only 15 of those were determined to have non-zero effectiveness. Consequently, the CRSS analysis was determined to be representative, but somewhat less reliable than the analysis of CRFS.

There is strong evidence of effectiveness of CRFS in essentially eliminating post-crash fire and thermal injuries in survivable crashes. Analysis of all crashes of rotorcraft compliant with Part 27/29.952 determined that there were no post-crash fires in crashes determined to be survivable (severe or less), and that fully compliant CRFS are moderately effective even in extreme impact crashes. This result agrees with several studies of CRFS effectiveness in U.S. Army helicopters[7].

Although full compliance with Part 27/29.952 is clearly effective, several manufacturers indicated that a partially compliant CRFS consisting of a compliant fuel bladder and elimination of rigid fuel lines may be

[7] Shanahan, D., "Crash Experience of the U.S. Army Black Hawk Helicopters," Aircraft accidents: Trends in Aerospace Medical Investigation Techniques, Neuilly-Sur-Seine, France: AGARD CP 532, pp 40-l -40-9. January 1992.

entirely or almost as effective as full compliance and avoid the necessity of discontinuing certain rotorcraft models. Most notably, Bell Helicopter has produced partially compliant fuel systems for almost 3 decades and Robinson has recently begun installing compliant fuel bladders in new R22 and R44 models and they require these fuel cells for retrofit for both models. Additional analysis of data from crashes of these rotorcraft should be considered before promulgation of a final rule. ROPWG intends to consider this and other issues as a part of Tasks 3 through 5.

Many OEMs have stated that full compliance with CRSS requirements (Parts 27/29.561, .562, and .785) for some existing models will be impractical or economically prohibitive due to the cost and weight penalty associated with making major structural changes to existing aircraft models, particularly smaller aircraft. For OEMs who manufacture only small helicopters, the impact may be particularly onerous. It has been suggested that the FAA consider partial compliance in new rulemaking affecting currently manufactured rotorcraft. ROPWG will consider this issue in subsequent tasks.

There were only two Part 29 crashes included in the study dataset, both of which had indeterminate potential benefit from integration of the new rules. However, long term benefits for Part 29 rotorcraft are expected to be proportionate to the calculated Part 27 benefits when considering the different accident rates, accident severity, production rate, and occupancy load factors. The appropriate factor was not determined during the current task.

CONCLUSIONS

1. While compliance with 27.952 was found to be extremely effective at preventing post-crash fires and thermal injuries, the calculated benefit is lower than what otherwise might be expected due the following considerations:
    a. This analysis is limited to studying the benefit for future production only, which limits the reach of CRFS to a relatively small percentage of the future fleet
    b. Several manufacturers have already started to voluntarily include CRFS in newly produced aircraft, thereby lessening the effect of a future mandate

    A much greater benefit (but also a much greater cost) is likely to be seen when the working group studies the effectiveness of retrofitting fielded aircraft with CRFS.

2. The proposed regulatory changes will likely lead to the elimination of some rotorcraft currently in production. Four OEMs participating in the ROPWG reported that the resulting aircraft performance impacts required for full compliance with the four proposed regulations would be so great that several models of aircraft would likely be discontinued.

3. It is the opinion of the working group that partial implementation of the subject regulations may provide a significant portion of the benefits while avoiding much of the costs. Further study during the next task phases of the ROPWG is expected and warranted.

4. The estimated benefits for compliance with 14 CFR 27/29.561, .562, and .785 (CRSS) have a high degree of uncertainty due to the lack of CRSS-compliant accident data.

5. There were only two Part 29 crashes included in the study dataset, both of which had indeterminate potential benefit from integration of the new rules. However, long term benefits for Part 29 rotorcraft are expected to be proportionate to the calculated Part 27 benefits when considering the different accident rates, accident severity, production rate, and occupancy load factors. The appropriate factor was not determined during the current task.

6. In the opinion of some members of the ROPWG, the empty weight and fuel capacity/range penalties outlined in the OEM Performance Data section (Appendix C) could potentially increase the accident rate for the following reasons:
    a. Operation at higher gross weights (GWs), even when still under max gross take-off weight (MGTOW), will reduce power margins, thereby increasing potential for loss of tail rotor effectiveness, settling with power, catastrophic rotor stall, and the inability to prevent collision with obstacles in power-limited situations.

    b. As a result of the decrease in fuel capacity, pilots may experience pressure (self-induced and/or external) to operate closer to established fuel reserves as part of task completion, leading to a greater incidence of accidents due to fuel starvation.

    c. Operating at higher gross weights will increase mechanical stress on affected aircraft, increasing component fatigue damage, maintenance costs, and the probability of premature component failure.

    Unfortunately, it was not possible to provide a meaningful dollar estimate for the cost of the accident rate concerns outlined above.

7. In the opinion of some members of the ROPWG, the current FAA methodology for calculating economic costs of fatal and serious injuries significantly underestimates the actual societal costs of these injuries.

8. In the opinion of the ROPWG, the current FAA standard methodology does not accurately consider the practical costs of aircraft modification. The ROPWG sought to correct this by using a methodology that it feels more accurately predicts actual industry costs.

9. The cost-benefit analysis was greatly inhibited by the fact that neither NTSB nor FAA determine impact conditions in an accident investigation nor injuries for the involved occupants. Lack of these data render occupant protection analysis almost impossible. If such data were available in a database similar to the National Highway Traffic Administration, National Accident Sampling System (NASS), rulemaking related to occupant protection in aircraft accidents would be greatly facilitated by allowing more detailed and reliable determinations of injury causation and the relationship of injuries to the crash environment and aircraft crashworthiness capabilities. The ROPWG recommends that NTSB establish a system similar to NASS for aircraft crashes.

FAA STATEMENT

The FAA representative on the ROPWG has reviewed the document. The ROPWG methods of calculating both the cost of development and the cost to operators are not fully understood by the FAA at this stage.

- Conclusion #7 states that the FAA benefits methodology underestimates benefits. The ROPWG used the FAA methodology.
- Conclusion #8 states that the ROPWG use a novel[8] method of cost analysis. FAA methodology for cost calculations is not used. The operator cost methodology does not follow the method of accounting for impact on empty weight and usable load that is used in other ARAC and FAA rulemaking economic impact analysis.
- The non-recurring costs are not broken down to a level that allows review and validation of costs from each manufacturer.
- Only averages for non-recurring costs are given.
- There is wide variation among individual manufacturers that the FAA believes may include outliers that should be investigated.
- International development costs are not split out separately. The FAA considers the international implications in a different section of an economic analysis when looking at the impact on the US economy.

The FAA can use the report as presented, with the understanding that the FAA will use the data and cost information to support development of the expected cost to the US economy. This cost-benefit report is intended to be one source of information to the FAA in directing the next tasking assignment to the ARAC ROPWG.

The FAA will continue to work with the ROPWG during the future tasking with the desire to create a more refined cost-benefit analysis which aligns with other ARAC and FAA economic analysis to support the next tasking actions.

[8] Conclusion 8 wording has been revised and no longer uses the description term "novel methodology." The FAA representative has elected to keep this statement based on the draft report wording.

ROPWG VOTING MEMBERS STATEMENTS OF NON-CONCURRENCE

All voting members reviewed the report and generally concurred with its methodology and findings. However, several members non-concurred with particular portions of the report. Each of these members prepared statements of non-concurrence and those statements are included in this section verbatim.

David Shear
Robinson Helicopter Company

Robinson Helicopter Company (RHC) generally concurs with the Rotorcraft Occupant Protection Working Group (ROPWG) Task 1 & 2 report reviewed on November 7, 2016, with the following exception:

RHC does not concur with the injury, fatality, and monetary benefits attributed to full compliance with the Crash Resistant Seat and Structure regulations (14 CFR 27/29.561,.562, and .785) for the following reasons:

- It is the opinion of RHC that the available Crash Resistant Seat and Structure (CRSS) data is insufficient to provide a meaningful estimate of the injury, fatality, and monetary benefits of full compliance with 27/29.561, .562, and .785.
- Because only minimal information is available regarding the FAA Office of Accident Investigation and Prevention (AVP) effectiveness scoring process utilized in this study, a critical evaluation of their methodology and results is not possible.
- While demonstration of compliance with 27.561, .562, and .785 is not required for the R22 and R44, RHC voluntarily performed research and development dynamic seat testing per 27.562 on these models at the FAA Civil Aeromedical Institute. These tests showed that the existing occupant protection features on the R22 and R44 are very effective, and meet the head impact criteria (HIC), lumbar spine load, and seat belt tension load requirements of 27.562. Therefore, for these models, there would be little to no benefit if the design revisions required to demonstrate full compliance with 27.561, .562, and .785 were incorporated. Note that the R22 and R44 account for slightly more than half of the calculated CRSS monetary benefit.

Matthew Palato
Sikorsky Aircraft

Sikorsky aircraft concurs with the report, with the exception of the conclusion that "However, long term benefits for Part 29 rotorcraft are expected to be proportionate to the calculated Part 27 benefits when considering the different accident rates, accident severity, production rate, and occupancy load factors. The appropriate factor was not determined during the current task." There is insufficient Part 29 data present in the report to make any conclusion.

Krista Haugen, RN, MN, CEN
Survivors Network for the Air Medical Community

As a member of the benefits group, much of the content of the cost section of this report is not within my area of expertise so I cannot comment on the numbers the cost group has presented. Within my area of expertise, however, are traumatic injuries and burns, and the sequelae of such injuries. I do not concur with several aspects of the benefits portion of this report for several reasons:

1.) **The lack of injury data:** The NTSB injury classification system does not allow for the determination of specific injuries. How can we accurately determine the effectiveness of energy-attenuating seats if we do not have data, for example, on rotorcraft occupants who sustained spine/spinal-cord injuries in crashes or hard landings? The lack of specific and quantifiable data related to rotorcraft occupant injuries is a massive shortcoming in the system and a major barrier to truly understanding the full extent of occupant injuries. This item alone makes an accurate assessment of injury costs nearly impossible.

2.) **The lack of injury costs:** Not only do we not know specific injuries in most cases, the costs for the injuries we do know of are not available. In this report, we have relied on the Value of a Statistical Life (VSL) numbers as a starting point, due to the lack of any other data. These numbers, however, are most certainly understated. The lack of transparency as to the costs of rotorcraft occupant injuries is another barrier that makes the accurate assessment of injury costs, and therefore this task, nearly impossible.

3.) **The limited number of occupants/injuries:** Because of the methodology and inclusion criteria utilized in this report, the number of rotorcraft occupants involved in crashes was severely limited. This report represents a small subsection of accidents and may lead the reader to believe that the impact of the lack of compliance with the Code of Federal Regulations (CFRs) is far smaller than it is, especially when represented in a comparative fashion with the extensive cost section.

4.) **Finally, I fully disagree with the representation of the Frisco crash (CEN15FA290) in the following paragraph**:

> **Discussion of CRFS Benefit Calculations, (p. 29)**
> *"There was only one serious thermal injury (CEN15FA290) in the nine accidents with ground fire, which resulted in a net benefit valuation of $2.4 million (for that individual). The medical expenses alone for this serious thermally injured survivor are expected to be more than the estimated value for a fatality since extensive thermal injuries are extremely painful, debilitating, and require numerous days or weeks of intensive care and subsequent rehabilitation and reconstructive surgery."*

In the earlier draft of this report, we elaborated further on this case. The thermally injured survivor of this crash sustained full-thickness burns to 90% of his body because of the post-crash fire. He was hospitalized in the Burn Intensive Care Unit for 11 months, with total hospitalization time just over 12 months. To say that the net benefit valuation for this individual is $2.4 million is misleading. While the $2.4 million is based on the VSL figures we used as estimates, the truth is that we know his injury costs far exceeded that. Further, to state that extensive thermal injuries "…require numerous *days* or weeks of intensive care" is misleading in this case as well. This paragraph doesn't begin to outline what this individual and his family have been through since his crash, nor what they continue to go through, the cost of which is immeasurable. He will require medical care for the rest of his life, not simply "days or weeks." And it must be emphasized that he literally would have walked away with minor blunt injuries, were it not for the post-crash fire.

For those who argue this individual is a statistical outlier, consider the following:

a) Because of advances in burn care, proximity to burn centers, and rapid/highly skilled scene response and transport, more people with high percentages of burns are surviving burns that have historically been non-survivable.

b) This individual was relatively young and fit, which are most certainly factors which positively influenced his highly unlikely survival. In the air medical transport industry, many crew members fit a similar profile which increases their potential for surviving extensive burns as the individual in this case did. This may lead to prolonged hospitalization, rehabilitation, and most likely, the need for lifelong medical care as well.

c) As noted in the Executive Summary, "…by the end of 2014 only 16% of the U.S. rotorcraft fleet were in compliance with the upgraded fuel system requirements, and only 10% were in compliance with the upgraded emergency landing requirements." The majority of the rotorcraft fleet not being in compliance, combined with the rotorcraft crash rate, leads me to the conclusion that it is entirely feasible, if not likely, that this scenario (CEN15FA290) may indeed happen again. Therefore, I do not believe this individual or this crash should be considered to be simply an outlier and the realities of this crash should not be minimized, as was attempted in this report. The *true* economic and non-economic costs of this and similar scenarios are exactly what we should be focusing on closely so that we can prevent them from happening again.

John Wittmaak
Bell Helicopter
Bell Helicopter agrees with the conclusions in the ROPWG's Cost/Benefit Report with the following exceptions:

Non-concurrence: "Thus, by the end of 2014 only 16% of the U.S. rotorcraft fleet were fully compliant with the upgraded fuel system requirements,"

It is Bell Helicopter's position that the existence of CRFS is not directly governed by FAR CFR 27/29.952 certification as all Bell Helicopters that were certified after 1982 have included CRFS features in them; long before the introduction of FAA 14 CFR 27/29.952 in 1994.

- Bell Helicopter worked with the Army to develop CRFS standards and later worked with the FAA to develop CRFS standards. These standards were introduced in Bell Helicopter fuel systems designs in the early 1980s.
- Other studies have reviewed the early Bell CRFS aircraft to justify the implementation of CRFS in the commercial fleet.
    - In 1994 the FAA Research Article "Rotorcraft Crashworthy Airframe and Fuel System Technology Development Program" references the 206L3 (predecessor to the 206L4 and 407) and the 412 as CRFS designs within the context of 27/29.952 regulation changes. (http://www.tc.faa.gov/its/worldpac/techrpt/ct91-7.pdf)
    - Hayden M, Shanahan D, Chen L, and Baker S. 2005 Crash-Resistant Fuel System Effectiveness in Civil Helicopter Crashes. Aviation, Space, and Environmental Medicine. Vol. 76, No.8 : 782-785 comparatively evaluates the benefits for CRFS between non-

CRFS 206s, CRFS 206s and AS350s. The findings concluded that the CRFS 206s (which are not certified to 27.952) significantly reduced PCFs.

