time segments does not create an undue burden on competition, rather, it provides the Market Maker with clarity as to the manner in which the System counts quotes and orders and thereby provides NOM Market Makers with an increased ability to monitor transactions.

Rounding

The Exchange's amendment to add that if the Issue Percentage, rounded to the nearest integer, equals or exceeds the Specified Percentage, the System automatically removes a Market Maker's quotes and orders in all series of an underlying security does not create an undue burden on competition because this amendment also provides the Market Maker with clarity as to the manner in which the System will remove quotes and orders and thereby provides NOM Market Makers with an increased ability to monitor transactions and set risk limits.

Reset

The amendment to the rule text concerning resetting does not create an undue burden on competition. The Exchange proposes to amend the manner in which a Market Maker may re-enter the System after a removal of quotes and orders. This amendment provides information to NOM Market Makers as to the procedure to re-enter the System after a trigger. This information is intended to provide NOM Market Makers with access to the market.

C. Self-Regulatory Organization's Statement on Comments on the Proposed Rule Change Received From Members, Participants, or Others

No written comments were either solicited or received.

III. Date of Effectiveness of the Proposed Rule Change and Timing for Commission Action

Because the foregoing proposed rule change does not: (i) Significantly affect the protection of investors or the public interest; (ii) impose any significant burden on competition; and (iii) become operative for 30 days from the date on which it was filed, or such shorter time as the Commission may designate, it has become effective pursuant to Section 19(b)(3)(A)(iii) of the Act [28] and subparagraph (f)(6) of Rule 19b–4 thereunder.[29]

At any time within 60 days of the filing of the proposed rule change, the Commission summarily may temporarily suspend such rule change if it appears to the Commission that such action is: (i) Necessary or appropriate in the public interest; (ii) for the protection of investors; or (iii) otherwise in furtherance of the purposes of the Act. If the Commission takes such action, the Commission shall institute proceedings to determine whether the proposed rule should be approved or disapproved. The Exchange has provided the Commission written notice of its intent to file the proposed rule change, along with a brief description and text of the proposed rule change, at least five business days prior to the date of filing of the proposed rule change.

[28] 15 U.S.C. 78s(b)(3)(a)(iii).

[29] 17 CFR 240.19b–4(f)(6).

IV. Solicitation of Comments

Interested persons are invited to submit written data, views, and arguments concerning the foregoing, including whether the proposed rule change is consistent with the Act. Comments may be submitted by any of the following methods:

Electronic Comments

- Use the Commission's Internet comment form (*http://www.sec.gov/rules/sro.shtml*); or
- Send an email to *rule-comments@sec.gov. Please include File Number SR–NASDAQ–2015–122 on the subject line.*

Paper Comments

- Send paper comments in triplicate to Brent J. Fields, Secretary, Securities and Exchange Commission, 100 F Street NE., Washington, DC 20549–1090.

All submissions should refer to File Number *SR–NASDAQ–2015–122.* This file number should be included on the subject line if email is used. To help the Commission process and review your comments more efficiently, please use only one method. The Commission will post all comments on the Commission's Internet Web site (*http://www.sec.gov/rules/sro.shtml*). Copies of the submission, all subsequent amendments, all written statements with respect to the proposed rule change that are filed with the Commission, and all written communications relating to the proposed rule change between the Commission and any person, other than those that may be withheld from the public in accordance with the provisions of 5 U.S.C. 552, will be available for Web site viewing and printing in the Commission's Public Reference Room, 100 F Street NE., Washington, DC 20549, on official business days between the hours of 10:00 a.m. and 3:00 p.m. Copies of the filing also will be available for inspection and copying at the principal office of the Exchange. All comments received will be posted without change; the Commission does not edit personal identifying information from submissions. You should submit only information that you wish to make available publicly. All submissions should refer to File Number *SR–NASDAQ–2015–122* and should be submitted on or before November 27, 2015.

For the Commission, by the Division of Trading and Markets, pursuant to delegated authority.[30]

Jill M. Peterson,

Assistant Secretary.

[FR Doc. 2015–28143 Filed 11–4–15; 8:45 am]

BILLING CODE 8011–01–P

[30] 17 CFR 200.30–3(a)(12).

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

Aviation Rulemaking Advisory Committee—New Task

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of a new task assignment for the Aviation Rulemaking Advisory Committee.

SUMMARY: The FAA assigned the Aviation Rulemaking Advisory Committee (ARAC) a new task to provide recommendations regarding occupant protection rulemaking in normal and transport category rotorcraft for older certification basis type designs that are still in production. The FAA amended regulations to incorporate occupant protection rules, including those for emergency landing conditions and fuel system crash resistance, for new type designs in the 1980s and 1990s. These rule changes do not apply to newly manufactured rotorcraft with older type designs or to derivative type designs that keep the certification basis of the original type design. This approach has resulted in a very low incorporation rate of occupant protection features into the rotorcraft fleet, and fatal accidents remain unacceptably high. At the end of 2014, only 16% of U.S. fleet had complied with the crash resistant fuel system requirements effective 20 years earlier, and only 10% had complied with the emergency landing requirements effective 25 years earlier. A recent fatal accident study has shown these measures would have been effective in saving lives.

This notice informs the public of the new ARAC activity and solicits

membership for the new Rotorcraft Occupant Protection Working Group.

FOR FURTHER INFORMATION CONTACT: Martin R. Crane, Federal Aviation Administration, 10101 Hillwood Parkway, Fort Worth, Texas 76177, *Martin.R.Crane@faa.gov,* phone number 817–222–5110, facsimile number 817–222–5961.

SUPPLEMENTARY INFORMATION:

ARAC Acceptance of Task

As a result of the September 17, 2015, ARAC meeting, the FAA assigned and ARAC accepted this task establishing the Rotorcraft Occupant Protection Working Group. The Rotorcraft Occupant Protection Working Group will serve as staff to the ARAC and provide advice and recommendations on the assigned task. The ARAC will review and accept the recommendation report and will submit it to the FAA.

Background

The FAA established the ARAC to provide information, advice, and recommendations on aviation-related issues that could result in rulemaking to the FAA Administrator, through the Associate Administrator of Aviation Safety.

The Rotorcraft Occupant Protection Working Group will provide advice and recommendations to the ARAC on occupant protection rulemaking, including both initial certification and continued airworthiness. The basic concept of occupant protection is to give all occupants the greatest possible chance to egress an aircraft without serious injury after a survivable emergency landing or accident. While the number of U.S. helicopter accidents and the corresponding accident rate over the past 10 years have steadily decreased, during that same time period data associated with fatal helicopter accidents and fatalities remains virtually unchanged. A number of regulations were promulgated in the 1980s and 1990s to address and greatly improve occupant protection in a survivable emergency landing or accident. These occupant protection improvements involve seat systems that reduce the likelihood of fatal injuries to the occupant in a crash (14 CFR 27.562, 27.785, 29.562, and 29.785); structural requirements that maintain a survivable volume and restrain large items of mass above and behind the occupant (14 CFR 27.561 and 29.561); and fuel systems that reduce the likelihood of an immediate post-crash fire (14 CFR 27.952 and 29.952). If the occupant protection improvement rules are not incorporated in new production helicopters, there will be no meaningful reduction in the number of fatalities in helicopter accidents.

Following a series of accidents involving post-crash fires, the Australian Civil Aviation Safety Authority asked the FAA for assistance in determining the airworthiness of certain helicopters. This request resulted in a collaborative post-crash fire/blunt force trauma study performed by the FAA's Rotorcraft Directorate and Civil Aerospace Medical Institute (CAMI). The data consisted of 97 fatal accidents involving U.S. registered, type-certificated helicopters in a five-year timeframe from 2008 to 2013. Part 27 rotorcraft comprised the largest mass of data (87 of 97 fatal accidents, 90% of the total) in the study. The post-crash fire portion of the study found that post-crash fires occurred in 30 of 76 (39%) of fatal accidents involving part 27 helicopters without fuel systems that meet the full crash resistance requirements of 14 CFR 27.952. The post-crash fire contributed to a fatality in 20% of these fatal accidents. While the data set for part 29 rotorcraft was much smaller (10 of 97 fatal accidents, 10% of the total), the results were comparable. Through the course of the study, the Rotorcraft Directorate further discovered that there were only about 16% of U.S. registered, type-certificated rotorcraft that fully complied with the fuel system crash resistance provisions in §§ 27.952 and 29.952, despite those rules having been in effect for 20 years at the time of the study.

In the time since increased rotorcraft occupant protection standards became effective as federal regulations, research efforts have studied injury patterns in fatal rotorcraft accidents. In April 2003, *Aviation, Space, and Environmental Medicine* published Narinder Taneja and Douglas A. Wiegmann's ''Analysis of Injuries Among Pilots Killed in Fatal Helicopter Accidents.'' Using autopsy data from 1993 to 1999, Taneja and Wiegmann analyzed the pattern of specific bony injuries (ribs, skull, and pelvis) and organ/visceral injuries (brain, lung, and heart) documented in 74 fatal rotorcraft accidents. They found blunt trauma as the cause of death in 88% of the cases, with the highest percentages of injuries to the head and core body regions. Among the implications cited in their study was, ''Protection of the occupants exposed to a crash is a realistic objective that can be achieved if crashworthiness becomes a primary element of initial helicopter design and future upgrade programs.''