- The Bell 407, despite being a modified Type Design, IS CERTIFIED to nearly all 27.952 regulations however the ROPWG Cost/Benefit report included it in the 16%, non-compliant aircraft.
- Cost/Benefit Report –In the Benefit Analysis the FAA Office of Accident Investigation and Prevention (AVP) reviewed each accident and their results could not associate financial savings with Bell products in the 27.952 analysis. In other words they determined that had the aircraft been fully certified to 27.952 it is doubtful a different outcome would have resulted. Also worth noting is the scarcity of Bell products in the 27.952 analysis which only looked at in-production aircraft; this demonstrates that the CRFS features Bell has made standard perform well.

It is Bell Helicopter's position that all in-production Bell models, whether certified to 27/29.952 or not, currently have CRFS as part of their basic aircraft offering.

Non-concurrence: "A much greater benefit (but also a much greater cost) is likely to be seen when the working group studies the effectiveness of retrofitting fielded aircraft with CRFS."
Bell Helicopter agrees that much greater benefit exists in retrofitting older non-CRFS aircraft but does not believe the cost to be much greater from the perspective of an OEM. Bell Helicopter already offers kits for the 206A, 206B, 206L, 206L1 and 212 models that do not have CRFS fuel systems in them currently. Many of these kits were certified for installation in the early 1990s prior to FAA 14 CFR 27/29.952 revisions in 1994. These kits upgrade older non-CRFS models to configurations similar to what are found today in the Bell 407 and 412 today. However, if rule changes require certification efforts to show full compliance to 27/29.952 costs and availability of these kits could be impacted significantly. Like currently produced Bell aircraft, these kits were created prior to the existence of 27.952 and it is Bell's position that these kits are CRFS.

Fundamentally Bell Helicopter believes CRFS can and has existed prior to 27/29.952 regulation changes in 1994. Bell Helicopter believes efforts to certify currently in-production CRFS systems provide no benefit and ultimately delay availability and increase costs associated to retrofit solutions for pre-CRFS aircraft.

APPENDIX A

ROPWG MEMBERSHIP

NAME	COMPANY/ REPRESENTING	Task Group	Position
Dennis F. Shanahan	Injury Analysis, LLC		Chair
Robert J. Rendzio	Safety Research Corporation of America (SRCA)	Benefits	Voting Member
Harold (Hal) L. Summers	Helicopter Association International	Benefits	Voting Member
Jonathan Archer	General Aviation Manufacturers Association (GAMA)	Benefits	Voting Member
Daniel B. Schwarzbach, SPO	Airborne Law Enforcement Association's (ALEA)	Benefits	Voting Member
Krista Haugen	Survivors Network for Air & Surface Medical Transport	Benefits	Voting Member
Joan Gregoire	MD Helicopters, Inc.	Costs	Voting Member
John Wittmaak	Bell Helicopter Textron, Inc.	Costs	Voting Member
Matthew Pallatto	Sikorsky	Costs	Voting Member
William Taylor	Enstrom Helicopter Corporation	Costs	Voting Member
Pierre Prudhomme-Lacroix	Airbus Helicopters	Costs	Voting Member
David Shear	Robinson Helicopter Company	Costs	Voting Member
Chris Meinhardt	Air Methods	Costs	Voting Member
John Heffernan	Air Evac Lifeteam	Costs	Voting Member
John Becker	Papillon Airways Inc	Costs	Voting Member
Christopher Hall	PHI Air Medical, LLC	Costs Chair	Voting Member
Bill York	Robertson Fuel Systems	Costs	Voting Member
Randall D. Fotinakes	Meggitt Polymers & Composites	Costs	Voting Member
Gianni Matteo	Leonardo-Finmeccanica	Costs	Voting Member
Marv Richards	BAE Systems	Benefits Chair	Voting Member
Laurent Pinsard	EASA Structures Engineer	Benefits	Non-Voting Member
Rémi Deletain	EASA Powerplant & Fuel Engineer	Costs	Non-Voting Member
Martin R. Crane	FAA Structures Engineer	Advisor	Non-Voting Member

APPENDIX B

OPERATOR COST

Calculation of Operator Costs Due to Reduction in Payload/Passengers, Reduction in Fuel Capacity/Range, and Increase in Fuel Burn Rate

Below is a detailed description of the parameters used to estimate the additional operator costs due to a reduction in payload/passengers, a reduction in fuel capacity/range, and an increase in the fuel burn rate.

<u>Number of Affected Helicopters</u>

Sales forecast data provided by the FAA (http://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2016-36_FAA_Aerospace_Forecast.pdf, Tables 28-31) projects the following average US sales for the next 10 years:

Piston helicopters: 85/year
Turbine helicopters: 200/year

Based on data from the participating OEMs, all the piston aircraft were assumed to be non-compliant and therefore affected by the proposed regulatory changes, while 50% (100 aircraft) of the turbine market was estimated to be affected.

Of those 100 affected turbine aircraft, model-specific sales figures provided by the OEMs were used to generate the following estimated breakdown by aircraft group:

Part 27 Single Turbine: 84/year
Part 27 Twin Turbine: 3/year
Part 29: 13/year

<u>Baseline Operator Cost per Flight Hour</u>

Model-specific direct operating cost estimates were provided by the participating OEMs for most of the helicopter models that would be affected by the proposed regulations. These costs represent the present day estimated hourly direct operating costs (before the required modifications). These costs were combined in a weighted average for each of the subgroups based on the estimated future sales of each helicopter model.

<u>Flight Hour Estimates</u>

Yearly flight hour estimates were available to some of the OEMs, and were combined in a weighted average for each of the subgroups.

Percentage Increase in Operator Costs Due to Reduction of Payload

For purposes of this analysis, increases in operator costs were considered equivalent to decreases in operator revenue.

The percentage loss of revenue was assumed to be equal to the percentage loss of payload with full fuel. This assumption is based on the following reasoning:

For large and/or repetitive operations (ferrying groups of people, or transporting multiple loads of cargo), a decrease in passenger/cargo capacity will require a corresponding increase in the number of trips required to transport all the passengers/cargo, and a corresponding increase in costs. For instance, if the passenger capacity of a helicopter is reduced by 20%, then the number of trips required will increase by 20%, as will the cost to the operator (this burden can be met with additional trips by one helicopter, or the addition of an additional helicopter(s) to the operator's fleet).

For smaller operations (transporting, on average, less than the maximum passenger/cargo capacity of the helicopter), the reasoning is as follows: most of the time, the reduced passenger/cargo capacity will not be needed, so the cost of those trips will remain the same. However, some percentage of the time, the reduced passenger/cargo capacity will require a second trip, doubling the cost of that operation. Assuming that the passenger/cargo load is evenly distributed between zero passengers/cargo and maximum passengers/cargo, the increase in the number of flights required is equal to the percentage reduction in passenger/cargo capacity. For instance, if the passenger capacity of a helicopter is reduced by 20%, then 80% of the time the flight can be completed as before at no additional (payload related) cost, but 20% of the time, a second flight will be required with a corresponding 100% increase in the cost of that trip. The resultant average increase in cost is therefore:

20% chance of second flight * 100% cost of second flight = 20% average increase in cost

For some helicopter models, compliance with 27/29.562 would reduce the number of passengers due to the inability to install complaint seats; in those instances, it was assumed that the "effective" loss of payload due to the loss of a passenger was equal to 85 pounds per lost passenger (one half of a standard FAA 170 lb. person). This one-half factor was considered a rational compromise, as for some operations (passenger transport), loss of a passenger seat would result in the loss of revenue for one passenger, while in other operations (cargo transport), loss of a crashworthy seat without the loss of payload (ability to carry weight) would not result in any loss of revenue. For purposes of calculating the operator costs due to the reduction of payload, the weight penalty for the loss of a passenger was in addition to the weight penalty due to the other modifications required for compliance with the applicable regulations.

For each of the regulations under discussion, initial payload and loss of payload data was estimated by the participating OEMs, and used to calculate a weighted average for the four aircraft categories (Table B1).

Table B1. Resultant Increase in Operator Costs/Decrease in Operator Revenue Due to Reduction of Payload, Per Year

Aircraft Type	Number of Aircraft Affected per Year (N)	Weighted Average Operational Cost per Flight Hour (C)	Weighted Average Number of Flight Hours per Aircraft per Year (H)	Weighted Average Payload Before Required Modifications (full fuel; lb.)	Weighted Average Effective Reduction in Payload (lb.)		Weighted Average Percentage Increase in Operator Costs/Decrease in Operator Revenue (P)		Resultant Increase in Operator Costs/Decrease in Operator Revenue Due to Reduction of Payload, per Year		
					.561, .562, .785	.952	.561, .562, .785	.952	.561, .562, .785	.952	Combined
Single Engine Piston	85	$201	298	632	50.0	8.5	7.9%	1.3%	$402,637	$68,179	$470,816
Single Engine Turbine	84	$475	346	1122	140.5	15.6	12.5%	1.4%	$1,731,873	$191,795	$1,923,668
Twin Turbine (Part 27)	3	$950	500	3125	0.0	0.0	0.0%	0.0%	$0	$0	$0
Part 29	13	$1,114	627	3646	271.8	72.4	7.5%	2.0%	$676,761	$180,202	$856,963
								Totals	**$2,811,271**	**$440,176**	**$3,251,447**

Reduction in Fuel Capacity/Range

The cost to operators of reduced fuel capacity/reduced range assumed that for a percentage of flights equal to the percent reduction in fuel capacity/range, operators would have to use a different helicopter at an additional cost of 20% per flight hour. This assumption is based on the following reasoning:

- Assuming that the distance flown by a helicopter is evenly distributed between zero and the (original) maximum range of the helicopter, the percentage of flights that will be beyond the range of the "modified" helicopter is equal to the percentage reduction in range. For instance, if the range of a helicopter is reduced by 5%, then 95% of the time flights can be completed as before at no additional (range-related) cost, but 5% of the time, a different helicopter with a longer range will be required.

- The 20% cost factor was the average estimate by the participating OEMs for the typical increase in hourly operating costs required when upgrading to helicopters with increased range. Alternatively, rather than using a different helicopter, the existing helicopter could possibly be outfitted with a larger/additional fuel tank, and/or refueling stops could be added to the operation. While these alternate solutions would not require the use of a more expensive helicopter, they would require additional costs in the form of fleet upgrades (for extra fuel capacity), loss of passenger/cargo capacity (due to the installation of the extra/larger fuel tanks), extra time (to stop for refueling), and/or extra logistical costs (to preposition the fuel at the refueling point). It was estimated by the OEMs that the cost of these alternative solutions is comparable to the 20% cost of using a different helicopter.

- The estimates for number of affected aircraft, cost per flight hour, and number of flight hours per year are the same as those detailed for the payload calculations (Table B2). The average fuel capacity for each model was provided by the OEMs and used to calculate a weighted average for the four aircraft categories.

Table B2. Resultant Increase in Operator Costs/Decrease in Operator Revenue, Per Year Due to Reduction in Range

Aircraft Type	Number of Aircraft Affected per Year	Weighted Average Operational Cost per Flight Hour	Weighted Average Number of Flight Hours per Aircraft per Year	Weighted Average Fuel Capacity Before Required Modifications (US gallons)	Weighted Average Reduction in Fuel Capacity (US gallons)		Weighted Average Reduction in Fuel Capacity (%)		Percentage Increase in Costs for Helicopter with Longer Range (%)	Resultant Increase in Operator Costs/Decrease in Operator Revenue Due to Reduction in Range, per Year		
					.561, .562, .785	.952	.561, .562, .785	.952		.561, .562, .785	.952	Combined
Single Engine Piston	85	$201	298	43	0	0.5	0.0%	1.2%	20.0%	$0	$12,188	$12,188
Single Engine Turbine	84	$475	346	117	0	10.0	0.0%	8.5%	20.0%	$0	$234,937	$234,937
Twin Turbine (Part 27)	3	$950	500	146	0	0.0	0.0%	0.0%	20.0%	$0	$0	$0
Part 29	13	$1,114	627	323	0	11.7	0.0%	3.6%	20.0%	$0	$65,853	$65,853
									Totals	**$0**	**$312,978**	**$312,978**

Increase in Fuel Consumption

As noted in the Summary of the Rotorcraft Performance Data section, the increase in empty weight of the affected aircraft will increase fuel consumption. As stated in the Summary of Rotorcraft Performance Data section, the increased fuel consumption was assumed to be 0.005 gallons/flight hour/extra lb. of empty weight. The extra fuel burn and cost was calculated using the previous estimates for the number of affected aircraft and the number of flight hours flown per year (Table B3). The assumed average fuel cost was a nationwide average of Jet A and 100LL fuel prices as reported by www.100LL.com on August 22, 2016. The estimated change in empty weight used in the range calculations was the same as that outlined for the operator costs related to loss of payload, except that it did not include the "effective" loss in payload due to the loss of seating capacity.

Table B3. Resultant Increase in Operator Fuel Costs, Per Year

Aircraft Type	Number of Aircraft Affected per Year	Weight Average Number of Flight Hours per Aircraft per Year	Additional Fuel Burn Rate (gallons/lb./hour)	Cost of Fuel (2016 USD/gallon)	Weighted Average Increase in Empty Weight Due to Proposed Regulatory Changes (lb.)		Resultant Increase in Operator Fuel Costs, per Year		
					.561, .562, .785	0.952	.561, .562, .785	.952	Combined
Single Engine Piston	85	298	0.005	$4.99	30.0	8.5	$18,968	$5,352	$24,320
Single Engine Turbine	84	346	0.005	$4.20	120.3	15.6	$73,518	$9,511	$83,030
Twin Turbine (Part 27)	3	500	0.005	$4.20	0.0	0.0	$0	$0	$0
Part 29	13	627	0.005	$4.20	213.0	72.4	$36,455	$12,389	$48,844
						Totals	**$128,942**	**$27,252**	**$156,193**

Cost Impact of Miscellaneous Operator Issues

Replacement of fleet aircraft may be required by some operators due to the inability of affected aircraft to comply with published government contract terms. As an example, based upon OEM data presented in the Summary of Rotorcraft Performance Data section, full compliance for the AS350B incurs an additional weight load that virtually eliminates its application with currently bid US government contracts already in place. If governmental agencies are unwilling to reduce payload requirements currently published for contract use for the purposes of meeting new Part 27 compliance, operators will have great difficulty competing for future bids utilizing currently published (unrevised) U.S. Government specifications. Operators utilizing the AS350B will likely have to identify an alternative aircraft for this business line, with an increased operational cost.

Data from air medical operators demonstrates the following impacts to fleet operations:

- Part 27 and 29 aircraft are dispatch ready with a fuel load of 400 pounds. The payload reductions specified in the Rotorcraft Performance Section will therefore substantially reduce the range of the average air medical helicopter, as patient weight is nominally fixed.
- Changes in aircraft capability have the potential to reduce access to rural patients because affected aircraft will be unable to operate far enough from receiving hospitals to make a meaningful difference in transport times for ill or injured patients.

Assuming similar maintenance/inspection procedures for compliant seats and fuel tanks, it is estimated that direct operating cost (DOC) is not impacted for these components beyond those factors already discussed. Installation of compliant seats and fuel tanks will drive minimal or no change to pilot training procedures, with nominal costs, if any.

It is difficult to estimate the impact to aircraft insurance costs; while the possible decrease in injuries or fatalities may result in lower payouts following an accident, this may be offset by higher aircraft replacement prices set by OEMs for aircraft that comply with the applicable regulations.

APPENDIX C

OEM PERFORMANCE

Performance data is essential for estimating the cost of complying with the applicable regulations, as changes in aircraft payload and fuel capacities will impact operating costs for each aircraft. It should be recognized that these are rough OEM estimates and are not the product of detailed design studies and/or tests. Therefore, actual changes due to implementation may vary from reported estimates.
Definitions (FAA Flight Standards Service, 2014):

- Payload Δ: The change (+/-) in capacity (measured in US pounds) of the payload, as a result of compliance with the applicable regulations. The data reported assumes a full fuel tank and all drainable oil, and flight crew.
    - The FAA defines **payload** as the combined weight of passengers, baggage, and cargo.
    - The FAA defines **useful load** as the difference between the gross weight and the basic empty weight. It includes the flight crew, usable fuel, drainable oil, if applicable, and payload.
    - The FAA defines **gross weight** as the sum of the basic empty weight and useful load.
    - The FAA defines **basic empty weight** as the weight of the standard helicopter, operational equipment, unusable fuel, and full operating fluids, including full engine oil.
- Fuel Capacity Δ: The change (+/-) in fuel storage capacity (measured in US pounds), as a result of compliance with the applicable regulations.

As the data highlights (Table C1), most of the reduction in payload can be attributed to the inclusion of 27/29.561, .562, and .785 requirements. It should be noted that 27/29.952(b) is structural load criteria which has close ties to 27/29.561. Some OEMs kept the weight/cost impacts of 27/29.952(b) as part of 27/29.561 because it was too difficult to untangle the cost/weight impacts.

Table C1. Part 27 Fuel Capacity

Subcategory	Total Weighted Average Fuel Capacity Δ (lbs.)
Part 27 – Single Piston	-3
Part 27 – Single Turbine	-68
Part 27 – Twin Turbine	0
Part 29	-80

It should also be noted that the application of 27/29.562 to the Helicopter Air Ambulance (HAA) industry is commonly altered via STCs for cabin seating. Many HAA operators have highly customized cabins and special seats are often installed. Those seats often allow the medical personnel to swivel and move around the cabin while attending to the patient, while remaining secured in restraints. Whether those seats comply with 27/29.562 is outside the OEM's area of influence as those are typically kits installed with a Supplemental Type Certificate (STC). This study does not address either the cost/weight or the benefits associated with those or any other STCs.

OEM Comments:

Airbus is advising an average decrease in recommended speed, as a result of the marginal increase in fuel burn.

- Part 27: decrease recommended speed by 1 kt.
- Part 29: decrease recommended speed by 2 kts.

Bell reports that the effects of compliance for Models 206L4 and 407 are as follows:

- Models 206L4 and 407 fuel capacity is expected to decrease as a result compliance with Part 27 (.561, .562, & .785). The addition of energy absorbing (EA) seats eliminates all under seat fuel storage. Otherwise the fuel system does not require modification for 27.952 compliance as it was designed to CRFS standards already.

Leonardo-Finmeccanica (FHD) reports that the effects of compliance for Model AW119 are as follows:

- Limited fuel capacity decrease is expected as a result of compliance with Part 27 (.952). Current fuel bladders (partial crash resistance type) must be replaced with full crash resistance type.

Enstrom Helicopters reports the concerns below, regarding compliance for Enstrom Models F-28X/280FX and 480B:

- Enstrom notes that reducing mission capability by losing the seating capacity is a primary concern. Increasing the cost of the aircraft while dramatically reducing its capability could drive a number of customers out of operation. By closing out the lower cost helicopters, the number of helicopter users will be dramatically reduced, which they believe will affect any economy of scale, thus driving costs disproportionately higher.

References:

FAA Flight Standards Service. (2014, May 15). *Helicopter Flying Handbook*. Retrieved from Federal Aviation Administration: https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/helicopter_flying_handbook/

APPENDIX D

FUEL SYSTEMS COMPLIANCE COST ANALYSIS

Cost data for the components required to implement CRFS was collected from aircraft fuel system manufacturers. The component cost data was reviewed by the rotorcraft Original Equipment Manufacturers (OEMs) and found reasonable. Data provided was used as reference by OEMs in estimating costs associated with integration of available CRFS into their manufacturing process, or for reference in estimating costs of OEM development.

CRFS compliant with CFR 14 27/29.952 typically incur additional weight along with reduced fuel capacity due to increased thickness of the fuel bladder and application of breakaway fittings. Structural changes to the airframe may be required to retain the mass of the fuel system under the higher g-loads specified by the current amendment to 27/29.561, further increasing the aircraft empty weight. Certification requires significant certification testing resulting in a non-recurring cost.

The average estimated delta hardware cost to integrate a CRFS is as follows:

- Part 27 rotorcraft: $7,050
- Part 29 rotorcraft: $11,200

These costs do not account for any structural changes to the aircraft that may be necessary, which are estimated in the accompanying Summary of OEM Cost Data section. A detailed breakdown of estimated CRFS component costs can be found below.

The average non-recurring test and certification costs for CRFS implementation are estimated as follows:

- Part 27 rotorcraft: $31,434
- Part 29 rotorcraft: $43,894

These test costs include the CRFS fuel system components, test and test facility time for both a slosh and vibration test and a fifty-foot crash impact test. Both tests typically require a representative (or actual) airframe structure test fixture. The estimates above do not include the cost of aircraft structures required to perform the slosh and vibration test or the crash impact tests, which are included in the estimates of OEM costs. A detailed breakdown of the estimated CRFS certification and test costs are included below.

Useful capacity loss is projected to be approximately 1 gallon for an average Part 27 fuel system and approximately 3 gallons for an average Part 29 fuel system. Since many operators report they currently operate close to gross weight, compliance with the current regulations may render current designs uneconomical by increasing empty weight and decreasing payload and range.

Compliance with 27/29.952 also requires new application of breakaway fittings, rollover vent valves, flexible fuel lines, and crash resistant gravity filler caps. The cost of these components and tests is shown in Table D1 below. In addition to the cost of designing a compliant fuel system, non-recurring costs also include crash impact testing and slosh and vibration testing. Crash impact testing costs include the cost of the testing process and materials costs (i.e., the wooden platform and the bladder model tested). Slosh and vibration testing costs include the cost of the testing process and the bladder model tested. For Part 27.952 crash resistant fuel system testing, the total cost is approximately $31,434. This total combines the cost of crash impact testing ($10,789) and slosh and vibration (S-V) testing costs ($20,645; avg.). For

Part 29.952 crashworthy fuel system testing, the total cost is approximately $43,894. This total combines the cost of crash impact testing ($18,663) and slosh & vibration (S-V) testing costs ($25,231; avg.).

Table D1. Average Fuel System Costs						
	Part 27			**Part 29**		
	TSO-C80	**27.952**	**Est. Change**	**TSO-C80**	**29.952**	**Est. Change**
Cost of bladder material, avg. (US$)	$2,059	$3,289	$1,230	$6,863	$10,963	$4,100
Cost of CRFS fittings	$0	$5,820	$5,820	$0	$7,100	$7,100
Total additional CRFS cost per unit	$2,059	$9,109	$7,050	$6,863	$18,063	$11,200
Costs of Testing	**Crash Impact**	**S-V**	**TOTAL**	**Crash Impact**	**S-V**	**TOTAL**
Cost of testing 27/29.952 compliant fuel systems (US$)	10,789	20,645	$31,434	$18,663	$25,231	$43,894

Note that these estimates do not include the costs of “in-structure” fuel tank drop testing. FAA requirements for “in-structure” testing are not uniformly applied between fuel systems manufacturers and rotorcraft manufacturers. “In-structure” testing will be required for each OEM to ensure compliance, which will increase testing costs well beyond these estimates.

APPENDIX E

SEAT COST

Data was collected from seat manufacturers (including rotorcraft manufacturers who develop their own seats) to be used by rotorcraft manufacturers as a resource in determining overall rotorcraft manufacturer costs for compliance with the applicable regulations. Therefore, these costs do not appear separately in the overall cost estimate for the industry.

Incorporating seats to meet the requirements of part 27/29.562 requires purchasing or developing energy absorbing (EA) seats that protect the occupant. Installation of EA seats as required by Part 27/29.562 may require increasing the strength of the surrounding structure. This will likely create an increase in the empty weight of the helicopter, in turn creating a significant monetary cost for the design, certification, and manufacturing of the new structure. Increased weight also reduces available payload for the affected rotorcraft.

Many helicopters were designed before the Head Injury Criteria (HIC) of Part 27/29.562 was developed. The cabin interior, including the structure supporting the windshield, may need to be redesigned. This is likely to reduce outside view and increase the empty weight of the helicopter. In some cases, the seating capacity will need to be reduced to meet the HIC requirements. Especially in smaller helicopters, significant certification testing is required to prove the installation meets these requirements.

Data for seats that comply with Parts 27/29.785 is provided in Table E1 below:

Table E1. Seat Costs (USD)

Manufacturer	Model	Non-EA Seat Cost	EA Seat Cost	Cost Δ
Manufacturer A	Utility	$500	$3,250	$2750
	VIP	$500	$4,250	$3750
Manufacturer B	Crew (Part 27) *	$1,200	$15,000	$13,800
	Crew (Part 29) *	$2,300	$10,300	$8,000
Manufacturer C	Cabin	$1,000	$5,000	$4,000
	Crew	$5,000	$15,000	$10,000
Average cost per seat		**$1,750**	**$8,800**	**$7,050**

*Typically seats would not differ between Part 27 and Part 29 aircraft however this manufacturer makes seats that fit unique airframe structures found in certain aircraft.

APPENDIX F

DISCUSSION OF VALUATION OF INJURIES

Valuation of Injuries

There is presently little data on the economic and non-economic costs of injuries including fatal injuries, to occupants involved in helicopter crashes. Because there is a lack of research in this area, this analysis relies heavily upon, and uses direct content from, Economic Values for FAA Investment and Regulatory Decisions, A Guide - Final Report, Sept. 2015, and The Economic & Societal Impact of Motor Vehicle Crashes, 2010 (Revised), L. Blincoe, et al, 2015. While the latter document is specific to injuries sustained in motor vehicle crashes, the methods and figures utilized to make calculations are relevant to the discussion of occupant injuries sustained in helicopter crashes. It is important to consider, however, that the accuracy of these figures will be impacted by the lack of specific data on injury degree for occupants in crashes reported in the NTSB database. Consequently, the true costs of injury in rotorcraft crashes are very likely underestimated in this report.

Value of Life

The benefit of preventing a fatality is measured by what is conventionally called the Value of a Statistical Life (VSL), defined as the additional cost that individuals would be willing to bear for improvements in safety (that is, reduction in risks) that, in the aggregate, reduce the expected number of fatalities by one. This conventional terminology has often provoked misunderstanding on the part of both the public and decision-makers. What is involved is not the valuation of life as such, but the valuation of reduction in risks.

The VSL is a measure of the implied value consumers place on their lives as revealed by the price they are willing to pay to avoid risk of death. A wide range of estimates of the value of VSL have been derived from numerous studies conducted over the past three decades. These “willingness to pay” studies (WTP) are most frequently based on wage rate differentials for risky jobs, or on studies of the prices consumers pay for products that reduce their risk of being fatally injured.

From an analysis conducted in 2015, the Office of the Secretary of Transportation (OST) guidance suggests that $9.4 million be used as the current estimate for the VSL, measured in 2014 dollars. To address the issue of uncertainty, OST noted that the value ranges from $5.2 million to $13 million should be used when conducting sensitivity analysis.

Value of Injuries

Nonfatal injuries are far more common than fatalities and vary widely in severity, as well as probability. OST guidance has established a procedure for valuing averted injuries based on the current value of life and the Maximum Abbreviated Injury Scale (MAIS). MAIS is a comprehensive system for rating the severity of accident-related injuries of an individual utilizing the six levels of injury severity in the Abbreviated Injury Scale (AIS). It classifies nonfatal injuries into five categories (1-5) depending on the short-term severity of the injury in terms of risk of death for that injury. A sixth category corresponds to injuries that are considered “maximum” and almost always result in death (Table F1). For practical reasons, a person is counted as fatal if his injuries result in death 30 days after the accident, since FAA and NTSB usually do not follow-up beyond that period. MAIS is determined on an injured individual as the highest AIS level of injury that person suffered considering all body regions. MAIS does not consider the risk of death for the combined injuries a person may suffer. Table F1 provides sample injuries based on MAIS for reference.

One barrier to accurately ascertaining the cost of injuries sustained in helicopter crashes is the inconsistency between the AIS/MAIS scale utilized by The National Highway Safety Administration (NHTSA), and the less comprehensive scale used by the NTSB. The NTSB scale utilizes only four categories: fatal, serious, minor, and none.

Table F1. Selected Sample of Injuries by the Abbreviated Injury Scale (MAIS)

MAIS	Injury Severity	Selected Injuries
1	Minor	Superficial abrasion or laceration of skin, digit sprain, first-degree burn; head trauma with headache or dizziness (no other neurological signs).
2	Moderate	Major abrasion or laceration of skin, cerebral concussion (unconscious less than 15 minutes), finger or toe crush/amputation. Closed pelvic fracture with or without dislocation.
3	Serious	Major nerve laceration; multiple rib fracture (but without flail chest); abdominal organ contusion; hand, foot, or arm crush/amputation.
4	Severe	Spleen rupture; leg crush; chest-wall perforation; cerebral concussion with other neurological signs (unconscious less than 24 hours).
5	Critical	Spinal cord injury (with cord transection); extensive second- or third-degree burns; cerebral concussion with severe neurological signs (unconscious more than 24 hours).
6	Maximum	Currently untreatable injuries such crushed skull with loss of skull contents or destruction of the heart.