The second component of the Rotorcraft Directorate/CAMI study involved blunt force trauma. Blunt force trauma accounted for cause of death in 92% of the 2008–2013 fatal accident data. In addition, blunt force trauma also was the cause of death in 80% of the part 27 fatal rotorcraft accidents where a post-crash fire occurred. The Rotorcraft Directorate and CAMI built their study using the framework and methodology previously established by Taneja and Wiegmann's 2003 study. Further, they used the percentages of bony injuries and organ/visceral injuries documented in Taneja and Wiegmann's study as a baseline for comparison. The intent was to see if a statistically significant change occurred in blunt force trauma injury patterns in fatal rotorcraft accidents in the 10 years since the previous study. They concluded there was no statistically significant difference across most categories of bony injuries and across all categories of organ/visceral injuries. The Rotorcraft Directorate further discovered that only 10% of U.S. registered, type-certificated rotorcraft complied with increased occupant protection measures related to blunt force trauma mandated in the §§ 27.562 and 29.562 rules, despite the rules being in effect for 25 years at the time of the study. The provisions of §§ 27.562 and 29.562 were specifically designed for increased protection of the head and core body regions, the same regions documented with the highest levels of injury in the fatal accident studies conducted by Taneja and Wiegmann and the Rotorcraft Directorate/CAMI.

Additional research found that about 9,000 occupants had been involved in U.S. helicopter accidents in the 25 years since §§ 27.562 and 29.562 became effective. Only 2% of helicopters in those accidents were compliant with §§ 27.562 and 29.562. Over 1,300 occupants were killed in accidents involving the 98% of helicopters that were not compliant with §§ 27.562 and 29.562.

The Task

The Rotorcraft Occupant Protection Working Group is tasked to:

1. Perform a cost-benefit analysis for incorporating the existing occupant protection standards 14 CFR 27.561, 27.562, 27.785, 27.952, 29.561, 29.562, 29.785, and 29.952 via §§ 27.2 and 29.2 for newly manufactured rotorcraft that addresses the following:

a. Estimate what the regulated parties would do differently as a result of the proposed regulation and how much it would cost.

b. Estimate the improvement in survivability of future accidents.

c. Estimate any other benefits (*e.g.,* reduced administrative burden) or costs that would result from implementation of the occupant protection standards identified above.

2. Develop a cost-benefit analysis report containing the information explained in task 1 above.

3. After the FAA accepts and considers the cost benefit analysis report, the FAA will task the Rotorcraft Occupant Protection Working Group either to make specific written recommendations on how all or part of the existing occupant protection standards 14 CFR 27.561, 27.562, 27.785, 27.952, 29.561, 29.562, 29.785, and 29.952 should be made effective via §§ 27.2 and 29.2 for newly manufactured rotorcraft, or to propose new alternative performance-based occupant protection safety regulations for newly manufactured rotorcraft that will be effective via §§ 27.2 and 29.2.

4. If new alternative performance-based occupant protection safety regulations effective via §§ 27.2 and 29.2 are proposed, perform a cost-benefit analysis that addresses the following:

a. Estimate what the regulated parties would do differently as a result of the proposed regulation and how much it would cost.

b. Estimate the improvement in survivability of future accidents from the proposed recommendations.

c. Estimate any other benefits (*e.g.,* reduced administrative burden) or costs that would result from implementation of the recommendations.

5. Develop an initial report containing recommendations on the findings and results of the tasks explained above.

a. The initial recommendation report should document both majority and dissenting positions on the findings and the rationale for each position.

b. Any disagreements should be documented, including the rationale for each position and the reasons for the disagreement.

6. Complete the following after the FAA accepts the initial recommendation report identified in task 5:

a. Specifically advise and make written recommendations on incorporating rotorcraft occupant protection improvements and standards into the existing rotorcraft fleet. Occupant protection standards include either all or part of 14 CFR 27.561, 27.562, 27.785, 27.952, 29.561, 29.562, 29.785, and 29.952, or new alternative proposed performance-based regulations.

b. Develop an addendum report containing recommendations on the findings and results of the tasks explained above.

c. Document both majority and dissenting positions on the findings and the rationale for each position.

d. Any disagreements should be documented, including the rationale for each position and the reasons for the disagreement.

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

Schedule

This tasking notice requires three reports.

- The task 2 cost-benefit analysis report must be submitted to the FAA for review and acceptance no later than 6 months after publication of this notice in the **Federal Register**.
- The task 5 initial recommendation report must be submitted to the FAA for review and acceptance no later than 12 months after initiation of task 3 above.
- The task 6 addendum recommendation report must be submitted to the FAA for review and acceptance no later than 6 months after the initial recommendation report is submitted.

Working Group Activity

The Rotorcraft Occupant Protection Working Group must comply with the procedures adopted by the ARAC as follows:

1. Conduct a review and analysis of the assigned tasks and any other related materials or documents.

2. Draft and submit a work plan for completion of the task, including the rationale supporting such a plan, for consideration by the ARAC.

3. Provide a status report at each ARAC meeting.

4. Draft and submit the recommendation reports based on review and analysis of the assigned tasks.

5. Present the cost-benefit analysis report in task 2 at the ARAC meeting.

6. Present the initial recommendation report at the ARAC meeting.

7. Present the findings from the addendum recommendation report at the ARAC meeting.

Participation in the Working Group

The Rotorcraft Occupant Protection Working Group will be comprised of technical experts having an interest in the assigned task. A working group member need not be a member representative of the ARAC. The FAA would like a wide range of members (normal category rotorcraft manufacturers, transport category rotorcraft manufacturers, and rotorcraft operators from various segments of the industry such as oil and gas exploration, emergency medical services, and air tour operators) to ensure all aspects of the tasks are considered in development of the recommendations. The provisions of the August 13, 2014, Office of Management and Budget guidance, ''Revised Guidance on Appointment of Lobbyists to Federal Advisory Committees, Boards, and Commissions'' (79 FR 47482), continues the ban on registered lobbyists participating on Agency Boards and Commissions if participating in their ''individual capacity.'' The revised guidance now allows registered lobbyists to participate on Agency Boards and Commissions in a ''representative capacity'' for the ''express purpose of providing a committee with the views of a nongovernmental entity, a recognizable group of persons or nongovernmental entities (an industry, sector, labor unions, or environmental groups, etc.) or state or local government.'' (For further information see Lobbying Disclosure Act of 1995 as amended, 2 U.S.C 1603, 1604, and 1605.)

If you wish to become a member of the Rotorcraft Occupant Protection Working Group, write the person listed under the caption **FOR FURTHER INFORMATION CONTACT** expressing that desire. Describe your interest in the task and state the expertise you would bring to the working group. The FAA must receive all requests by December 7, 2015. The ARAC and the FAA will review the requests and advise you whether or not your request is approved.

If you are chosen for membership on the working group, you must actively participate in the working group, attend all meetings, and provide written comments when requested. You must devote the resources necessary to support the working group in meeting any assigned deadlines. You must keep your management and those you may represent advised of working group activities and decisions to ensure the proposed technical solutions do not conflict with the position of those you represent. Once the working group has begun deliberations, members will not be added or substituted without the approval of the ARAC Chair, the FAA, including the Designated Federal Officer, and the Working Group Chair.

The Secretary of Transportation determined the formation and use of the ARAC is necessary and in the public interest in connection with the performance of duties imposed on the FAA by law.

The ARAC meetings are open to the public. However, meetings of the

Rotorcraft Occupant Protection Working Group are not open to the public, except to the extent individuals with an interest and expertise are selected to participate. The FAA will make no public announcement of working group meetings.

Issued in Washington, DC, on October 30, 2015.

Lirio Liu,

Designated Federal Officer, Aviation Rulemaking Advisory Committee.

[FR Doc. 2015–28151 Filed 11–4–15; 8:45 am]

BILLING CODE 4910–13–P

DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

[Docket No. NHTSA–2015–0053; Notice 2]

BMW of North America, Inc., Grant of Petition for Decision of Inconsequential Noncompliance

AGENCY: National Highway Traffic Safety Administration (NHTSA), Department of Transportation (DOT).

ACTION: Grant of Petition.

SUMMARY: BMW of North America, Inc. (BMW) has determined that certain model year (MY) 2015 MINI Cooper, Cooper S hardtop 2 door, and Cooper S hardtop 4 door passenger cars do not fully comply with paragraph S4.2.3(a) of Federal Motor Vehicle Safety Standard (FMVSS) No. 226, *Ejection Mitigation.* BMW has filed an appropriate report dated May 20, 2015, pursuant to 49 CFR part 573, *Defect and Noncompliance Responsibility and Reports.*

ADDRESSES: For further information on this decision contact Karen Nuschler, Office of Vehicle Safety Compliance, the National Highway Traffic Safety Administration (NHTSA), telephone (202) 366–5829, facsimile (202) 366–3081.

SUPPLEMENTARY INFORMATION:

I. Overview: Pursuant to 49 U.S.C. 30118(d) and 30120(h) (see implementing rule at 49 CFR part 556), BMW submitted a petition for an exemption from the notification and remedy requirements of 49 U.S.C. Chapter 301 on the basis that this noncompliance is inconsequential to motor vehicle safety.

Notice of receipt of the petition was published, with a 30-day public comment period, on September 1, 2015 in the **Federal Register** (80 FR 52845). No comments were received. To view the petition, and all supporting documents log onto the Federal Docket Management System (FDMS) Web site at: *http://www.regulations.gov/.* Then follow the online search instructions to locate docket number ''NHTSA–2015–0053.''