There is no direct relationship between the scale used by the NTSB and the more extensive and widely used AIS Scale utilized by NHTSA. Per the NTSB Form 6120.1, the definitions of fatal and severe injuries are as follows:

- “Fatal injury” refers to any injury that results in death within thirty days of the accident.
- “Serious injury" means any injury that (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fracture of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle, or tendon damage; (4) involves injury to any internal organ; or (5) involves second- or third-degree burns, or any burns affecting more than 5 percent of the body surface.

It should be noted that it is likely that injuries are under reported. There are anecdotal examples of occupants whose injuries were not immediately apparent, but caused disability beyond the immediate post-crash timeframe such as neck strains and other musculoskeletal injuries. Even “minor” injuries can be career ending for those who work in aviation or physically challenging occupations. Another major complex of problems faced by crash survivors are psychological. The occurrence of Post-Traumatic Stress Disorder (PTSD) related issues is either not reported or under reported in the wake of crashes and may require additional research. Unmitigated PTSD can have costly ramifications; whereas, if identified and treated early, PTSD can be managed effectively with far less costly consequences. Further, addiction to pain medications can arise as people try to manage their pain from injuries, leading to another costly variable.

To establish a valuation for each MAIS injury severity level, the MAIS level can be related to the loss of quality and length of life resulting from an injury typical of that level. This loss is expressed as a fraction of the value placed on an avoided fatality. These disutility factors are reported in Table F2 along with their corresponding dollar values (based on a $9.6 million VSL). The fractions shown in column 3 of Table F2 should be multiplied by the current VSL to obtain the values of preventing injuries of the types affected by the government action being analyzed. For example, if an analyst were seeking to estimate the value of a "serious" injury (MAIS 3), he or she would multiply the fraction of VSL for a serious injury (0.105) by the VSL ($9.5 million) to calculate the value of the serious injury ($1,008,000). Values for injuries in the future would be calculated by multiplying these fractions of VSL by the future values of VSL as defined above.

Table F2. Relative Disutility Factors by Injury Severity Level

MAIS Code	Description	Fractional Value of Life Fatality Values	Dollar Value
1	Minor	0.003	$28,800
2	Moderate	0.047	$451,200
3	Serious	0.105	$1,008,000
4	Severe	0.266	$2,553,600
5	Critical	0.593	$5,692,800
6	Maximum	1.000	$9,600,000

The disutility factors or fractions are based on work conducted by Rebecca S. Spicer and Ted R. Miller ''Final Report to the National Highway Traffic Safety Administration Uncertainty Analysis of Quality Adjusted Life Years Lost "Pacific Institute for Research and Evaluation. February 5" 2010.

Although the methodology specified above should be used when possible, aviation injury data is often incomplete and/or unavailable at the AIS level. Most frequently, aviation injuries are reported by the number of victims suffering "serious" and "minor" injuries as reported by the NTSB and defined by the International Civil Aviation Organization (ICAO). Under this classification, serious injury victims are typically those with at least one injury at AIS 2 or higher, whereas minor injury victims typically have injuries at the AIS 1 level only.

To calculate economic values for the ICAO serious injury categories, the Office of Aviation Policy and Plans (APO) took a simple average of the disutility factors for MAIS 2 through MAIS 5 and used these values to create a simple average level of disutility.[1] These values were then applied to current VSL to estimate the value of preventing serious injuries as defined by ICAO. Table F3 reports these values along with those values where there is direct match in terminology between MAIS Codes and the NTSB Classifications. Values for injuries in the future would be calculated by multiplying these modified fractional fatality VSLs by the future values of VSL as described in the formula above.

[1] It should be noted, however, that the recommendation of the author of the NHTSA paper, Larry Blincoe, is to use a weighted average rather than a simple average. The values reflected in this paper utilize the simple average. For future study, a weighted average should be considered since it is probably more accurate.

Table F3. Recommended Injury Values Based on the NTSB Classification of Injuries			
MAIS Code	**NTSB Classification**	**Modified Fractional Fatality Values of Life**	**Dollar Value**
MAIS 1 – Minor	Minor	0.003	$28,800
MAIS 2 – Moderate	Serious	0.253	$2,428,800
MAIS 3 – Serious			
MAIS 4 – Severe			
MAIS 5 – Critical			
MAIS 6 – Fatal	Fatal	1.000	$9,600,000

As the injury data for victims of helicopter crashes are generally unavailable in the NTSB record and not at the MAIS level, for the purposes of this paper we utilized the values in Table F3 to determine the costs of injuries and fatalities. There are limitations to this approach, but because of the lack of data in accident dockets it appears to be the most reasonable approach possible at this time.

Non-Economic Considerations

Economic costs represent only one aspect of the consequences of helicopter crashes. People injured in these crashes often suffer physical pain and emotional anguish that is beyond any economic recompense. The permanent disability of burns, spinal cord damage, loss of mobility, and serious brain injury can profoundly limit a person's life, resulting in dependence on others for routine physical care and activities of daily life. More commonly, less serious injuries, can cause physical pain and limit a victim's physical activities for years after the crash. Serious burns or lacerations can lead to long-term discomfort and the emotional trauma associated with permanent disfigurement. For an individual, these outcomes can be the most devastating aspect of surviving a helicopter crash and usually lead to an inability to work which can have a devastating effect on family income.

The family and friends of the victim feel the psychological repercussions of the victim's injury acutely as well. Caring for an injured family member can be very demanding for others in the family, resulting in economic loss and emotional burdens for all parties concerned. It can change the very nature of their family life and the emotional difficulties of the victim can affect other family members and the cohesiveness of the family unit. When a crash leads to death, the emotional damage is even more intense, affecting family and friends for years afterward and sometimes leading to the breakup of previously stable family units.

Action taken by society to alleviate the individual suffering of its members can be justified in and of itself; to increase the overall quality-of-life for individual citizens. In this context, economic benefits from such actions are useful to determine the net cost to society of programs that are primarily based on humane considerations. If the focus of policy decisions was purely on the economic consequences of helicopter crashes, the most tragic, and, in both individual and societal terms, possibly the costliest aspect of such crashes would be overlooked.[2]

[2] The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised), pg. 1-21

APPENDIX G

DETAILS OF ACCIDENTS UTILIZED TO DETERMINE CRFS PERFORMANCE

14 CFR 27/29.952 FULLY COMPLIANT ROTORCRAFT

ACCIDENTS FROM 1996-2015

Event ID: 20121023X30148	**NTSB No:** CEN13FA025	**Registration:** N385RH	**Accident date:** 10/22/2012
Make: Agusta	**Model:** AW139	**Part 27/29:** 29	**Fire:** N
Injuries: 1S, 1N	**Thermal Injury:** N	**Fuel Spillage:** N	**Crash Severity:** Minor

Summary: The helicopter had sudden and severe vertical vibrations during landing, which resulted in a collision with terrain.

Supporting Data:

Event ID: 20110105X95224	**NTSB No:** ERA11LA106	**Registration:** N854EC	**Accident date:** 12/29/2010
Make: BK117	**Model:** C2	**Part 27/29:** 29	**Fire:** N
Injuries: 3N	**Thermal Injury:** N	**Fuel Spillage:** N	**Crash Severity:** Minor
Summary: Pilot had a stroke in flight & was assisted in landing by the flight nurse—ended in a hard landing.			
Supporting Data: According to a report produced by engineers at American Eurocopter, there was buckling of the exterior skin immediately aft of the right-hand sliding door, above the clam shell doors along the aft edge of the airframe, buckling on the right-hand side lower section of the slant frame, and the equipment deck below the tail cone on the left-hand side. The right-hand landing gear was damaged and exhibited crush damage around the aft end of the skid tube. The aft cross tube was bent and had a ground clearance measurement of 180 millimeters and the bearing rings were displaced from their originally installed position. The forward cross tube was bent and had a measured ground clearance of 503 millimeters. The tail stinger was bent in the positive direction and 26 of the 41-tail boom mating ring mount bolts were loose.			

Event ID: 20110113X14327	**NTSB No:** CEN11CA152	**Registration:** N145SM	**Accident date:** 1/1/2011
Make: Airbus	**Model:** BK117-C2	**Part 27/29: 29**	**Fire:** N
Injuries: 3N	**Thermal Injury:** N	**Fuel Spillage: N**	**Crash Severity:** No crash
Summary: This aircraft landed without incident after experiencing an unusual in-flight noise & rattle.			
Supporting Data: Probable Cause: The pilot's inadequate preflight inspection of the engine cowling latches prior the flight, which resulted in the cowling door opening in-flight and striking the main rotor blades.			

Event ID: 20061226X01846	**NTSB No:** DFW07LA043	**Registration:** N171AE	**Accident date:** 12/21/2006
Make: Airbus	**Model:** EC 120B	**Part 27/29: 27**	**Fire:** N
Injuries: 2N	**Thermal Injury:** N	**Fuel Spillage:** No mention	**Crash Severity:** Moderate
Summary: Intentional autorotation which missed landing area at too high landing speed			
Supporting Data: While performing a practice 180-degree autorotation, the 5,943-hour flight instructor observed that the student would not make the landing area. The flight instructor took over the helicopter controls and elected to land in the grass near the runway. The helicopter touched-down hard with low rotor energy and at a higher than normal touchdown speed. The helicopter proceeded to skid on the soft grass before digging in and rolling forward on its nose. The rotor blades subsequently impacted the ground before the helicopter rolled and came to rest on its right side			

Event ID: 20120724X52626	**NTSB No:** CEN12CA474	**Registration:** N455MH	**Accident date:** 7/24/2012
Make: Airbus	**Model:** BK117-C2	**Part 27/29: 29**	**Fire:** N
Injuries: 3N	**Thermal Injury:** N	**Fuel Spillage:** N	**Crash Severity:** No crash
Summary: Cowling opened and struck rotor blades. Helicopter landed successfully			
Supporting Data: The emergency medical services helicopter was about 800 feet above ground level and landing at a rooftop hospital helipad in a congested metropolitan area when the left side engine cowling opened. The cowling partially separated and impacted the bottom of all four main rotor blades, resulting in substantial damage to the rotor blades.			

Event ID: 20060516X00584	**NTSB No:** DFW06LA118	**Registration:** N514AL	**Accident date:** 5/5/2006
Make: Airbus	**Model:** EC 120B	**Part 27/29: 27**	**Fire:** N
Injuries: 1M	**Thermal Injury:** N	**Fuel Spillage:** Unknown	**Crash Severity:** Moderate
Summary: Pilot lost control making a turn and crash landed into water			

Event ID: 20130215X30422	**NTSB No:** ERA13LA134	**Registration:** N481LF	**Accident date:** 2/14/2013
Make: Airbus	**Model:** BK117-C2	**Part 27/29: 29**	**Fire:** N
Injuries: 4N	**Thermal Injury:** N	**Fuel Spillage: N**	**Crash Severity:** No crash
Summary: Aircraft contacted a crane marker on approach to a hospital helipad but did not crash			
Supporting Data:			
Supporting Data: Somewhere between 300 and 400 feet, the pilot initiated a left turn to a northerly heading. At that time the pilot experienced an uncommanded cyclic movement to the right-forward quadrant and the collective started to come up (increase). The pilot added that the nose of the helicopter pitched-up and the helicopter started to roll to the left. The pilot stated that he concluded that he had experienced "a hydraulic failure of some kind," so as per the emergency procedures, he turned the hydraulic control switch on the collective lever to the "off" position. The pilot added that the hydraulic light on the console was activated indicating that the hydraulics were "off." The action taken by the pilot were not effective and the pilot was not able to regain control of the helicopter. The helicopter continued rolling to the left and entered a spin to the left while the helicopter remained in a nose low attitude. The pilot stated that the helicopter spun for about 3 to 5 revolutions and impacted the water between a 70 and a 90-degree nose down attitude			

Event ID: 20070223X00214	**NTSB No:** CHI07FA069	**Registration:** N690WR	**Accident date:** 2/12/2007
Make: Airbus	**Model:** EC 120B	**Part 27/29: 27**	**Fire:** N
Injuries: 2F	**Thermal Injury:** N	**Fuel Spillage:** Not noted	**Crash Severity:** Extreme
Summary: Impact with oil rig platform during gusty winds followed by water impact. The helicopter and its occupants were later located and recovered from 101 feet of water, approximately 2,900 feet from the platform.			
Supporting Data: An autopsy of the pilot was performed by the Lafayette Parish Coroner's Office on February 15, 2007. The final autopsy report listed the cause of death as "multiple blunt force trauma." The pilot and passenger were both reportedly located strapped in their seats and the seat belts were cut during extrication. The helicopter was equipped with attenuating seats. The left front seat pan showed deformation to the right and the seat pan was buckled in the center. The right front seat pan was also crushed.			