II. Vehicles Involved: Affected are approximately 4,208 MY 2015 MINI Cooper, Cooper S hardtop 2 door, and Cooper S hardtop 4 door passenger cars manufactured from February 25, 2015 to April 24, 2015.

III. Noncompliance: BMW explains that written information describing the ejection mitigation countermeasure installed in the vehicles was not provided to the vehicle consumers as required by paragraph S4.2.3(a) of FMVSS No. 226.

IV. Rule Text: Paragraph S4.2.3 of FMVSS No. 226 requires in pertinent part:

> S4.2.3 *Written information.*
> (a) Vehicles with an ejection mitigation countermeasure that deploys in the event of a rollover must be described as such in the vehicle's owner manual or in other written information provided by the vehicle manufacturer to the consumer. . . .

V. Summary of BMW's Arguments: BMW stated its belief that the subject noncompliance in the affected vehicles is inconsequential to motor vehicle safety. A summary of its reasoning is provided as follows. Detailed explanations of its reasoning are included in its petition:

1. The vehicles are equipped with a countermeasure that meets the performance requirements of FMVSS No. 226.
2. The owner's manuals contain a description of the ejection mitigation countermeasure in the context of side impact.
3. The owner's manuals contain precautions related to the [ejection mitigation] system even though not required by FMVSS No. 226.
4. The [ejection mitigation] system uses the FMVSS No. 208 required readiness indicator, as allowed by FMVSS No. 226.
5. BMW has not received any customer complaints due to this issue.
6. BMW is not aware of any accidents or injuries due to this issue.
7. NHTSA may have granted similar manufacturer petitions re owner's manuals.
8. BMW has corrected the noncompliance so that all future production vehicles will comply with FMVSS No. 226.

In summation, BMW believes that the described noncompliance of the subject vehicles is inconsequential to motor vehicle safety, and that its petition, to exempt BMW from providing recall notification of noncompliance as required by 49 U.S.C. 30118 and remedying the recall noncompliance as required by 49 U.S.C. 30120 should be granted.

NHTSA's Decision

NHTSA's Analysis: NHTSA believes that while written information was not provided to vehicle owners describing the installed head air bags (side curtain) as vehicle occupant ejection mitigation countermeasures that deploy in the event of a rollover, the owner's manuals for the affected vehicles otherwise effectively describe, and illustrate the location of, the head air bags. NHTSA also believes that the status of the head air bags is monitored by the vehicle's air bag readiness indicator intended to show operational readiness of the entire airbag system. Therefore, drivers should be alerted to a malfunction of the head air bags that are intended to provide ejection countermeasures in the event of a rollover event, and occupant protection in the event of a significant side impact event.

BMW has also reported that they have not received any complaints from vehicle owners regarding the subject noncompliance and that vehicle production was corrected so that the noncompliance did not occur in subsequent vehicles. *NHTSA's Decision:* In consideration of the foregoing, NHTSA has decided that BMW has met its burden of persuasion that the subject FMVSS No. 226 noncompliance in the affected vehicles is inconsequential to motor vehicle safety. Accordingly, BMW's petition is hereby granted and BMW is exempted from the obligation of providing notification of, and a remedy for, that noncompliance under 49 U.S.C. 30118 and 30120.

NHTSA notes that the statutory provisions (49 U.S.C. 30118(d) and 30120(h)) that permit manufacturers to file petitions for a determination of inconsequentiality allow NHTSA to exempt manufacturers only from the duties found in sections 30118 and 30120, respectively, to notify owners, purchasers, and dealers of a defect or noncompliance and to remedy the defect or noncompliance. Therefore, this decision only applies to the subject vehicles that BMW no longer controlled at the time it determined that the noncompliance existed. However, the Granting of this petition does not relieve vehicle distributors and dealers of the prohibitions on the sale, offer for sale, or introduction or delivery for introduction into interstate commerce of the noncompliant vehicles under their control after BMW notified them that the subject noncompliance existed.

U.S. Department
of Transportation
**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, DC 20591

OCT 7 2016

Mr. Todd Sigler
Senior Manager, Regulatory & Rulemaking Strategies
The Boeing Company
P.O. Box 3707, MC 07-30
Seattle, WA 98124-2207

Dear Mr. Sigler:

This is in response to your letters transmitting to the Federal Aviation Administration (FAA) the following recommendation reports:

- Airman Certification System Working Group's recommendation report, submitted to the Aviation Rulemaking Advisory Committee (ARAC) and approved on March 23, 2016. (The original tasking notice was issued on January 24, 2014 (79 FR 4800, January 29, 2014).)

- Materials Flammability Working Group's recommendation report, submitted to the Transport Airplane and Engine (TAE) Subcommittee, who approved on November 4, 2015 and submitted to the ARAC and approved on December 17, 2015. (The original tasking notice was issued on January 14, 2015 (80 FR 2772, January 20, 2015).)

- Rotorcraft Occupant Protection Working Group interim costs and benefits recommendation report, submitted to the ARAC and approved on March 23, 2016. (The original tasking notice, task 2, issued on October 30, 2015 (80 FR 68599, November 5, 2015).)

I wish to thank the working group members who continue to provide resources to develop, review, and approve the recommendations. The industry-wide cooperation and engagement achieved through your leadership was necessary to produce the innovative recommendations presented in the report.

I also wish to thank the TAE Subcommittee members and the ARAC members who reviewed and approved the recommendation reports. The recommendation reports and the other official documents were placed on the FAA's Committee Database Website.

Finally, I apologize for the tardiness of this letter. Due to the loss of our long-term focal point for committee matters, the tracking of these letters was dropped while we waited to bring on a replacement.

The FAA considers this submittal of the recommendation reports from the Airman Certification System Working Group, the Materials Flammability Working Group, and the Rotorcraft Occupant Protection Working Group as completion of the original tasking notices.

Sincerely,

Lirio Liu
Director, Office of Rulemaking

ROTORCRAFT OCCUPANT PROTECTION WORKING GROUP

TASKS 1 AND 2

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

Submitted March 13, 2016

ROTORCRAFT OCCUPANT PROTECTION WORKING GROUP

TASKS 1 AND 2

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

INTRODUCTION

The FAA requested the Aviation Rulemaking Advisory Committee (ARAC) to provide recommendations related to occupant protection rulemaking in normal and transport category rotorcraft with older certification basis type designs and that are still in production.[1] 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; .952) to incorporate occupant protection rules in newly certificated rotorcraft. Newly manufactured rotorcraft with older certification bases or derivative type designs still in production, however, were excluded from the requirements of the new rules. By the end of 2014 only 16% of the U.S. rotorcraft fleet were in compliance with the upgraded fuel system requirements established 20-years earlier and only 10% were in compliance with the upgraded emergency landing requirements effective 25-years earlier.

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 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 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, .952) in newly manufactured rotorcraft; 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

[1] Department of Transportation, Federal Aviation Administration. Aviation Rulemaking Advisory Committee—New Task. Federal Register, 80 (214): 68599-68602, November 5, 2015.

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 19 voting members and 3 non-voting advisors (including the FAA Advisor). The list of members is at 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 each 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.

COST ANALYSIS

Members of the Cost Task Group queried original equipment manufacturers (OEM's) and suppliers and reviewed existing literature to obtain the data obtained in the cost analysis report. OEM and supplier responses were quite variable. The weight, volume, and performance cost analysis below are average costs for Part 27 and Part 29 helicopters based on input from multiple OEM's. This means that the relative costs will be lower for smaller aircraft within those groups and higher for larger aircraft. Costs are reported in 2015 U.S. dollars.

Fuel Systems Compliance Costs (Part 27.952/29.952)

Transition from aluminum skin fuel tanks or from fuel tanks compliant with the Technical Standard Order, TSO-C80, Flexible Fuel and Oil Cell Material to full compliance with Part 27.952 and 29.952 incurs additional weight and costs due to increased thickness of fuel bladder material and application of breakaway fittings. Structural changes to the airframe may also be required to retain the mass of the fuel system under the higher g-loads specified by the current amendment to 27/29.952 and 27/29.561. Compliance also frequently results in an overall loss in useful fuel capacity. Lastly, compliance requires significant certification testing of newly designed Part 27/29 fuel systems, further increasing per airframe costs (Table 1).

Crash resistant bladder construction requires a doubling of the thickness of bladder material from 1.0 to 2.0 mm. Soft goods weight nearly doubles, increasing from 3.63 lbs. to 7.04 lbs. for Part 27 (50 gallon) bladders and from 10.15 lbs. to 19.71 lbs. for Part 29 (200 gallon) bladders. While the number of fittings remains unchanged, the hard goods weight of crashworthy fittings increases by 56.6% for Part 27 systems (from 6.6 lbs. to 10.3 lbs), and by 42.3% for Part 29 systems (from 23.6 lbs. to 33.6 lbs.). This increase in total weight of the fuel system for Part 27.952 is nearly 70%, ranging from 10.2 to 17.3 lbs. and Part 29.952 weight increase is 58%, ranging from 33.8 to 53.3 lbs. Based on the above considerations, compliance could potentially affect airframe design and construction for rotorcraft manufacturers as well as aircraft utilization by rotorcraft operators.

Thicker material affects bladder construction by changing the radii of seams, which reduces overall available volume per surface area and useful volume (measured in gallons). Useful capacity loss is projected to be approximately 1 gal for Part 27 fuel systems and approximately 3 gal for Part 29 fuel systems. Loss of useful fuel capacity will have an impact on operator ranges and capabilities.

Since many operators report they currently operate close to gross weight, compliance with the current regulations increasing weight and decreasing range may render their current fleet uneconomical by decreasing payload and range.

Table 1. Fuel Systems Costs						
	TSO-C80	27.952	Est. Change	TSO-C80	29.952	Est. Change
Material thickness (mm)	1.0	2.0	0.04 (100%)	1.0	2.0	1.0 (100%)
Soft goods weight (lbs.)	3.63	7.04	3.41 (94%)	10.15	19.71	9.56 (89%)
Hard goods weight (lbs.)	6.6	10.3	3.7 (56%)	23.6	33.6	10 (42%)
Total Wt. (lbs.)	10.2	17.3	7.1 (70%)	33.8	53.3	19.5 (58%)
Volume loss (gal)	0.53	1.06	0.53 (100%)	1.49	2.98	1.49 (100%)
Cost of bladder material, avg. (US$)	$2,059	$3,289	$1,309 (59.7%)	$6,863	$10,963	$4,363 (59.7%)
Cost of CRFS fittings	0	$5,820	$5,820	0	$7,100	$7,100
Total cost CRFS		$9,100			$18,000	
Costs of Testing	Impact	S-V[2]	TOTAL	Impact	S-V[2]	TOTAL
Cost of testing 27/29.952 compliant fuel systems (US$)	10,789	20,645	31,434	18,663	25,231	43,894

When compared with data from the 1994 study of Crash Resistant Fuel Bladder Costs, overall costs for bladder construction to meet compliance with Part 27.952 and 29.952 are increased by an inflation index of 60%.[3] This represents an increase in cost of construction from $2,059 to $3,289 for Part 27 fuel systems, and an increase from $6,863 to $10,963 for Part 29 fuel systems. Compliance with 27/29.952 also requires new application of breakaway fittings, to minimize potential fuel spillage. Costs for breakaway valves for Part 27 (8 required x $600) and Part 29 (10 x $600) and rollover vent valves ($500) combine for an average total of $5,300-6,500. Flexible fuel lines for Part 27 (8 x $75) and Part 29 (10 x $75) and crash resistant gravity filler caps ($300) total approximately $1,100. Crash resistant fuel system components, in total, result in additional costs of approximately $5,800-7,100 per aircraft.

Costs for certification testing of crashworthy fuel systems includes costs for impact testing and slosh and vibration testing. 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 crashworthy 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.). 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 increase testing costs

[2] Slosh and vibration testing

[3] Department of Transportation, Federal Aviation Administration. Airworthiness Standards; Crash Resistant Fuel Systems in Normal and Transport Category Rotorcraft. 14 CFR Parts 27 and 29; Docket No. 26352; Amendment No. 27-30, 29-35, 1994

beyond these estimates. These costs may be amortized over the life of an aircraft model type certificate.

One pilot training operator reports having completed seventeen (fuel system) bladder retrofits for Part 27 helicopters in the past 2-3 years, with completion of the operator fleet by end of year 2016. This operator estimates the cost at $7,000 per aircraft, plus 40 labor hours.

Seat Costs

Incorporating seats to meet the requirements of 27/29.562 requires purchasing or developing stroking seats that protect the occupant as required by 27/29.562 and increasing the strength of the surrounding structure, thereby requiring an increase in the empty weight of the helicopter, and significant monetary costs for the design, certification, and manufacturing of the new structure. Data was requested from six seat manufacturers, but was provided by only one. This manufacturer makes two models of seats that comply with Parts 27/29.785. These models are listed by weight and cost in Table 2:

Table 2. Seat Costs

Manufacturer	Model	Weight (lbs.)	Cost (USD)
Manufacturer A	Utility	14	$3,000-3,500
	VIP	21	$4,000-4,500

This manufacturer makes seats that are relatively inexpensive because they are not tailored to a particular rotorcraft. It is expected that the actual costs for compliant seats will be considerably greater for certain applications depending on whether separate pilot seats or bench seats for occupants are required and whether specially manufactured seats are required.

Structural Change Costs

Revising older designs to meet the requirements of 27.561 and 27.785 requires increasing the strength of the helicopter structure in numerous locations, thereby requiring an increase in the empty weight of the helicopter, and significant monetary costs for the design, certification, and manufacturing of the new structure. The weight and monetary costs for these changes is included in the overall cost of compliance presented in the subsection below.

Total Cost of Compliance

Data was provided by seven rotorcraft manufacturers: Agusta Westland, Airbus, Bell, Enstrom, MDHI, Robinson, and Sikorsky. These manufacturers currently produce aircraft complying with current sections of FAA Parts 27 and 29 (.561, .562, .785, and .952). These rotorcraft are referred to as “compliant” or “fully compliant”. The following analysis considers the costs for newly manufactured non-compliant rotorcraft to become fully compliant with current regulations. Models of each currently manufactured aircraft (as of 02/19/2016) are listed in Table 3.

Raw data collected was divided into two sets—performance data and cost data. Analysis of this data is presented in the accompanying Tables 4 and 5, which represent overall cost estimates and percentages for each participating manufacturer:

- Performance Data: data is presented in units and percentages, as available. Factors presented include changes in weight (empty and gross, as available), useful payload, fuel capacity, and mission capability, primarily range. This data was shared with rotorcraft operators to estimate potential impact to direct operating costs, mission profiles and associated downstream revenue. Some OEM's also reported on reductions in seating and cruise speeds. Overall data is presented in Table 4.

Table 3
Currently Manufactured Helicopters

Type Certificate Holder	Model	Part27/29	Notes
AgustaWestland	A109	27	
AgustaWestland	A119	27	
Airbus Helicopters	H155 (EC155)	29	Only EC155 B1 still manufactured
Airbus Helicopters	H225 (EC225)	29	
Airbus Helicopters	H215 (AS332)	29	Only AS332 C1 L1 still manufactured
Airbus Helicopters	H125 (AS350)	27	Only AS 350 B3e still manufactured
Airbus Helicopters	AS355[4]	27	Only AS 355 NP still manufactured
Airbus Helicopters	AS365	29	Only AS 365 N3 still manufactured
Bell	206L4	27	
Bell	407	27	
Bell	412	29	
Enstrom	F-28F	27	
Enstrom	280FX	27	
Enstrom	480B	27	
MDHI	369E, 369FF	27	
MDHI	MD900	27	
MDHI	500N	27	
MDHI	600N	27	
Robinson Helicopter Co.	R22	27	
Robinson Helicopter Co.	R44	27	
Sikorsky	269C	27	
Sikorsky	S-76	29	

[4] Airbus AS355 will no longer be manufactured after 2016.

- Cost Data: direct costs to Rotorcraft OEM's for changes in design, manufacturing (including parts, labor and retooling), certification (testing and conformity), and maintenance (training and schedule costs) as well as recurring costs per airframe. This data was compiled and overall estimates are presented in Table 5.

Performance Data

Performance Data reporting is not uniform, due to OEM concerns about release of potentially sensitive proprietary data. OEM'S varied in reporting actual weights/capacities or percentages, or both. The data in Table 4 is presented where uniform criteria were available, with accompanying narrative where needed to capture additional OEM specific data. It should be recognized that these are OEM estimates only, and attempts to extrapolate conclusions from these data may not be universally applicable.

Table 4.
Performance Data

OEM	Part 27/29	Useful Payload (.561, .562, .785)	Useful Payload[5] (27/29.952)	Fuel capacity change
Agusta Westland	27	-3.2%	-0.9%	-4 liters
Airbus	27	-10.3%	-3.5%	0%
	29	-5.9%	-2.7%	-3%
Bell	27	-8.2%	0 %	-7.2 %
	29	-1.1%	0 %	0%
Enstrom	27	-1.3%	-0.6%	-2%
MDHI	27	0%	-0.5%	-0.7%
Robinson	27	-4.8%	-0.8%	0%
Sikorsky	27	-25%	-5%	-6%
	29	-5%	-1%	-6%

AgustaWestland reports that compliance for Models AW119 and AW109E are as follows:

- Model AW119 will incur an increased empty weight of 791 lbs. Overall useful payload will decrease by 7 lbs. Fuel Capacity is expected to decrease by 4 liters (~1.1 gal.), with a reduction of range of 2 nm.
- Model AW109E will incur an increased empty weight of 841 lbs. Overall useful payload will decrease by 8 lbs. Fuel Capacity is expected to decrease by 4 liters, with a reduction of range of 2 nm.

Airbus Helicopters reports that compliance for Airbus Models AS350 (5 & 6 seat configurations), AS365, EC155, AS332L1, and EC225 are as follows:

- Model AS350 (5-seats) overall useful payload will decrease by 13%. Fuel Capacity remains unchanged, but increased weight will reduce range by approximately 17%.

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[5] OEM data demonstrated a nearly identical amount for "empty weight" and "useful load." Depending on configuration requirements, empty weight may differ from useful load. Thus, empty weight could remain unchanged, but useful load may be decreased due to configuration requirements (which may take up useful space).

- Model AS350 (6-seats) overall useful payload will decrease by 15%. Fuel Capacity remains unchanged, but increased weight will reduce range by approximately 21%.
- Model AS365 overall useful payload will decrease by 13%. Fuel capacity will decrease by 6%. This, combined with increased weight will reduce range by 15%.
- Model EC155 overall useful payload will decrease by 14%. Fuel capacity will decrease by 6%. This, combined with increased weight will reduce range by 17%.
- Model AS332L1 overall useful payload will decrease by 11%. Fuel capacity will decrease by 3%. This, combined with increased weight will reduce range by 15%.
- Model EC225 overall useful payload will decrease by 1%. Fuel capacity remains unchanged. Range is expected to be reduced by 1%.