<table>
<tr><td>Event ID:
20070307X00258</td><td>NTSB No:
ATL07CA037</td><td>Registration:
N491AE</td><td>Accident date:
2/3/2007</td></tr>
<tr><td>Make: Airbus</td><td>Model: EC 120B</td><td>Part 27/29: 27</td><td>Fire: N</td></tr>
<tr><td>Injuries: 3N</td><td>Thermal Injury: N</td><td>Fuel Spillage: Not mentioned</td><td>Crash Severity: Moderate</td></tr>
<tr><td colspan="4">Summary: Training flight at low altitude hover resulting in a spin and subsequent ground impact</td></tr>
<tr><td colspan="4">Supporting Data: The helicopter's tail rotor struck the ground, and the helicopter rolled over on its right side. The pilot and CFI did not report any mechanical or flight control anomalies with the helicopter. Examination of the helicopter revealed the tail boom separated from the fuselage and main rotor blades were destroyed</td></tr>
</table>

<table>
<tr><td>Event ID:
20091016X45106</td><td>NTSB No:
CEN10WA016</td><td>Registration:
N871SA</td><td>Accident date:
10/15/2009</td></tr>
<tr><td>Make: Airbus</td><td>Model: EC 120B</td><td>Part 27/29: 27</td><td>Fire: N</td></tr>
<tr><td>Injuries: 3F</td><td>Thermal Injury: N</td><td>Fuel Spillage:
Unknown</td><td>Crash Severity:
Extreme</td></tr>
<tr><td colspan="4">Summary: Fatal crash in the Dominican Republic. Minimal crash details available</td></tr>
<tr><td colspan="4">Supporting Data:
On October 15, 2009, about 2035 Coordinated Universal Time (UTC), a single-engine Eurocopter EC-120B helicopter, registration N871SA, impacted terrain en route from San Domingo to San Jose de Ocoa. The pilot, and two passengers, received fatal injuries. No docket available.</td></tr>
</table>

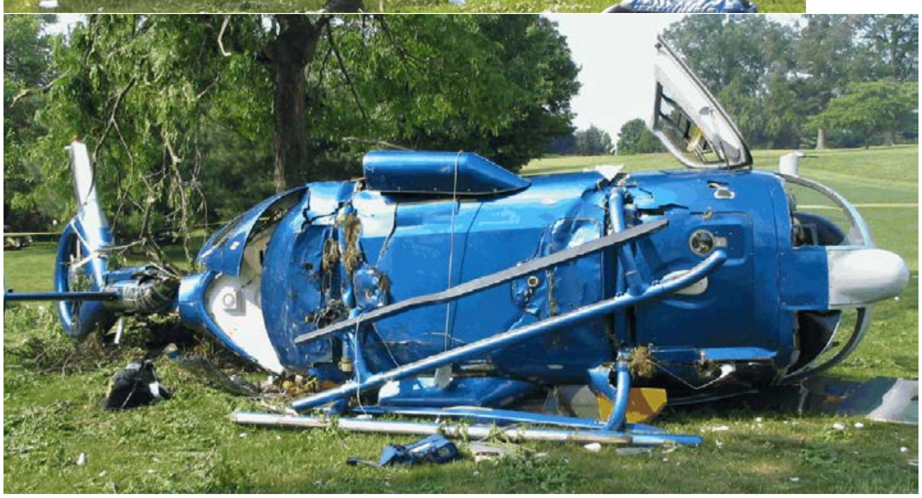
<table>
<tr><td>Event ID:
20111005X91033</td><td>NTSB No:
CEN12TA004</td><td>Registration:
N3925A</td><td>Accident date:
04-Oct-11</td></tr>
<tr><td>Make: Airbus</td><td>Model: EC 120B</td><td>Part 27/29: 27</td><td>Fire: None</td></tr>
<tr><td>Injuries: 2M</td><td>Thermal Injury:
None</td><td>Fuel Spillage:
None</td><td>Crash Severity:
Moderate</td></tr>
<tr><td colspan="4">Summary: Run-on landing on soft ground which led to nose over and rolling the helicopter on its side</td></tr>
<tr><td colspan="4">Supporting Data:
From the narrative: “The helicopter touched down between 16 and 24 knots, and slid forward approximately 34-feet before the helicopter began a forward pitching moment. The helicopter's wire strike protection system (WSPS) and the main rotor blades struck the ground. As the helicopter continued to pitch over it began a counter-clockwise rotation and came to rest on its right side, severing the tail boom. The skids and main rotor blades were also damaged.”</td></tr>
</table>

Event ID: 20120726X62312	**NTSB No:** WPR12WA327	**Registration:** N8899	**Accident date:** 20-Jul-12
Make: Airbus	**Model:** EC 120B	**Part 27/29:** 27	**Fire:** None
Injuries: 3F, 1N	**Thermal Injury:** None	**Fuel Spillage:** Unknown	**Crash Severity:** Minor
Summary: Water ditching in Malaysia (detailed accident data not available). Fatalities were drownings not related to the crash			
Supporting Data: From the narrative: "On July 20,1012, at 1335 universal coordinated time, a Eurocopter EC120B, N8899, ditched into the Batang Lupar River, near Triso, Malaysia. The helicopter had a United States registration and was operated by the Sebiro Holding Company under the provisions of the Malaysian Civil Aviation Regulations 1996. The commercial pilot was not injured, and three passengers who survived the ditching subsequently drowned in the river.			

Event ID: 20060607X00691	**NTSB No:** NYC06MA131	**Registration:** N601FH	**Accident date:** 30-May-06
Make: Airbus	**Model:** EC 135-P1	**Part 27/29:** 27	**Fire:** None
Injuries: 1F, 3S	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Moderate

Summary: Rotorcraft lost power while attempting to land at the hospital helipad. An attempted emergency landing at a nearby golf course resulted in a tree impact and crash. The on-board injured patient was fatally injured.

Supporting Data:
From the narrative: "Once over the golf course, the helicopter began to vibrate. The vibration increased, the nose yawed from side to side, and the helicopter "went into a spin." It descended vertically, struck a tree, then terrain, and rolled over on its side."



Event ID: 20131112X12840	**NTSB No:** CEN14LA048	**Registration:** N911KB	**Accident date:** 09-Nov-13
Make: Airbus	**Model:** EC 135-P1	**Part 27/29:** 27	**Fire:** None
Injuries: 3M	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Moderate
Summary: Check flight after maintenance resulted in loss of yaw control, followed by crash landing.			
Supporting Data: From the narrative: "When the helicopter was abeam to fence the pilot heard a "pop" and the helicopter began a rapid spin. Directional control of the helicopter was lost and the pilot attempted to regain control by using the anti-torque pedals but he found them ineffective. The pilot was not able to regain control of the helicopter and he reduced the engine throttle for an autorotation. The helicopter descended, landed, rolled, and came to rest on its right side."			

Event ID: 20080612X00843	**NTSB No:** NYC08FA198	**Registration:** N238AM	**Accident date:** 30-May-08
Make: Airbus	**Model:** EC 135-P2+	**Part 27/29:** 27	**Fire:** None
Injuries: 3M	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Moderate
Summary: Take-off with only one engine under power followed by crash landing.			
Supporting Data:			

Event ID: 20151119X93456	**NTSB No:** GAA16LA056	**Registration:** N36RX	**Accident date:** 19-Nov-15
Make: Airbus	**Model:** EC 135-P2+	**Part 27/29:** 27	**Fire:** None
Injuries: 5N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** No crash
Summary: Ingested foreign object debris (FOD) into the Fenestron during landing			
Supporting Data: From the narrative: "The training consisted of multiple takeoffs and landings from the training center landing site. He reported that during the third landing, between two to three feet above ground level, he felt the helicopter "shutter unexpectedly." The pilot immediately landed and shut down the helicopter without further incident."			

Event ID: 20100214X92140	**NTSB No:** WPR10FA133	**Registration:** N127TS	**Accident date:** 14-Feb-10
Make: Airbus	**Model:** EC 135-T1	**Part 27/29:** 27	**Fire:** Ground
Injuries: 5F	**Thermal Injury:** Yes, however cause of death was blunt impact	**Fuel Spillage:** Yes	**Crash Severity:** Extreme
Summary: Main rotor blade strike of tail boom during cruise. Investigation concluded that inadvertent cyclic input by a child seated on the co-pilot's lap most likely caused the crash.			

Supporting Data:

From the NTSB factual report, Table showing all fatalities caused by blunt impact injuries:

Table 2: A table of the occupant injury description and classification.

Occupant Location	Gender	Age	Height	Weight	Description Of Injuries	Injury
Pilot, Front, right	Male	63	68"	237 lbs	Blunt impact to head, torso and extremities Fractures of the skull Avulsion of brain Lacerations of scalp and face Fractures of axial skeleton Lacerations of pericardium, diaphragm and viscera Avulsion of viscera Torso soft tissue lacerations Avulsion of arm, forearm and hand Fractures of appendicular skeleton Lacerations to extremities Body surface burns	Fatal
Front, left	Male	64	69"	185 lbs	Blunt impact injuries[4]	Fatal
Front, left, adult's lap	Female	5	47.5"	42 lbs	Blunt impact injuries[4]	Fatal
Rear-facing passenger seat, left front	Female	40	69"	130 lbs	Blunt impact injuries[4]	Fatal
Forward-facing passenger seat, right rear	Male	38	70"	160 lbs	Blunt impact injuries[4]	Fatal

Excerpt from the Component Investigation Report: (note last bullet point: "accident was non-survivable)

III. ACCIDENT SITE

- The wreckage path was approximately 1/3 mile long on a southerly heading.
- The main wreckage came to rest in relatively confined area, consistent with a vertical impact.
- Crushing and other damage observed on the aircraft structure suggests the aircraft was slightly nose low, with a slight right bank on impact.

IV. WRECKAGE EXAMINATION

A. General

- All major aircraft components, with the exception of main rotor blade tip material, were accounted for near or along the wreckage path.
- No evidence of an in-flight fire was observed.
- The accident was non-survivable.

Event ID: 20060524X00615	**NTSB No:** MIA06CA096	**Registration:** N914EF	**Accident date:** 21-Apr-06
Make: Airbus	**Model:** EC 135-T2	**Part 27/29:** 27	**Fire:** None
Injuries: 1M, 2N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Minor
Summary: Hard emergency landing after takeoff and entering low visibility.			
Supporting Data: From the narrative: "He pulled max torque and within 1 or 2 seconds the helicopter landed level and hard, just off the side at the very end of the runway. The helicopter bounced into the air after the impact. He brought the helicopter to a hover and noted the helicopter was dangerously close to bushes and trees. He maneuvered the helicopter away from the tree line toward the runway and landed at the helipad." From the pilot report, one occupant complained of back pain: Ross Pritchard complained after landing that he may have strained his back was taken to a local hospital for X-Rays as a precautionary measure.			

Event ID: 20151204X43427	**NTSB No:** ERA16CA060	**Registration:** N639ME	**Accident date:** 06-Nov-15
Make: Airbus	**Model:** EC 135-T2	**Part 27/29:** 27	**Fire:** None
Injuries: 4N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Minor
Summary: Fenstron ingested FOD just after takeoff. Landed after loss of yaw control.			
Supporting Data: From the narrative: "After liftoff during a helicopter emergency medical service (HEMS) flight with a patient on board, the pilot of the HEMS helicopter brought it in to a 1 to 2-foot hover and was preparing to make a right pedal turn into the wind, when a cover from a wheeled fire extinguisher, was blown airborne by the main rotor wash and ingested into the tail rotor (Fenestron) of the helicopter. The helicopter lost tail rotor authority and began to spin clockwise. The pilot lowered the collective and the helicopter rotated approximately 150 degrees, then impacted the ground and continued to rotate another 20 to 30 degrees, for a total of 170 to180 degree turn, and came to rest."			

<table>
<tr><td>Event ID:
20080520X00702</td><td>NTSB No:
CHI08FA128</td><td>Registration:
N135UW</td><td>Accident date:
10-May-08</td></tr>
<tr><td>Make: Airbus</td><td>Model: EC 135-T2+</td><td>Part 27/29: 27</td><td>Fire: None</td></tr>
<tr><td>Injuries: 3F</td><td>Thermal Injury:
None</td><td>Fuel Spillage:
None noted</td><td>Crash Severity:
Extreme</td></tr>
<tr><td colspan="4">Summary: Impact with trees during night time flight with inclement weather.</td></tr>
<tr><td colspan="4">Supporting Data: From the narrative:
“The main wreckage consisted of the fuselage (cockpit and cabin areas), the engines, main rotor transmission, main rotor mast and main rotor blade roots. The cockpit and cabin areas were completely compromised.”

From the Eurocopter detailed report:

3. Aircraft Examination

A. The aircraft was destroyed during the accident sequence.

B. The accident was non-survivable.

H. The physical evidence gathered at the post accident examination and the digital data recorded by the above components revealed the following:

1. The aircraft impacted treetops in a level attitude at a high rate of forward airspeed.</td></tr>
</table>

<table>
<tr><td>Event ID:
20150901X73122</td><td>NTSB No:
CEN15LA395</td><td>Registration:
N429AR</td><td>Accident date:
22-Aug-15</td></tr>
<tr><td>Make: Bell</td><td>Model: 429</td><td>Part 27/29: 27</td><td>Fire: None</td></tr>
<tr><td>Injuries: 4N</td><td>Thermal Injury:
None</td><td>Fuel Spillage:
None</td><td>Crash Severity:
No crash</td></tr>
<tr><td colspan="4">Summary: Forced landing after mechanical failure (no crash)</td></tr>
<tr><td colspan="4">Supporting Data: From the narrative: “On August 22, 2015, at an unknown time, a Bell Helicopter 429, N429AR, experienced a tail rotor pitch change link failure during flight and landed uneventfully at the Midstream Port O'Conner Heliport (XA81), Port O'Connor, Texas. The pilot and three passengers were not injured. The helicopter was substantially damaged.”</td></tr>
</table>

Event ID: 20070328X00342	**NTSB No:** DFW07CA065	**Registration:** N451DL	**Accident date:** 06-Feb-07
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 2N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Minor
Summary: Emergency landing after loss of power. Successful autorotation and landing.			
Supporting Data: From the narrative: "The pilot added that following the loss of engine power, he immediately entered autorotation and landed to a logging road surrounded by tall trees. The aircraft sustained structural damage to the tail boom and main rotor blades during the forced landing. The helicopter came to rest in the upright position. The pilot and his passenger were not injured and were able to egress the helicopter unassisted."			

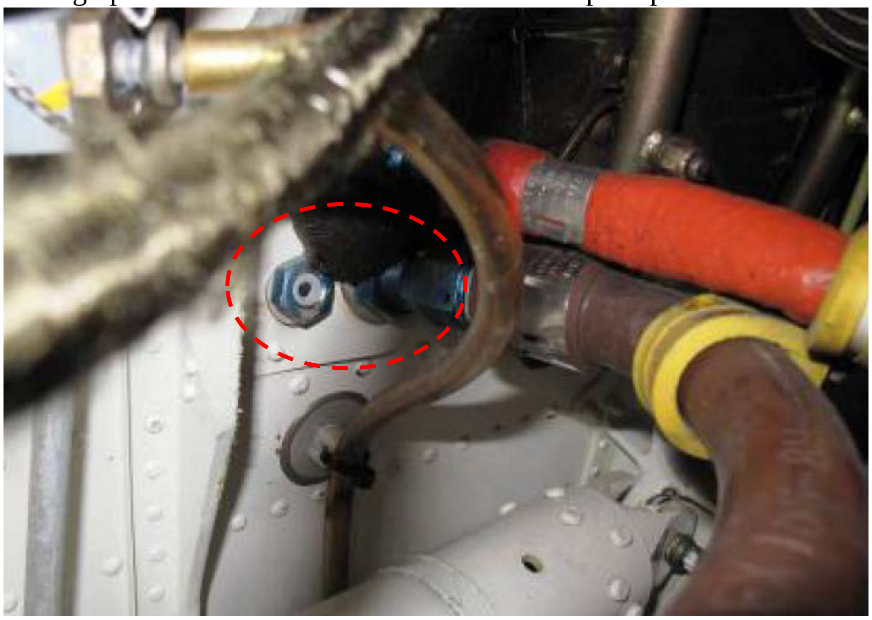
Event ID: 20080410X00451	**NTSB No:** CHI08CA098	**Registration:** N160KC	**Accident date:** 26-Mar-08
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 2M	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Minor
Summary: Hard landing.			
Supporting Data: From the narrative: "The helicopter was being operated as a corporate/executive flight when it received substantial damage during a hard landing. The pilot had been demonstrating inputs needed to control the helicopter to the passenger. He was demonstrating a normal approach to a hover by talking through all the control inputs during a visual approach. The tail boom separated from the fuselage during the hard landing."			