Bell reports that compliance for Models 206L4, 407, and 412 are as follows:
- Models 206L4 and 407 will incur an increased empty weight of 205 lbs. Overall useful payload will decrease by 205 lbs. Fuel Capacity is expected to decrease by 180 lbs.
- Model 412 will incur an increased empty weight of 75 lbs. Overall useful payload will decrease by 75 lbs. Fuel Capacity remains unchanged.

Enstrom Helicopters reports that compliance for Enstrom Models F-28X/280FX and 480B are as follows[6]:
- Model F-28X/280FX overall useful payload will decrease by 4%. Fuel Capacity is expected to decrease by 4%. Of note, Enstrom also expects a reduction in seating capacity from three to two occupants.
- Model 480B overall useful payload will decrease by 3%. Fuel Capacity is expected to remain unchanged. Of note, Enstrom also expects a reduction in seating capacity from five to four occupants.

MDHI reports that compliance for Models 369E, 369FF, 500N, 600N, and MD900 are as follows:
- Models 369E, 369FF, and 500N overall useful payload will decrease by 0.5%. Fuel Capacity is expected to decrease by 0.7%.
- Models 600N and MD900 overall useful payload will decrease by less than 1%. Fuel Capacity is expected to remain unchanged.

Robinson Helicopters reports that compliance for Models R22 and R44 are as follows:
- Model R22 overall useful payload will decrease by 6.7%. Fuel Capacity is expected to remain unchanged. Due to increased empty weight, range is expected to decrease by 1.5%, and cruise speed is expected to decrease by 0.8%.
- Model R44 overall useful payload will decrease by 4.4%. Fuel Capacity is expected to remain unchanged. Due to increased empty weight, range is expected to decrease by 0.7%, and cruise speed is expected to decrease by 0.7%.

[6] Enstrom notes that losing 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.

Sikorsky Helicopters reports that compliance for Models S-76 and S-269c are as follows:

- Model S-76 overall useful payload (with a fixed range) will decrease by 34%. Fuel Capacity is expected to decrease by 6%. Range with a fixed payload is expected to decrease by 37%.
- Model S-269C overall useful payload (with a fixed range) will decrease by 52%. Fuel Capacity is expected to decrease by 6%. Range with a fixed payload is expected to decrease by 86%.

Cost Data

Cost Data reporting, as with performance data, was not 100 percent, due to OEM concerns about release of potentially sensitive proprietary data. The data in Table 5 is solely based on data provided by the OEM's. Basically, two main costs were reported by the OEM's, 1) one-time primarily development costs and 2) recurrent costs associated with each airframe produced. One-time costs are average costs per OEM for all models produced and are shown separately for Parts 27/29.561; .562 compliance and for compliance with 27/29.952. "Parts & Labor" is also considered a one-time cost and is listed per OEM. The one-time cost data includes potential costs associated with manufacturing such as parts, labor, retooling, and certification (testing and conformity). Most OEM's also reported recurrent costs per aircraft unit produced and these costs are associated with maintenance (training and schedule costs) and the increased costs of parts and labor. Recurrent costs are also listed by manufacturer. The totals at the bottom of the chart are average costs for all reporting OEM's and may be considered an overall one-time industry cost except for recurrent costs, which occur on a per unit manufactured basis. The accuracy of these estimates is diluted by the absence of reporting by some OEM's and could be improved with complete participation of all rotorcraft OEM's building or exporting rotorcraft to the U.S.

Table 5

OEM	Part 27/29	Overall One-time Cost (.561, .562, .785)	Overall One-time Cost (27/29.952)	Parts & Labor (USD)	Recurrent Costs (USD)
OEM A	27	0	3.2M	(not reported)	(not reported)
OEM B	27	9.5M	6M	(not reported)	126,000
OEM C	27	53M	23M	210K (0.3%)	6,000
	29	1.7M	0.6M	175K (7%)	1,000
OEM D	27	1M	0.2M	18K (2%)	25,800
OEM E	27	(not reported)	(not reported)	(not reported)	(not reported)
OEM F	27	2M	0.2M	8K (0.3%)	7500
OEM G	27	13M	13M	(not reported)	25%
	29	63M	63M	(not reported)	5%
Totals (based upon averages reported)		>143M	>109.2M	>411K	>167,000

Robinson Helicopter Company (RHC), along with other smaller rotorcraft manufacturers, have expressed that the monetary costs listed are not the primary concern for smaller aircraft (e.g., RHC R22). Rather, RHC is concerned that the required increase in gross weight, especially for the R22, could have the following consequences:

1. The R22 will have a significantly reduced useful load, and as a result:
    a. Operators that respect the gross weight limitation will likely find that at least 50% of their current operations with the maximum (2) occupants (such as flight training) will no longer be possible.
    b. Operators that do not respect the gross weight limitation will likely fly (illegally) at weights even further above the limit, increasing the risk of an accident.
2. The R44 will also have a reduced useful load, and will have similar (though less severe) problems as outlined for the R22 above.

It is the opinion of RHC that these consequences are far more significant than the monetary costs outlined, and that incorporation of current requirements could force discontinuation of certain models of rotorcraft. The cost of these consequences are difficult to predict and are not included in this cost/benefit analysis.

Based on the data presented in Table 5, it is estimated that, the total one-time cost of complying with the current regulations for rotorcraft currently in production would be greater than $252M. Recurrent costs will be in excess of an average of $167,000 per compliant airframe produced. This estimate includes only OEM costs and is based solely upon their input to the ROPWG. Operators would incur additional costs as well. In some cases, these costs would be considerable if not unsustainable.

Rotorcraft Operator Data

Data was collected from operators representing governmental contracting, corporate contracting, tour operations, pilot training and air medical services. Data provided from fuel system manufacturers, crashworthy seat manufacturers and OEM's was used by operators to estimate cost impact of full compliance (Parts 27/29, sections .561, .562, .785 and .952) to rotorcraft operations.

It must be understood that imposition of the current regulations upon newly manufactured rotorcraft certified to older standards will impose significant economic and operational costs upon certain models of rotorcraft. In fact, according to input from OEM's, certain airframes will have to be substantially redesigned to meet the increased structural demands of 27/29.561. As an example, based upon OEM data presented in the above OEM section, full compliance for the AS350B incurs an additional weight load that has a significant impact on tour and utility operations for this Part 27 aircraft. For government utility operations, the additional weight of the AS350B 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. Aviation companies utilizing the AS350B will likely have to identify an alternative aircraft for this business line. Replacement of a rotorcraft fleet incurs significant, and yet to be estimated, additional costs. These costs are associated with replacement of the current fleet, retraining of maintenance and aviation staff, adoption of new maintenance schedules and retooling. Further costs associated with implementation of replacement aircraft cannot be fully predicted at this time, as a suitable replacement aircraft (with similar capabilities to the AS350B) is yet to be determined. However, even in the absence of this data, it is expected that the economic impact to affected operators will be in the millions and the total industry cost will be much greater.

For tour operations, the additional weight incurred effectively reduces the passenger payload by one. This passenger reduction is required to optimize safe operations of the AS350B during take-off and landing operations. Using the passenger count from 2015 operations, one operator estimates that this passenger reduction will affect not only capacity for tour operations, but scheduling of tour operations. The economic impact of this change for the AS350B is predicted to result in a potential loss of gross revenue of $4.4M per year. Considering all the tour operators operating in the U.S., the losses sustained by the entire helicopter tour industry will be considerably greater.

Assuming similar maintenance/inspection procedures for compliant seats and fuel tanks, it is estimated that direct operating cost (DOC) is not impacted by installed equipment. Installation of compliant seats and fuel tanks will drive minimal or no change to pilot training procedures, with nominal costs, if any. With regard to aircraft insurance costs, for large fleet operators, adjustment of premium for the implementation of an individual safety system is negligible to not applicable. The insurance markets would anticipate that the better operations would systematically implement the best safety features as they came on the market. Each operator is underwritten as an entire package and not on specific safety systems.

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 Part 27 and Part 29 regulations. The general approach was to examine all rotorcraft crashes in the NTSB database over the past 10-years and use that as a basis for determining levels of injury and establishing the cost of each injury incurred in these crashes. This effort was complicated by the fact that the National Transportation Safety Board (NTSB) database and, indeed dockets, do not contain information on impact velocity or aircraft orientation at impact, nor do they contain any specificity as to injury as will be discussed later in this report. Previously published studies and FAA rulemaking documents were also used as a basis for some data.

Compliance levels of current production rotorcraft

Since different rotorcraft currently under production have different levels of compliance with current regulations ranging from none to fully compliant, the rotorcraft involved in crashes from the NTSB database were divided into levels of compliance as shown in Table 6.

Dataset Preparation and Filtering

The data was extracted from the NTSB's Microsoft Access database, current through 2/1/2016. 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 (most recent 10 year data available)
- homebuilt = *N* or is null (excludes homebuilt helicopters that were not type certificated and also catches cases where NTSB inadvertently left the field unpopulated)

The above query resulted in 1,442 accident records. The dataset was then filtered retaining only rotorcraft currently in production resulting in 793 records.