Event ID: 20090220X14000	**NTSB No:** WPR09GA119	**Registration:** N608BP	**Accident date:** 19-Feb-09
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 2S, 1M	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Moderate
Summary: Autorotation after engine failure, followed by hard landing			
Supporting Data: From the narrative: "The pilot performed an autorotation, maneuvering the helicopter to avoid obstacles. The helicopter sustained substantial damage after landing hard, semi-submerged in the surf zone of a beach. During the landing sequence, a main rotor blade made contact with the tail boom and the helicopter sustained crush damage to the lower fuselage." From the NTSB Form 6120.1: There was no post crash fire and apparently no fuel spills. Note: The 6120.1 form states all occupants received minor injury (no serious injuries as reported in the NTSB database). However, the 6120.1 form is filled out by the owner/pilot, and reflects his/her opinion of the injuries.			

Event ID: 20091013X04846	**NTSB No:** WPR10TA016	**Registration:** N613BP	**Accident date:** 12-Oct-09
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 1M, 1N	**Thermal Injury:** None	**Fuel Spillage:** Yes	**Crash Severity:** Minor

Summary: Extreme hard landing during intentional autorotation. Left landing gear partially collapsed which tore through the rotorcraft skin. Post-accident photograph shows spill absorbent on the runway under the punctured skin. Detailed post-accident report from MD helicopters identified a broken fuel pump return line that spilled some fuel on the runway.

Supporting Data:
Photographs at accident site and from MD Helicopters post-accident investigation



Excerpt from the MD Helicopters post-accident investigation:

h. Fuel System:

The main fuel tank contained approximately 600 pounds of fuel. The engine fuel pump return line fitting was broken at the engine firewall and a small amount of fuel from this line leaked on the runway. The broken fitting appeared to be related to the landing gear strut/damper and engine mount attachment fitting damage. No other fuel leaks were reported.

Event ID: 20120808X44331	NTSB No: ANC12FA084	Registration: N737TV	Accident date: 07-Aug-12
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 1F	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Severe

Summary: Pilot lost control while repositioning helicopter after landing on a helipad in a mountainous area. The helicopter tumbled down a heavily wooded mountain slope.

Supporting Data:
From the narrative: "The cockpit was severely damaged with extensive deformation. The canopy was segmented and separated with all canopy glass windscreens and overhead transparencies shattered or missing."

Event ID: 20140427X71558	**NTSB No:** WPR14LA173	**Registration:** N606BP	**Accident date:** 27-Apr-14
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 1S, 2M	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Moderate
Summary: Pilot lost control after take-off.			
Supporting Data: Accident photograph found online:			

Event ID: 20151208X01729	**NTSB No:** CEN16LA058	**Registration:** N607BP	**Accident date:** 07-Dec-15
Make: MDHI	**Model:** MD 600N	**Part 27/29:** 27	**Fire:** Yes, ground
Injuries: 1M, 1N	**Thermal Injury:** None	**Fuel Spillage:** Unknown	**Crash Severity:** Moderate
Summary: Minor crash during an attempted off airport landing. Following a loss of control, the rotorcraft spun and impacted terrain, and rolled onto its left side. The accident docket was not readily available (perhaps not completed yet), however accident photographs are available online. The fire appears to have been contained to the engine compartment area and to a small grassy area on the ground near the engine exhaust. It appears that the fire self-extinguished and the CRFS prevented significant fuel spillage. Had there been significant fuel spillage, it is expected the fire would have spread and consumed the airframe.			

Supporting Data:

Event ID: 20060403X00379	**NTSB No:** ANC06LA038	**Registration:** N912LH	**Accident date:** 22-Mar-06
Make: MDHI	**Model:** MD-900	**Part 27/29:** 27	**Fire:** None
Injuries: 2N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** No crash
Summary: Post-flight inspection of helicopter after a high-performance video session found damage to the main rotor hub. Helicopter landed normally (no crash)			
Supporting Data: From the narrative: "All the maneuvers were completed uneventfully, with no in-flight anomalies noted, and the helicopter returned to the MD Helicopters facility in Mesa."			

Event ID: 20141204X91829	**NTSB No:** CEN15LA066	**Registration:** N902LC	**Accident date:** 26-Nov-14
Make: MDHI	**Model:** MD-900	**Part 27/29:** 27	**Fire:** None
Injuries: 1M, 2N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** No crash
Summary: Main rotor blades damaged from wire strike during remote landing (no crash).			
Supporting Data: From the narrative: "He attempted to move the helicopter left to avoid the power lines, but the main rotor blades inadvertently struck one of them. The pilot maintained control of the helicopter and landed it safely."			

Event ID: 20110713X53504	**NTSB No:** ERA11RA398	**Registration:** N810AG	**Accident date:** 12-Jul-11
Make: Robinson	**Model:** R-66	**Part 27/29:** 27	**Fire:** None
Injuries: 2F	**Thermal Injury:** Unknown	**Fuel Spillage:** Unknown	**Crash Severity:** Extreme
Summary: From the narrative:" A witness observed the helicopter flying in a northeasterly direction, then heard a crack sound, followed by seeing something separate from the helicopter. The witness noted the helicopter spinning about the vertical axis while descending, followed by impact. The helicopter came to rest on its left side; the tail cone and tail rotor were found separated, and were located about 46 meters from the main wreckage."			
Supporting Data: None other than narrative information above. Crash in Columbia so no detailed reports readily available.			

Event ID: 20111001X63448	**NTSB No:** CEN12FA001	**Registration:** N266CY	**Accident date:** 01-Oct-11
Make: Robinson	**Model:** R-66	**Part 27/29:** 27	**Fire:** Yes, ground
Injuries: 1F	**Thermal Injury:** Unknown	**Fuel Spillage:** Yes	**Crash Severity:** Extreme
Summary: Very severe crash after main rotor separation during flight.			
Supporting Data: From the narrative: "The helicopter wreckage and debris came to rest on rolling ranch land and was spread out over an area approximately 1,520 feet long by 600 feet wide. The main rotor head, with attached blades, came to rest 513 feet from the main wreckage. The main wreckage consisted of the fuselage, engine, and tail rotor assembly."			

Event ID: 20130728X45845	**NTSB No:** ERA13FA336	**Registration:** N646AG	**Accident date:** 27-Jul-13
Make: Robinson	**Model:** R-66	**Part 27/29:** 27	**Fire:** None
Injuries: 5F	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Extreme

Summary: Non-instrument rated pilot crashed after entering IMC (departed under VFR). Crash was in a heavily wooded area

Supporting Data:
From the Robinson detailed report:

when the line was detached from the fuel pump. No breaches of the fuel systen noted, and there was no evidence of fuel spillage on the ground. When the wre was examined at the facilities of Anglin Aircraft Recovery Services by NTSB per on 17 September 2013, approximately 54 gallons of fuel were drained from tl tank. A sample of the fuel was collected and retained.

Photograph showing extensive cabin crush

Event ID: 20141105X83801	**NTSB No:** CEN15CA039	**Registration:** N67GA	**Accident date:** 29-Oct-14
Make: Robinson	**Model:** R-66	**Part 27/29:** 27	**Fire:** None
Injuries: 2N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** No crash
Summary: Helicopter made successful landing after bird strike to main rotor blade (no crash).			
Supporting Data: From the narrative: "The instructor pilot took the controls as one of the birds and the retreating main rotor blade collided. The pilot landed the helicopter without further incident. Examination of the helicopter revealed substantial damage to the main rotor blade."			

Event ID: 20141222X43102	**NTSB No:** ERA15CA079	**Registration:** N64HF	**Accident date:** 22-Dec-14
Make: Robinson	**Model:** R-66	**Part 27/29:** 27	**Fire:** None
Injuries: 1N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Minor
Summary: Tail rotor struck a snowbank during landing			
Supporting Data: No fuel leakage noted in docket documents. Photograph also shows no sign of fuel leakage. 			

Event ID: 20030702X01008	**NTSB No:** CHI03FA179	**Registration:** N298HS	**Accident date:** 25-Jun-03
Make: Airbus	**Model:** EC 120B	**Part 27/29:** 27	**Fire:** None
Injuries: 1F	**Thermal Injury:** None noted	**Fuel Spillage:** None noted	**Crash Severity:** Extreme
Summary: CFIT during night flight with bad weather. The pilot was not instrument rated.			
Supporting Data: From the narrative: "The wreckage debris path was distributed in a straight line, over approximately 400 feet on a 345-degree magnetic heading. There were several fragmented portions of the main rotor system near the initial impact point. The tail boom and shrouded tail rotor were located 321 feet and 328 feet from the initial impact point, respectively. The main cabin was located 340 feet from the initial impact point. The main transmission, engine, mast and rotor head were located 392 feet from the initial impact point."			

Event ID: 20030715X01110	**NTSB No:** FTW03LA186	**Registration:** N162TA	**Accident date:** 08-Jul-03
Make: Airbus	**Model:** EC 120B	**Part 27/29:** 27	**Fire:** None
Injuries: 3N	**Thermal Injury:** None	**Fuel Spillage:** None noted	**Crash Severity:** Minor
Summary: Blade strike during landing on a ship platform. Rotorcraft ditched successfully.			
Supporting Data: From the narrative: "During the descent, he informed the passengers that they were going down and deployed the emergency floats. The pilot stated that the landing "was soft onto the water, and was stable upon touchdown."			

Event ID: 20040128X00115	**NTSB No:** ATL04LA070	**Registration:** N125MG	**Accident date:** 24-Jan-04
Make: Airbus	**Model:** EC 120B	**Part 27/29:** 27	**Fire:** None
Injuries: 2N	**Thermal Injury:** None noted	**Fuel Spillage:** None noted	**Crash Severity:** Minor
Summary: Student pilot applied too much aft cyclic during autorotation practice causing the main rotor to severe the tail boom.			
Supporting Data: From the narrative: "According to the CFI, during the touchdown phase of the autorotation, the main rotor blades made contact with and severed the tail boom. The helicopter landed and the CFI shut down the engine."			

Event ID: 20050718X01046	**NTSB No:** LAX05GA231	**Registration:** N266SD	**Accident date:** 13-Jul-05
Make: Airbus	**Model:** EC 120B	**Part 27/29:** 27	**Fire:** In flight and on ground
Injuries: 2F, 1S	**Thermal Injury:** None noted	**Fuel Spillage:** None noted	**Crash Severity:** Severe

Summary: Severe crash into a hill side following engine failure. Severe cabin crush in the front area of the helicopter (Non-survivable for both front occupants). A ground fire was started near the initial impact point but did not follow the wreckage to its final resting point. There is no mention of fuel spillage or fuel fire in the docket reports.

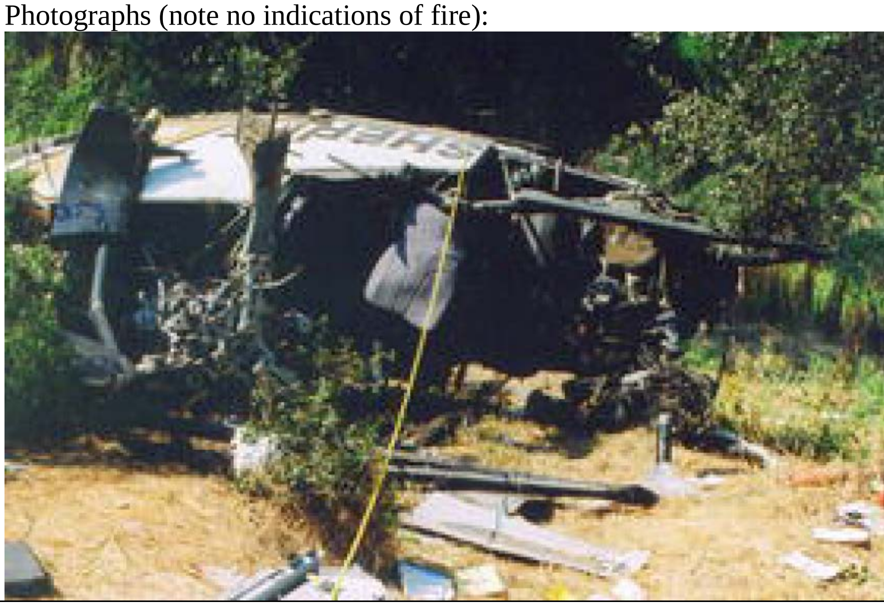
Supporting Data:

In flight engine fire was noted by ground observers. From the narrative: “He witnessed a 2.5-foot yellow flame coming from the base of the engine, just below the main rotor blades.”

Ground fire is noted in the Department of Forestry and Fire Protection report. The investigation concluded that the fire initiated some 90 feet from the wreckage final resting point. Impact marks and small pieces of wreckage were found at that point. The fuselage was not consumed by fire and the area near the wreckage final resting point did not burn. This indicates no significant fuel spillage.

Eurocopter performed a detailed crash investigation (report in the docket). There is no mention of fuel spillage or lack of performance of the CRFS.

Photographs (note no indications of fire):



Event ID: 20001211X11617	**NTSB No:** NYC99FA032	**Registration:** N44NY	**Accident date:** 03-Dec-98
Make: Airbus	**Model:** EC 135-P1	**Part 27/29:** 27	**Fire:** Inflight
Injuries: 2M	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Moderate
Summary: Water impact following engine failure. The crash was severe enough that both occupied seats stroked downward.			
Supporting Data: (from the narrative) Notes on crash severity and CRFS performance: "The fuselage floor was fractured between the middle and rear rows of seats. The paneling on the bottom of the fuel tank was not recovered. However, the fuselage fuel tank bladder mounted in the lower aft fuselage was not ruptured or leaking. The helicopter was equipped with attenuating seats that were designed to collapse downward under increased "g" loads. Post-accident examination revealed that both occupied crew seats had collapsed downward, and neither occupant received serious injuries." Notes on inflight fire: Video of the helicopter was taken by a nearby news helicopter. Excerpts from the video review: "When Chopper 4 was visually acquired, a momentary burst of flame was observed emitting from the helicopter. The source could not be determined. As Chopper 4 continued to descend, the glow of both engines could be discerned. Occasional bursts of flame were seen from the rear of the helicopter; however, the exact location they originated from was not determined. About 5.5 seconds prior to water impact, as the helicopter slowed and descended, bright flashes were observed, and several bright glowing objects exited from the rear of the helicopter and fell toward the ground."			