The initial review of the dataset showed that eight accidents included either rotorcraft damage as "minor" or "none." However, there were five fatalities included in these eight accidents. The accident narratives were reviewed and all injuries were not related to a crash event, such as being struck by a main or tail rotor. These accidents were removed from the dataset resulting in 785 records as shown in Table 7.

Table 6. Current Production Rotorcraft and Compliance Levels

Make	Model	Compliance Level			
		27/29.561	27/29.562	27/29.785	27/29.952
Agusta Westland	A109	C	N	N	N
Agusta Westland	A109 S/SP	C	C	C	C
Agusta Westland	A119	C	N	N	N
Agusta Westland	AW139	C	C	C	C
Agusta Westland	AW189	C	C	C	C
Airbus Helicopters	BK117[(1)]	C	C	C	C
Airbus Helicopters	H120 / EC120	C	C	C	C
Airbus Helicopters	H130 / EC130[(2)]	C	C	C	C
Airbus Helicopters	H135 / EC135[(3)]	C	C	C	C
Airbus Helicopters	H155 / EC155[(4)]	P[(9)]	P	P[(10)]	N
Airbus Helicopters	H225 / EC225	P[(9)]	N	N	N
Airbus Helicopters	H215 / AS332[(5)]	P[(9)]	N	N	N
Airbus Helicopters	H125 / AS350[(6)]	P	P	P[(10)]	N
Airbus Helicopters	AS355[(7)]	P	P	P[(10)]	N
Airbus Helicopters	AS365[(8)]	P[(9)]	N	N	N
Bell	206L4	N	N	N	P[(11)]
Bell	407	N	N	P[(12)]	P[(13)]
Bell	412	P	P	P[(14)]	P[(11)]
Bell	429	C	C	C	C
Enstrom	F-28	N	N	N	N
Enstrom	280	N	N	N	N
Enstrom	480	N	N	N	P
MDHI	369E, 369FF	N	N	N	N
MDHI	MD900	P	C	C	C
MDHI	500N	N	N	N	N

Table 6. Current Production Rotorcraft and Compliance Levels (Continued)					
Make	Model	Compliance Level			
		27/29.561	27/29.562	27/29.785	27/29.952
MDHI	600N	N	N	N	C
Robinson	R22	P	N	P	P
Robinson	R44	P	N	P	P
Robinson	R66	C	C	C	C
Sikorsky	269/300/TH-55	N	N	N	N
Sikorsky	S-76	P	N	N	N
Sikorsky	S-92	C	C	C	C

Notes :

1) C=fully compliant
2) P=partially compliant
3) N=non-compliant
4) Only BK 117 C2 C2e D2 D2m still manufactured
5) Only EC130 T2 still manufactured
6) Only EC135 P2+ T2+ P3 T3 still manufactured
7) Only EC155 B1 still manufactured
8) Only AS332 C1 L1 still manufactured
9) Only AS 350 B3e still manufactured
10) Only AS 355 NP still manufactured
11) Only AS 365 N3 still manufactured
12) Only heavy masses 27/29.561 compliant
13) Only forward seats 27/29.785 compliant
14) Fuel bladders were drop tested 50ft without structure
15) Amdt. 27-21
16) Fully compliant except for 27.952(b)1
17) All aircraft delivered with seat kit = 29.561(b) & 29.785 to Amend 29-29; 29.562 to Amend 29-41

The dataset was also reviewed for duplicate injuries. When two aircraft collide, the NTSB generates a report for each aircraft involved, but lists the combined number of injuries in each record, thus creating duplicate injuries in the record. The accidents in the dataset contained 13 records with duplicate injuries. By reviewing the narrative of each of these accidents, the correct number and level of injury could be assigned to each rotorcraft occupant involved in the accident. Table 8 provides a list of these records and the corrected injuries. The corrected data was incorporated into the analysis dataset of 785 records. A Microsoft Excel file was created and fields were added for each rotorcraft compliance level shown in Table 6. This allowed filtering the dataset accidents based on compliance levels of the involved rotorcraft.

Table 7. Details of eight Accidents removed from the Dataset		
Event ID	Narrative Portion / Notes	Injuries
20070319X00305	A Eurocopter EC-120B, U. S. registration N263CP, and a Robinson R-22 BETA, Netherlands registration PH-JGR, collided while hovering at the Stadtlohn Airport, Vreden, Germany. The R-22 sustained substantial damage while the EC-120 sustained minor damage. *Note: The U.S. registered accident was the EC-120B and it had only minor damage and no injuries. From the standpoint of the EC-120s damage and injuries, it was not considered an NTSB recordable accident.*	None onboard the EC120B 2 minor aboard the R22
20130928X12809	As the relieved pilot was walking away from the helicopter and between the 10- and 11-o'clock position forward of the helicopter, he came into contact with a rotating main rotor blade.	1 fatal

Table 7. Details of eight Accidents removed from the Dataset		
Event ID	Narrative Portion / Notes	Injuries
20100525X54249	During the descent the helicopter hit unseen power lines on its left side, breaking the power lines and seriously injuring the passenger in the left seat. *Note: the NTSB public docket for this accident described the passenger's injuries as 3rd degree burns on his shoulder and his calf. Presumably these were from the power line since there is no mention nor documentation of a post-crash fire*	1 serious
20071227X01994	While walking toward the unoccupied helicopter, the pilot was struck by the idling main rotor.	1 fatal
20081014X22933	The paramedic had been struck by the main rotor blades.	1 fatal
20140408X81146	The hoist operator was unable to release the hoist cable quickly enough to prevent pulling the ship pilot off the deck and had to cut the cable. The ship pilot fell a few feet to the deck and fractured his scapula.	1 serious
20110830X71207	The wing walker subsequently fell, impacting a grass area within the air show performance area. Both aircraft involved landed safely after the accident, without damage to either aircraft.	1 fatal
20150428X84204	The hoist operator stated that the spin had almost stopped, and he noticed that the flight nurse was riding in a position lower than normal. The flight nurse then fell from the line.	1 fatal

Table 8. NTSB Database Records with Duplicate Injury Reporting											
Event ID	Make	Model	DESCRIPTION	NTSB Database Injuries				Corrected Injuries			
				F	S	M	N	F	S	M	N
20080715X01051	Bell	407	Two 407's struck midair	7				3			
20080715X01051	Bell	407	Two 407's struck midair	7				4			
20090202X21409	Robinson	R22	R-22 and T-6G on runway				4			2	
20070614X00722	Robinson	R22 Beta	R-22's collided on runway				4				2
20070614X00722	Robinson	R22 Beta	R-22's collided on runway				4				2
20120220X14409	Robinson	R22 Beta	R22 midair with Beechcraft				3				1
20150129X05038	Robinson	R22 Beta	R22 midair with Piper PA-28				4				2
20141023X01333	Robinson	R44 II	R44 midair with Cirrus SR22	3		1	1	3			
Totals				17	0	1	20	10	0	2	7

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 level in the NTSB database. Consequently the true costs of injury in rotorcraft crashes are 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 recognizing 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 particular injury. A sixth category corresponds to injuries that are considered “maximum” and almost always result in death. 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. MAIS does not consider the risk of death for the combined injuries a person may suffer. Table 9 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. There is no direct relationship between the scale used by the NTSB and the more extensive and widely used AIS and MAIS utilized by NHTSA. Per the NTSB Form 6120.1, the definitions of fatal and severe injuries are as follows:

Table 9. 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.

“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 10 along with their corresponding dollar values (based on a $9.4 million VSL). The fractions shown in column 3 of Table 10 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 ($9.4 million) to calculate the value of the serious injury ($987,000). 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 10. Relative Disutility Factors by Injury Severity Level			
MAIS Code	**Description**	**Fractional Fatality Values Value of Life**	**Dollar Value**
1	Minor	0.003	$28,200
2	Moderate	0.047	$441,800
3	Serious	0.105	$987,000
4	Severe	0.266	$2,500,400
5	Critical	0.593	$5,574,200
6	Maximum	1.000	$9,400,000
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 MAIS 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 MAIS 2 or higher, whereas minor injury victims typically have injuries at the MAIS 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.[7] These values were then applied to current VSL to estimate the value of preventing serious injuries as defined by ICAO. Table 11 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.

<table>
<tr><th colspan="4">Table 11. Recommended Injury Values Based on the NTSB Classification of injuries.</th></tr>
<tr><th>MAIS Code</th><th>NTSB Classification</th><th>Modified Fractional Fatality Values of Life</th><th>Dollar Value</th></tr>
<tr><td>MAIS 1 – Minor</td><td>Minor</td><td>0.003</td><td>$28,200</td></tr>
<tr><td>MAIS 2 – Moderate</td><td rowspan="4">Serious</td><td rowspan="4">0.253</td><td rowspan="4">$2,378,200</td></tr>
<tr><td>MAIS 3 – Serious</td></tr>
<tr><td>MAIS 4 – Severe</td></tr>
<tr><td>MAIS 5 – Critical</td></tr>
<tr><td>MAIS 6 – Fatal</td><td>Fatal</td><td>1.000</td><td>$9,400,000</td></tr>
</table>

As the injury data for victims of helicopter crashes are generally unavailable in the NTSB record and definitely not at the MAIS level, for the purposes of this paper we will be utilizing the values

[7] 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.

in Table 10 to determine the costs of injuries and fatalities. There are limitations to this approach, but because of the lack of data 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 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; in order 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 most costly aspect of such crashes would be overlooked.[8]

Benefit Based on Overall Dataset Review

The dataset supporting this effort was filtered to allow a binary overall comparison between fully compliant and all non-fully complaint (including partially compliant) rotorcraft accidents (Table 12). This simple approach allows direct comparison of occupant injury rates between the two groups, but has the following limitations:

- NTSB accident data does not include crash kinematics information (impact velocities, impact attitude, etc.). Crash kinematics greatly affect crash performance and occupant injury levels. For instance the NTSB database does not distinguish between a crash with minor structural deformation and a high velocity impact with the ground resulting in total destruction of the aircraft. The introduction of crash safety upgrades alone is not expected to significantly influence the crash kinematics; however, crash kinematics are often platform dependent.

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

- A large quantity of data (number of crashes) is required so that the crash kinematics extremes and injury cost extremes will be statistically identical when comparing different models of rotorcraft.
- Other rotorcraft features other than those governed by 27/29.561, 27/29.562, 27/29.785, and 27/29.952 can influence injury rates during a crash. This would include such factors as landing gear energy absorption, propensity to rollover during a crash, blade strike potential, occupant shell crushing strength (from barrier impact), and other factors.

Table 12. Accident and Injury Summary, Grouped by Compliance Level

Make	Model	Compliance Level				Total	Total	Fatal		Serious		Minor		None	
		.561	.562	.785	.952	Incdt	Occpt	No.	Pct	No.	Pct	No.	Pct	No.	Pct
Agusta	A109S	C	C	C	C	0	0	0	0%	0	0	0	0	0	0
Agusta	AW139	C	C	C	C	1	2	0	0	1	50.0%	0	0	1	50.0%
Agusta	AW189	C	C	C	C	0	0	0	0	0	0	0	0	0	0
Airbus	BK117	C	C	C	C	4	13	0	0	0	0.0%	0	0	13	100.0%
Airbus	EC120	C	C	C	C	7	17	8	47.1%	0	0.0%	3	17.6%	6	35.3%
Airbus	EC130	C	C	C	C	0	0	0	0	0	0	0	0	0	0
Airbus	EC135	C	C	C	C	3	9	1	11.1%	0	0	3	33.3%	5	55.6%
Bell	429	C	C	C	C	1	4	0	0	0	0	0	0	4	100.0%
Robinson	R66	C	C	C	C	5	11	8	72.7%	0	0	0	0	3	27.3%
Sikorsky	S-92	C	C	C	C	0	0	0	0	0	0	0	0	0	0
Subtotal Fully Compliant						**21**	**58**	**19**	**32.8%**	**1**	**1.7%**	**6**	**10.3%**	**32**	**55.2%**
Agusta	A109	C	N	N	N	8	22	8	36.4%	4	18.2%	0	0	10	45.5%
Agusta	A119	C	N	N	N	3	11	0	0.0%	0	0	0	0	11	100.0%
Airbus	EC155	P	P	N	N	0	0	0	0	0	0	0	0	0	0
Airbus	EC225	P	N	N	N	0	0	0	0	0	0	0	0	0	0
Airbus	AS332	P	N	N	N	0	0	0	0	0	0	0	0	0	0
Airbus	AS350	P	P	P	N	44	102	20	19.6%	9	8.8%	15	14.7%	58	56.9%
Airbus	AS355	P	P	P	N	0	0	0	0	0	0	0	0	0	0
Airbus	AS365	P	N	N	N	0	0	0	0	0	0	0	0	0	0
Bell	206L4	N	N	N	P	19	41	13	31.7%	4	9.8%	1	2.4%	23	56.1%
Bell	407	N	N	P	P	38	96	25	26.0%	7	7.3%	14	14.6%	50	52.1%
Bell	412	P	P	P	P	4	22	13	59.1%	0	0.0%	7	31.8%	2	9.1%
Enstrom	F-28	N	N	N	N	21	34	0	0.0%	4	11.8%	4	11.8%	26	76.5%
Enstrom	280	N	N	N	N	13	24	2	8.3%	4	16.7%	4	16.7%	14	58.3%
Enstrom	480	N	N	N	P	2	3	1	33.3%	0	0.0%	0	0.0%	2	66.7%
MDHI	MD900	P	C	C	C	2	5	0	0.0%	0	0.0%	1	20.0%	4	80.0%
MDHI	600N	N	N	N	C	8	19	4	21.1%	4	21.1%	7	36.8%	4	21.1%
MDHI	369	N	N	N	N	44	109	12	11.0%	17	15.6%	24	22.0%	56	51.4%
MDHI	500N	N	N	N	N	4	11	0	0.0%	0	0.0%	1	9.1%	10	90.9%
Robinson	R22	P	N	P	P	219	376	28	7.4%	26	6.9%	76	20.2%	246	65.4%
Robinson	R44	P	N	P	P	194	417	77	18.5%	46	11.0%	70	16.8%	224	53.7%
Sikorsky	269	N	N	N	N	129	221	12	5.4%	18	8.1%	46	20.8%	145	65.6%
Sikorsky	S-76	P	N	N	N	11	68	11	16.2%	3	4.4%	2	2.9%	52	76.5%
Subtotal Partial/Non-Compliant						**763**	**1581**	**226**	**14.3%**	**146**	**9.2%**	**272**	**17.2%**	**937**	**59.3%**
Overall Total						**784**	**1639**	**245**	**14.9%**	**147**	**9.0%**	**278**	**17.0%**	**969**	**59.1%**

Table 12 provides the summary data comparing injury rates for the fully compliant and all non-fully complaint rotorcraft accidents. Of the total only 2.7 percent (21 accidents of 785 total) involved aircraft that are fully compliant. Evaluating data with so few data points results in a relatively high margin of error.

While the number of accidents with full crash safety compliance is relatively low, an increased number of accidents may not lead to decreased injury rates as recorded by the NTSB when compared to the non-fully complaint rotorcraft. Some additional issues to consider include:

- The low fidelity of the NTSB injury levels tend to mask significant improvements even though costly injuries may be avoided. Consider a crash severe enough to cause occupant spinal compressive fracture and consequent paraplegia. Introduction of an energy absorbing (EA) seat may prevent the spinal fracture in a similar crash, but less severe injuries (such as a broken arm) are still likely. In this a case, the EA seat is providing significant injury reduction value (paraplegia vs. broken arm), but both injuries would be reported as "serious" implying that there is little to no benefit to an EA seat.
- Low severity crashes are more likely to cause substantial damage in early compliant 27/29.561 rotorcraft. As low severity crashes generally cause lower occupant injuries, this may lead to the false conclusion that these rotorcraft would not benefit from increased crash safety (i.e., have a low injury rate due to inclusion of low severity accidents).

Benefits of Implementing 27/29.952 Compliance

Due to the low number of Part 29 certificated rotorcraft, both Part 27 and Part 29 certified rotorcraft are examined collectively. Only the Bell 412, Sikorsky S-76 and the Airbus H155, H215 and H225 are certified to Part 29. None the less, the NTSB data can be used to show the capability of the Crash Resistant Fuel System (CRFS) to reduce fire during a crash event. As shown in Table 13 only two out of 30 accidents (6.7%) involving compliant rotorcraft had a ground fire. In addition, there were six other accidents with no survivors that were considered non-survivable by the ROPWG due to their significant impact velocity. Table 14 shows excerpts from the narratives for these six accidents. The three non-survivable accidents in Table 14 without fire indicate that the 27/29.952 compliant CRFS are preventing ground fires in severe accidents at least up to the survivability level of these rotorcraft.

If data from Textron Bell Helicopter whose aircraft include bladder-equipped fuel systems including the Bell 206, 412 and the Bell 407 are added to the analysis in Table 13, there are 90 total accidents of 27/29.952 compliant rotorcraft in the dataset. It should be pointed out that only the Bell 407 is nearly compliant, whereas the Bell 206 and 412 have bladders only. These bladders reportedly meet the 50 foot drop standard. Although not fully compliant, these aircraft are closer to compliance than rotorcraft without fuel bladders. Based on this assumption, verified by a previous study showing a 50 percent decrease in post-crash fires for Bell 206 models after the bladders were integrated, the ROPWG felt that the bladder-equipped aircraft should be considered.[9] These 90 accidents including full and partially 27/29.952 compliant are illustrated in Table 15 due to the minimal amount of data available for Part 29 crashes. To separate the two

[9] Hayden, M.S. et al. Crash-resistant fuel system effectiveness in civil helicopter crashes. Aviat Space Environ Med 2005; 76:782-5

certification Parts at this time would cause significant data dilution. Aircraft certified to Part 29 standards include the Bell 412, Sikorsky S-76 and the Airbus H155, H215, and the H225. This analysis brings the total number of ground related fires to six (6.7%). Five (5) of these accidents did not have survivors, and in the other incident (N607BP), both the pilot and passenger exited with minor or no injury.