Event ID: 20021220X05621	**NTSB No:** SEA03LA019	**Registration:** N311MS	**Accident date:** 17-Dec-02
Make: Airbus	**Model:** EC 135-P1	**Part 27/29:** 27	**Fire:** None
Injuries: 4N	**Thermal Injury:** None noted	**Fuel Spillage:** None noted	**Crash Severity:** Minor
Summary: Emergency landing after entering bad weather			
Supporting Data: From the narrative: "While attempting to slow the helicopter and either turn around or make a precautionary landing on a road (Hwy 395) the helicopter entered a high rate of descent. I ended up making a hard landing on Hwy 395 in pretty much a complete white out."			

Event ID: 20050120X00080	**NTSB No:** NYC05MA039	**Registration:** N136LN	**Accident date:** 10-Jan-05
Make: Airbus	**Model:** EC 135-P2	**Part 27/29:** 27	**Fire:** None
Injuries: 2F, 1S	**Thermal Injury:** Yes	**Fuel Spillage:** None noted	**Crash Severity:** Severe
Summary: Water impact into the Potomac river. Pilot apparently misjudged his height above the water (CFIT). The crash survivor was treated for burns (as stated in the narrative), but the NTSB Factual report states there was no evidence of an inflight or post-crash fire.			
Supporting Data: From the narrative: "The State of Maryland, Office of the Chief Medical Examiner, performed autopsies on the pilot and the flight paramedic. The medical examiner determined that the pilot's cause of death was "multiple injuries." The flight paramedic's cause of death was listed as "drowning complicated by hypothermia"; [12] the paramedic was found still belted into the left aft cabin seat. According to the flight nurse, after the crash, he was submerged in water but was able to remove his seat restraints, exit the helicopter, and remain near the helicopter's partially submerged tail section until a rescue boat arrived. He was taken to a hospital and treated for a broken arm and burns." From the NTSB Factual Report: "Examination of the helicopter's wreckage debris revealed no evidence of an in-flight or post-crash fire." Photographs from the docket:			

Event ID: 20050106X00024	**NTSB No:** LAX05LA060	**Registration:** N135NW	**Accident date:** 03-Jan-05
Make: Airbus	**Model:** EC 135-T1	**Part 27/29:** 27	**Fire:** None
Injuries: 1M, 1N	**Thermal Injury:** None noted	**Fuel Spillage:** None noted	**Crash Severity:** Moderate
Summary: Loss of control during flight caused by mechanical failure (maintenance error). Hard emergency landing led to rollover.			
Supporting Data: From the narrative: "As the helicopter neared the ground, the pilots flared and the helicopter hit the ground in a tail low attitude and rolled over."			

Event ID: 20001205X00356	**NTSB No:** LAX99TA115	**Registration:** N626SB	**Accident date:** 09-Mar-99
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 3M	**Thermal Injury:** None	**Fuel Spillage:** None noted	**Crash Severity:** Moderate
Summary: Pilot entered IFR and collided with mountainside. Accident severity may be minor based on no serious injury			
Supporting Data: Need docket to verify impact severity. Moderate based on occupant injuries (only minor).			

Event ID: 20001208X07083	**NTSB No:** LAX97LA061	**Registration:** N630N	**Accident date:** 21-Nov-96
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 1N	**Thermal Injury:** None noted	**Fuel Spillage:** None noted	**Crash Severity:** Moderate

Summary: Series of intentional autorotations. The landing gear limit was exceeded on the fourth autorotation causing collapse of the landing gear skids.
Supporting Data: From the narrative: "During touchdown on the fourth autorotation, the helicopter contacted the runway and displaced both skids with the right skid separating from the aircraft at the brace assembly connecting bolt hole. The fuselage was buckled and cracked along the right side and the bottom of the fuselage." Video was being taken and was analyzed by MD engineers. The touchdown rate was about 13.5 feet per second. The design limit for this landing gear (skid) system was 6.5 feet per second.

Event ID: 20001208X07311	**NTSB No:** LAX97FA091	**Registration:** N9202L	**Accident date:** 18-Jan-97
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 1N	**Thermal Injury:** None noted	**Fuel Spillage:** None noted	**Crash Severity:** Moderate
Summary: Intentional autorotation resulted in excessive vertical descent rate.			
Supporting Data: From the narrative: "A video recording of the accident revealed that as the aircraft touched down, the skids collapsed and the tail boom was severed by contact with the main rotor blades. The tail boom separation resulted in loss of directional control and the aircraft began yawing left during the accompanying ground run. As the ground run progressed, the aircraft veered off the left side of the runway and onto snow covered sod. The main rotor blades struck the ground as the aircraft rolled onto its right side and came to rest."			

Event ID: 20001211X09466	**NTSB No:** LAX98LA076	**Registration:** N176SP	**Accident date:** 16-Jan-98
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 2N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Minor
Summary: Intentional autorotation with too high descent rate which caused tail boom main rotor strike.			
Supporting Data: From the narrative: "According to the aircraft manufacturer, the touchdown resulted in a hard landing, which caused the main rotor blades to flex and contact the tail boom. The tail boom was subsequently fractured by the rotor blade contact. The aircraft remained upright and the engine was shutdown using the emergency shutdown procedures."			

Event ID: 20001211X09574	**NTSB No:** LAX98LA093	**Registration:** N9204D	**Accident date:** 03-Feb-98
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 1N	**Thermal Injury:** None	Fuel Spillage: None	**Crash Severity:** Minor
Summary: Intentional autorotation exceeded the design descent rate. The vertical impact was sufficient to buckle the seat support structure.			
Supporting Data: From the narrative: "The aircraft landed hard at the intended touchdown point, while in a near level attitude. The aircraft was hover-taxied from the landing area and a normal shutdown was completed. A post-accident inspection of the aircraft revealed the airframe and landing gear exhibited bending, cracking, and tearing from fuselage station (FS) 78.5 to FS44.65. The bulkhead at FS124 and the engine door frame at FS137.5 were buckled and cracked on both the left and right sides. The cockpit seat pan support structures were buckled. The right and left landing gear struts were also bent and displaced."			

Event ID: 20001211X10374	**NTSB No:** LAX98TA202	**Registration:** N185SD	**Accident date:** 17-Jun-98
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 1N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Minor
Summary: External water bucket snagged edge of ground tank when attempting to depart, causing the helicopter to spin and crash from about 20 ft AGL.			
Supporting Data: From the narrative: "The damage consisted of a collapsed left skid, abrasions to the end of the tail boom, damage to the tail boom attachment point, and damage to the main rotor blade ends."			

Event ID: 20001212X20685	**NTSB No:** MIA00FA102	**Registration:** N611BC	**Accident date:** 03-Mar-00
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** Ground
Injuries: 2F	**Thermal Injury:** Unknown	**Fuel Spillage:** Yes	**Crash Severity:** Extreme
Summary: Pilot was known to perform high speed aerobatic maneuvers by pulling up to a vertical climb followed by a hard turn. Witnesses observed the helicopter pulling near vertical at which point the tail boom separated due to main rotor blade strike. The reported postmortem results were that the cause of death was “helicopter crash”.			
Supporting Data: Excerpts from the narrative: “The main wreckage of N611BC was in two different locations. The tail boom assembly had separated from the main fuselage at station number 275, and was located on the back porch adjacent to a swimming pool located at 9305 SW 122nd Lane Miami, Florida, in the Oak Ridge Residential complex. The main body of the wreckage was located on an island planter (flower bed) adjacent to a circular drive at the north entrance of Oak Ridge near SW 121 Street and 93rd Avenue.” The Miami-Dade Medical Examiner Department was contacted to obtain details of the autopsy reports. Email from Darren Caprara, Director of Operations received June 29, 2016, includes the following excerpt: “The internal damage to both victims was extensive. They both would have died without the fire. Both had lacerations that essentially cut through the heart/aorta, in addition to other significant internal injuries.”			

Event ID: 20010306X00552	**NTSB No:** LAX01TA092	**Registration:** N606BP	**Accident date:** 21-Feb-01
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 2N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Minor
Summary: Intentional run on landing caused the main rotor to strike the tail boom.			
Supporting Data: From the synopsis: “During the landing slide, the main rotor blew back, contacted the tail boom, and severed it.”			

Event ID: 20010821X01741	**NTSB No:** LAX01FA277	**Registration:** N70457	**Accident date:** 14-Aug-01
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 3M, 1N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Minor
Summary: Crash during practice landing maneuvers. Touched down with sideward velocity hitting a berm and rolling the helicopter over.			
Supporting Data: From the narrative: “As the helicopter neared the ground, the yaw finally stopped; however, the helicopter was translating sideways toward a berm. The helicopter touched down on the right skid against the berm and it rolled over.”			

Event ID: 20011105X02192	**NTSB No:** LAX02LA016	**Registration:** N451DL	**Accident date:** 24-Oct-01
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 6N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** No crash
Summary: Blade strike with tail boom during engine start up.			
Supporting Data: From the narrative: "On engine startup, after about two revolutions of the rotor blades, three of the five blades contacted the tail boom."			

Event ID: 20020517X00686	**NTSB No:** ATL02LA095	**Registration:** N810LA	**Accident date:** 10-May-02
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** None
Injuries: 3N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Minor
Summary: Hard emergency landing following ECU failure warning.			
Supporting Data: From the narrative: "During the emergency descent to land the pilot increased collective to arrest the descent. The "low rotor" warning light came on again and the helicopter landed hard. The main rotor blades came in contact with the tail boom and severed it from the airframe."			

Event ID: 20021018X05335	**NTSB No:** LAX03GA001	**Registration:** N625SB	**Accident date:** 03-Oct-02
Make: MDHI	**Model:** MD-600N	**Part 27/29:** 27	**Fire:** Ground
Injuries: 2S	**Thermal Injury:** None reported	**Fuel Spillage:** None	**Crash Severity:** Moderate
Summary: Crash landing after engine power reduction due to a loose fuel line fitting. Pilot failed to initiate an autorotation in a timely manner.			
Supporting Data: From the synopsis: "First responders to the accident site, which included sheriff's air unit mechanics, found the engine running at idle and a fire in the engine compartment" From the narrative: "The helicopter was equipped with two interconnected crash-resistant non-self-sealing bladder type fuel cells that were certified in accordance with 14 CFR Part 27.952 (Fuel System Crash Resistance). Fire damage was noted to the lines at fittings at the firewall; however, no visible seepage was noted from the fuel system. " "The helicopter came to rest facing a southeast heading. The main wreckage area distribution and associated debris field was contained in an area approximately 80 feet in diameter. The left skid and about 4 feet of the tail section remained at the first identified point of impact (IPI). The helicopter came to rest about 20 feet northwest of the IPI. The helicopter was lying on its left side. The right landing gear skid remained attached to the fuselage structure. The Plexiglas from the left side door windows shattered. Both doors were crushed; however, they remained connected to the fuselage. The tail boom separation at the fan section was jagged in nature. The outside cabin area portion of the fuselage from the aft doors to the fan and engine sections were thermally damaged and soot marked."			

Event ID: 20001211X11501	**NTSB No:** SEA99LA016	**Registration:** N977LF	**Accident date:** 29-Nov-98
Make: MDHI	**Model:** MD-900	**Part 27/29:** 27	**Fire:** None
Injuries: 4N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** No crash
Summary: Main blade strike with power lines after takeoff. The helicopter continued flight and landed at the intended destination.			
Supporting Data: From the narrative: "Post-flight examination revealed crazing of the windscreen and damage to four of the five main rotor blades requiring major repair/replacement."			

Event ID: 20031029X01827	**NTSB No:** LAX04TA017	**Registration:** N179PA	**Accident date:** 16-Oct-03
Make: MDHI	**Model:** MD-900	**Part 27/29:** 27	**Fire:** None
Injuries: 5N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Minor
Summary: Rotorcraft entered uncontrolled spin during landing. The helicopter rolled on its side after landing.			
Supporting Data: From the narrative: "the pilot maneuvered the helicopter away from the trees as it continued to descend. Upon touchdown, the helicopter rolled on its left side, and the main rotor blades impacted the terrain."			

Event ID: 20041021X01675	**NTSB No:** LAX04LA333	**Registration:** N9016W	**Accident date:** 08-Sep-04
Make: MDHI	**Model:** MD-900	**Part 27/29:** 27	**Fire:** None
Injuries: 1N	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Minor
Summary: NOTAR failure just after takeoff. Pilot was able to land on the runway.			
Supporting Data: From the narrative: "The pilot lowered the collective to the full down position, and the helicopter touched down about 30 to 40 knots ground speed."			

APPENDIX H

DETAILS OF ACCIDENTS WITH GROUND FIRES
ROTORCRAFT PRODUCED FROM 2006-2015
NOT FULLY COMPLIANT TO 14 CFR 27.952

Event ID: 20130612X12326	**NTSB No:** CEN13FA344	**Registration:** N935EM	**Accident date:** June 11, 2013
Make: Airbus	**Model:** AS350-B2	**Part 27/29: 27**	**Fire:** Ground
Injuries: 1F, 1S, 2M	**Thermal Injury:** None	**Fuel Spillage:** Engine area	**Crash Severity:** Moderate

Summary: Impact with utility pole shortly after take-off. The medical patient was fatally injured. Fire contained to the engine area.

Supporting Data:
First responders report the engine was still running and fuel was leaking out of the engine area and burning. The engine was subsequently shut down and the fire put out by hand fire extinguishers. There is no report of fire entering the occupant compartment or mention of thermal injury. Photographs of the crash scene show fire damage only to the engine area of the wreckage.

Event ID: 20100325X93604	NTSB No: ERA10MA188	Registration: N855HW	Accident date: 3/25/2010
Make: Airbus	**Model:** AS350-B3	**Part 27/29:** 27	**Fire:** Ground
Injuries: 3F	**Thermal Injury:** No	**Fuel Spillage:** Yes	**Crash Severity:** Extreme

Summary: FIT after entering foul weather. Extreme (non-survivable) crash.

Supporting Data:

From the narrative: "The main debris field was about 250 feet long and 150 feet wide, oriented toward 180 degrees magnetic. The global positioning system (GPS)-measured elevation was 386 feet msl. All the major components of the helicopter were accounted for at the accident site.

Initial ground scars contained main rotor blade fragments and parts of the left landing gear skid, along with helicopter belly pieces. The scars were oriented consistent with the helicopter impacting the ground in near nose-level, 33-degree left bank attitude.

The main wreckage, consisting of the cabin and cockpit areas, came to rest about 112 feet south of the initial ground scars and was mostly destroyed by a post impact fire."

"An autopsy was performed on the pilot at the Shelby County Medical Examiner's Office, Memphis, Tennessee. The autopsy report noted the cause of death as multiple blunt force injuries."

Photograph of accident:

Event ID: 20100728X92614	**NTSB No:** WPR10FA371	**Registration:** N509AM	**Accident date:** 7/28/2010
Make: Airbus	**Model:** AS350-B3	**Part 27/29:** 27	**Fire:** Ground
Injuries: 3F	**Thermal Injury:** Yes 2F	**Fuel Spillage:** Yes	**Crash Severity:** Severe

Summary: Near vertical crash on top of a block wall. The fuel tank burst and a severe post-crash fire occurred. First responders (Tucson Fire dept.) could hear the pilot screaming for help, found one passenger that was conscious and able to speak but badly burned, and found one passenger dead at the scene. The thermally injured pilot and passenger died approximately 2.5 hr. after the accident. The third fatality cause was not determinable from available data.

Supporting Data:

Photograph of accident:

From the full narrative, pilot autopsy report:
"An autopsy was performed on the pilot on July 30, 2010, by the Tucson Police Department, Pima County, Arizona. The opinion of the Forensic Pathologist was that the cause of death was ascribed to multiple blunt force and thermal injuries."

From the docket, NTSB Witness Statements:

Tucson Fire Engine 5

Capt Mike Garcia

When he arrived on-scene he identified 1 dead. A second crew was identified in the middle of the wreckage. He was responsive, could mumble, and make communicative gestures with his hands. They had to cut his harness to remove him from the wreckage. Capt Garcia said could hear unintelligible screams coming from the corner of the wreckage (pilot). When they were able to removed the pilot from the wreckage he could see burn areas and marks where the seat harness had been on the pilot.

Tucson Fire Paramedics

Lilly Pesqueira
Adam Bower

They treated and transported the crew member that was conscious (Parker). He could state his name and age. He was badly burned on his hands, arms, face, and his right leg was broken at the hip. Burns over 60% of his body. Parker said he was having difficulty breathing and that they needed to intubate him. They could not intubate him because he was still breathing on his own. He was concerned about his breathing and kept informing the paramedics that they need to intubate him. They put high flow O2 on him. He did not say anything about what happen before or during the accident sequence.

Event ID: 20140110X63030	NTSB No: CEN14GA109	Registration: N3948A	Accident date: January 10, 2014
Make: Airbus	**Model:** AS350-B3	**Part 27/29:** 27	**Fire:** Ground
Injuries: 1S, 2M	**Thermal Injury:** None	**Fuel Spillage:** None	**Crash Severity:** Moderate

Summary: Impact with trees and terrain after loss of control. A small fire in the engine compartment was extinguished by first responders.

Supporting Data:

From the narrative: "The fuel tank remained undamaged and secured within the fuselage; no fuel was observed leaking from the helicopter nor smelled at the accident site." "Thermal damage was evident on the left and top sides of the engine cowling and the inlet plenum. The thermal damage patterns on the structure were similar to a post -impact fire in the final resting position. The oil, fuel, and air lines remained secured; however, the external accessories of the engine were damaged from the post-impact fire."

Photograph of crash scene:

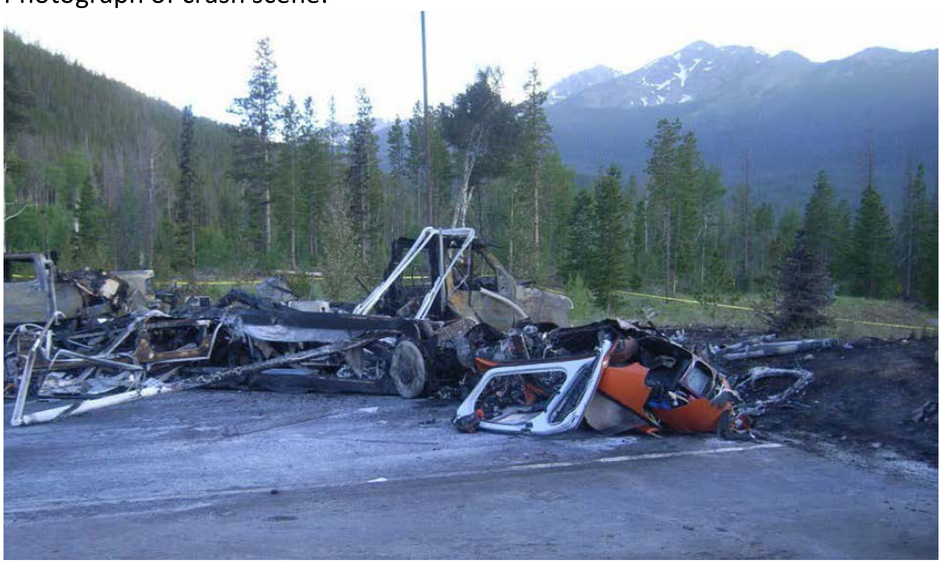
Event ID: 20150703X00859	NTSB No: CEN15FA290	Registration: N390LG	Accident date: July 03, 2015
Make: Airbus	**Model:** AS350-B3E	**Part 27/29:** 27	**Fire:** Ground
Injuries: 1F, 2S	**Thermal Injury:** 1F, 1S	**Fuel Spillage:** Yes	**Crash Severity:** Severe

Summary: Helicopter lost control after take-off, and impacted an RV in a parking lot. A large post-crash fire ensued when the main fuel tank ruptured. The pilot received fatal thermal injuries, one passenger received extreme thermal injuries, and another passenger received impact injuries (non-thermal).

Supporting Data:

This accident has been well publicized as video was taken at the accident scene. The pilot received critical blunt trauma injury as well as extreme (fatal) thermal injury and died shortly after the crash. One flight nurse sustained spinal fractures without thermal injury and the other flight nurse sustained burns over 90% of his body.

Photograph of crash scene:



Portion from pilot's autopsy report showing fatal thermal injury:

64-year-old Pilot Thermal Injuries			
Body Region	**Injury**	**AIS Code**	**AIS Severity Score**
Chest	Thermal changes extending from the mainstem bronchus to the intra-alveolar spaces including sloughing of the respiratory mucosa	419208	6

Event ID: 20151118X05037	**NTSB No:** WPR16FA029	**Registration:** N711BE	**Accident date:** 11/18/2015
Make: Airbus	**Model:** AS350-B3e	**Part 27/29:** 27	**Fire:** Ground
Injuries: 2F	**Thermal Injury:** No	**Fuel Spillage:** Unknown	**Crash Severity:** Minor

Summary: Entered ground resonance spinning on ground for approximately 5 minutes. No significant fire.

Supporting Data:

Narrative or docket not available. However, video of the incident was captured and broadcast on local TV. Below is a screen shot of the helicopter being towed from the runway.

Event ID: 20130102X35708	NTSB No: CEN13FA122	Registration: N445MT	Accident date: 1/2/2013
Make: Bell	**Model:** 407	**Part 27/29:** 27	**Fire:** Ground
Injuries: 3F	**Thermal Injury:** No	**Fuel Spillage:** Unknown	**Crash Severity:** Extreme

Summary: High speed impact after apparent engine ice build-up

Supporting Data:

From the narrative: "The helicopter impacted a harvested agricultural field. The debris path was about 100 feet long and was oriented on a 246-degree magnetic bearing. The helicopter was fragmented, and the cockpit and cabin areas were compromised. A post impact fire ensued. The main wreckage consisted of the main rotor blades, transmission, engine, portions of the fuselage, and the tail boom. The tail rotor had separated from the tail boom and was located about 80 feet east-northeast of the main wreckage. The landing skids had separated from the fuselage. The left skid was located at the initial impact point; the right skid was located about 35 feet west of the main wreckage."

"An autopsy of the pilot was completed at the Mercy Medical Center, Mason City, Iowa, on January 3, 2013. The pilot's death was attributed to multiple blunt force injuries sustained as a result of the accident."

Photograph:

Event ID: 20090626X94114	**NTSB No:** CEN09WA390	**Registration:** N878EE	**Accident date:** 5/28/2009
Make: Enstrom	**Model:** 480B	**Part 27/29:** 27	**Fire:** Ground
Injuries: 1F	**Thermal Injury:** Unknown	**Fuel Spillage:** Unknown	**Crash Severity:** Unknown
Summary: Crash in the Dominican Republic. No crash details available			
Supporting Data: From the narrative: "On May 28 2009, about 1440 Coordinated Universal Time (UTC), a single-engine Enstrom helicopter, registration N878EE, impacted terrain en route from Bavaro to San Domingo. The pilot, sole occupant, received fatal injuries. The accident investigation is under the control and jurisdiction of the Government of the Dominican Republic."			

Event ID: 20141202X73240	NTSB No: WPR15FA051	Registration: N3234U	Accident date: 12/2/2014
Make: Robinson	**Model:** R44 II	**Part 27/29:** 27	**Fire:** Ground
Injuries: 2F	**Thermal Injury:** No	**Fuel Spillage:** Unknown	**Crash Severity:** Extreme
Summary: Extreme accident after main rotor separation during flight.			

Supporting Data:

From the NTSB preliminary report:

“Witnesses, who were in the area of the accident site, reportedly heard popping sounds then saw the main rotor and empennage separate from the helicopter as the helicopter flew overhead. Several of the witnesses then saw the helicopter tumble in flight and impact the top of a building. The main rotor blade and empennage impacted the ground a few hundred feet from the impacted building. The owner of the helicopter reported that mechanics performed maintenance to the main rotor assembly and the purpose of the post-maintenance flight was to check the "track and balance" of the main rotor blades.”

“Examination of the accident site by the National Transportation Safety Board (NTSB) investigator-in charge revealed that the helicopter impacted the top of a two-story building about 2,000 feet southwest of the approach end of runway 34 at BTF. A post-impact fire occurred that was concentrated at the main wreckage. The main wreckage had impact damage and was partially damaged by post impact fire. The main rotor and empennage were found within the wreckage debris field. The wreckage debris field was about 880 feet in length and about 400 feet in width and on a 277-degree magnetic heading.”

APPENDIX I

MISCELLANEOUS COST AND BENEFIT TABULATIONS

Table I1. Summary of 10-Year Industry Costs (2016 USD) of Compliance for Models Still in Production

Cost Category	Part 27		Part 29		Combined Part 27/29	
	Cost in 2016	Present Day Value at 7%	Cost in 2016	Present Day Value at 7%	Cost in 2016	Present Day Value at 7%
Non-Recurring Cost (.561,.562, and .785)	$185,050,000	$141,173,759	$72,700,000	$55,462,482	$257,750,000	$196,636,241
Non-recurring Cost (.952)	$15,110,000	$11,527,347	$75,580,000	$57,659,620	$90,690,000	$69,186,967
Total Non-Recurring Costs (.561, .562, .785, .952)	$200,160,000	$152,701,106	$148,280,000	$113,122,102	$348,440,000	$265,823,208
10-Year Unit Cost Increase (.561, .562, .785)	$103,420,000	$59,294,147	$62,490,000	$35,827,609	$165,910,000	$95,121,756
10-Year Unit Cost Increase (.952)	$30,563,000	$17,522,791	$14,310,000	$8,204,402	$44,873,000	$25,727,193
10-Year Total Unit Cost Increase	133,983,000	$76,816,938	$76,800,000	$44,032,010	$210,783,000	$120,848,949
Total 10 Year OEM Costs	$334,143,000	$229,518,044	$225,080,000	$157,154,113	$559,223,000	$386,672,156
10-Year Operator Cost Increase (.561, .562, .785)	$122,484,813	$63,151,996	$39,226,895	$20,225,009	$161,711,708	$83,377,005
10-Year Operator Cost Increase (.952)	$28,707,901	$14,801,527	$14,214,404	$7,328,821	$42,922,305	$22,130,348
10-Year Operator Cost Increase	$151,192,714	$77,953,523	$53,441,299	$27,553,830	$204,634,013	$105,507,353
Total 10-Year Estimated Industry Cost	$485,335,714	$307,471,567	$278,521,299	$184,707,942	$763,857,013	$492,179,510

Table I2. OEM Cost Summary				
Cost in 2016				
Cost Category	**CRSS (.561, .562, .785)**		**CRFS (.952)**	
	Part 27	**Part 29**	**Part 27**	**Part 29**
Non-Recurring costs	$185,050,000	$72,700,000	$15,110,000	$75,580,000
10-Year Unit Costs	$103,420,000	$62,490,000	$30,563,000	$14,310,000
Total 10-Year OEM Costs	$288,470,000	$135,190,000	$45,673,000	$89,900,000
Present day value at 7% discount				
Cost Category	**CRSS (.561, .562, .785)**		**CRFS (.952)**	
	Part 27	**Part 29**	**Part 27**	**Part 29**
Non-Recurring costs	$141,173,759	$55,462,482	$11,527,347	$57,659,620
10-Year Unit Costs	$59,294,147	$35,827,609	$17,522,791	$8,204,402
Total 10-Year OEM Costs	$200,467,906	$91,290,090	$29,050,137	$65,864,022

Table I3. 10-Year Estimated Injury Value Benefit Summary[1], Part 27 Rotorcraft[4]		
Regulation	**Value 2016 Dollars**	**Present Value at 7% Discount**
CRFS[2]	$30,312,162	$17,142,135
CRSS[3]	$113,217,324	$64,026,666
Total	**$143,529,486**	**$81,168,801**

1) Values calculated for ten-year period from 2020-2029 utilizing a 2.5% annual flight hour growth factor
2) CRFS = Crash Resistant Fuel System compliant to 14 CFR Part 27/29.952
3) CRSS = Crash Resistant Seats and Structure compliant to 14 CFR Part 27/29.561, .562, and .785.
4) There were only two Part 29 rotorcraft crashes.

Table I4. 10-Year Estimated Cost vs. Benefit Summary[1]

	Regulation	Part 27		Part 29	
		Value 2016 Dollars	Present Value at 7% Discount	Value 2016 Dollars	Present Value at 7% Discount
COST	CRSS [3]	$410,954,813	$263,619,903	$174,416,895	$111,515,099
	CRFS [2]	$74,380,901	$43,851,665	$104,104,404	$73,192,843
	Total	**$485,335,714**	**$307,471,567**	**$278,521,299**	**$184,707,942**
BENEFIT	CRSS [3]	$113,217,324	$64,026,666	$0[4]	$0[4]
	CRFS [2]	$30,312,162	$17,142,135	$0[4]	$0[4]
	Total	**$143,529,486**	**$81,168,801**	**$0[4]**	**$0[4]**

1) Values calculated for ten-year period from 2020-2029 utilizing a 2.5% annual flight hour growth factor
2) CRFS = Crash Resistant Fuel System compliant to 14 CFR Part 27/29.952
3) CRSS = Crash Resistant Seats and Structure compliant to 14 CFR Part 27/29.561, .562, and .785.
4) There were only two Part 29 rotorcraft crashes in the dataset. One accident occurred in Peru and accident details were not available for scoring. The other was an extreme accident (non-survivable) which received a zero score