Table 13. 27/29.952 Compliant Rotorcraft Injuries and Fires

Make	Model	Event ID	Reg. No.	Fatal	Serious	Minor	None	Fire
AgustaWestland	AW139	20121023X30148	N385RH		1		1	NONE
Airbus	EC135	20151119X93456	N36RX				5	NONE
Airbus	EC120	20060516X00584	N514AL			1		NONE
Airbus	EC120	20061226X01846	N171AE				2	NONE
Airbus	EC120	20091016X45106	N871SA	3				NONE
Airbus	EC120	20111005X91033	N3925A			2		NONE
Airbus	EC120	20120726X62312	N8899	3			1	NONE
Airbus	BK117	20110105X95224	N854EC				3	NONE
Airbus	EC135	20080612X00843	N238AM			3		NONE
Airbus	EC135	20080520X00702	N135UW	3				NONE
Airbus	BK117	20110113X14327	N145SM				3	NONE
Airbus	BK117	20120724X52626	N455MH				3	NONE
Airbus	BK117	20130215X30422	N481LF				4	NONE
Airbus	EC120	20070307X00258	N491AE				3	NONE
Airbus	EC120	20070223X00214	N690WR	2				NONE
Bell	429	20150901X73122	N429AR				4	NONE
MDHI	900	20141204X91829	N902LC			1	2	NONE
MDHI	900	20060403X00379	N912LH				2	NONE
MDHI	600N	20090220X14000	N608BP		2	1		NONE
MDHI	600N	20091013X04846	N613BP			1	1	NONE
MDHI	600N	20070328X00342	N451DL				2	NONE
MDHI	600N	20080410X00451	N160KC			2		NONE
MDHI	600N	20120808X44331	N737TV	1				NONE
MDHI	600N	20140427X71558	N606BP		1	2		NONE
MDHI	600N	20151208X01729	N607BP			1	1	GRD
Robinson	R66	20110713X53504	N810AG	2				NONE
Robinson	R66	20130728X45845	N646AG	5				NONE
Robinson	R66	20111001X63448	N266CY	1				GRD
Robinson	R66	20141222X43102	N64HF				1	NONE
Robinson	R66	20141105X83801	N67GA				2	NONE

Table 14. Narrative Summary for 27/29.952 Compliant Rotorcraft with no Survivors		
Event ID	Narrative Excerpt / Summary	Crash Severity / CRFS Result
20091016X45106	The accident occurred in the Dominican Republic. The NTSB has no additional details about the event published on their website.	Unknown crash severity No ground fire
20080520X00702	The helicopter had impacted trees along a sparsely populated ridgeline with 50- to 60-foot tall trees in the area initially struck by the helicopter. Distribution of the wreckage was consistent with the helicopter impacting the trees in a nearly level flight attitude under controlled flight. The cockpit and cabin areas were completely compromised.	Considered non-survivable. No ground fire
20070223X00214	The helicopter and its occupants were later located and recovered from 101 feet of water, approximately 2,900 feet from the platform. An autopsy of the pilot listed the cause of death as "multiple blunt force trauma."	While considered a severe crash, unable to determine if CRFS performed properly as fires after water impact are rare
20110713X53504	The accident occurred in the country of Colombia. The NTSB credits the foreign authority as the source for the following information: A Robinson Helicopter Company R66 collided with terrain near Girardot, Colombia. The helicopter sustained substantial damage, and the commercial pilot and one passenger were fatally injured.	Considered non-survivable. No ground fire
20130728X45845	Major parts of the helicopter consisting of the main rotor assembly, mast, transmission, tail rotor assembly, and horizontal and vertical stabilizers were separated from the helicopter and located along the energy path southwest of the resting portion of the main wreckage. Numerous cockpit and cabin furnishings as well as cockpit and cabin doors, landing gear pieces, and personal effects were also located along the energy path.	Considered non-survivable. No ground fire.
20111001X63448	The helicopter was on a cross-country flight when it experienced a separation of the main rotor mast 8 inches below the teeter bolt, and the main rotor blade assembly separated from the flying helicopter. A ground observer estimated the helicopter to be flying 1,000 ft. AGL about 30 seconds prior to the accident.	Considered non-survivable. Included ground fire.

Table 15. 27/29.952 Compliant and Partial Compliant (Bell only) Rotorcraft Injuries and Fires								
Make	Model	Event ID	Reg. No.	Fatal	Serious	Minor	None	Fire
Agusta	AW139	20121023X30148	N385RH		1		1	NONE
Airbus	EC135	20151119X93456	N36RX				5	NONE
Airbus	EC120	20060516X00584	N514AL			1		NONE
Airbus	EC120	20061226X01846	N171AE				2	NONE
Airbus	EC120	20091016X45106	N871SA	3				NONE
Airbus	EC120	20111005X91033	N3925A			2		NONE
Airbus	EC120	20120726X62312	N8899	3			1	NONE
Airbus	BK117	20110105X95224	N854EC				3	NONE
Airbus	EC135	20080612X00843	N238AM			3		NONE
Airbus	EC135	20080520X00702	N135UW	3				NONE
Airbus	BK117	20110113X14327	N145SM				3	NONE
Airbus	BK117	20120724X52626	N455MH				3	NONE
Airbus	BK117	20130215X30422	N481LF				4	NONE

Table 15. 27/29.952 Compliant and Partial Compliant (Bell only) Rotorcraft Injuries and Fires								
Make	Model	Event ID	Reg. No.	Fatal	Serious	Minor	None	Fire
Airbus	EC120	20070307X00258	N491AE				3	NONE
Airbus	EC120	20070223X00214	N690WR	2				NONE
Bell	206	20090310X83102	N410RL				1	NONE
Bell	206	20140912X72236	N64AW				2	NONE
Bell	206	20150101X15630	N57AW	2				NONE
Bell	206	20081013X24743	N6ZV	2				GRD
Bell	206	20130620X92326	N467AE				3	NONE
Bell	206	20140612X31159	N207MY	2				NONE
Bell	206	20150604X51830	N73AW				1	NONE
Bell	206	20060207X00171	N225GH				2	NONE
Bell	206	20080821X01273	N94PD				2	NONE
Bell	206	20081211X45825	N180AL	5				NONE
Bell	206	20070824X01235	N1813		2	1		NONE
Bell	206	20071227X01999	N95CH				4	NONE
Bell	206	20090309X04818	N863H	1				NONE
Bell	206	20110303X04000	N154MW				1	NONE
Bell	206	20110513X45549	N266P		2		1	NONE
Bell	206	20120529X90616	N7077F	1				NONE
Bell	206	20130514X15720	N2036F				2	NONE
Bell	206	20130606X65516	N720RL				2	NONE
Bell	206	20140521X35335	N55SL				2	NONE
Bell	407	20060913X01334	N407SH				1	NONE
Bell	407	20061109X01634	N407KH				3	IFLT
Bell	407	20061222X01838	N407JJ	2				NONE
Bell	407	20071108X01772	N407LL				3	NONE
Bell	407	20080122X00087	N801DS				2	NONE
Bell	407	20080613X00858	N416PH	4				NONE
Bell	407	20080715X01051	N407GA	3				GRD
Bell	407	20080715X01051	N407MJ	4				NONE
Bell	407	20081223X62856	N407GB		1			NONE
Bell	407	20090311X25311	N2592T				4	NONE
Bell	407	20090505X03225	N164RL				1	NONE
Bell	407	20090925X05043	N6040Y				2	NONE
Bell	407	20100512X45440	N31VA				2	NONE
Bell	407	20101122X91647	N408UH				3	NONE
Bell	407	20111214X21335	N8067Z			5		NONE
Bell	407	20120216X03340	N407HL	1	2			NONE
Bell	407	20120324X31438	N31PB			2		NONE
Bell	407	20120414X64253	N509MT			1		NONE
Bell	407	20120826X42003	N407N	1				NONE
Bell	407	20120831X72351	N11SP			1		NONE
Bell	407	20121005X04242	N406AL	1				NONE
Bell	407	20121010X63824	N108MF	2	1			NONE
Bell	407	20130101X65128	N534MT				4	NONE
Bell	407	20130531X95830	N407HC				4	NONE

Table 15. 27/29.952 Compliant and Partial Compliant (Bell only) Rotorcraft Injuries and Fires								
Make	Model	Event ID	Reg. No.	Fatal	Serious	Minor	None	Fire
Bell	407	20130815X95202	N53LP			3		NONE
Bell	407	20140912X71805	N142MA			1		NONE
Bell	407	20150609X15345	N501PH				5	NONE
Bell	407	20151104X14945	N496AE				3	NONE
Bell	407	20121226X70416	N489AE				3	NONE
Bell	407	20140508X30821	N407MH				3	NONE
Bell	407	20150309X04646	N41BH				2	NONE
Bell	407	20151104X84701	N420PH				1	NONE
Bell	407	20151211X13514	N408FC	4				NONE
Bell	407	20150702X05414	N311RL		1			NONE
Bell	407	20130423X65502	N937GR				3	NONE
Bell	407	20130102X35708	N445MT	3				GRD
Bell	407	20091228X85137	N600CE		2	1		NONE
Bell	407	20130102X23415	N407KS				1	NONE
Bell	412	20100923X80619	N412PD			6		NONE
Bell	412	20150819X23543	N412LA			1	2	NONE
Bell	412	20061220X01815	N410MA	3				GRD
Bell	429	20150901X73122	N429AR				4	NONE
MDHI	900	20141204X91829	N902LC			1	2	NONE
MDHI	900	20060403X00379	N912LH				2	NONE
MDHI	600N	20090220X14000	N608BP		2	1		NONE
MDHI	600N	20091013X04846	N613BP			1	1	NONE
MDHI	600N	20070328X00342	N451DL				2	NONE
MDHI	600N	20080410X00451	N160KC			2		NONE
MDHI	600N	20120808X44331	N737TV	1				NONE
MDHI	600N	20140427X71558	N606BP		1	2		NONE
MDHI	600N	20151208X01729	N607BP			1	1	GRD
Robinson	R66	20110713X53504	N810AG	2				NONE
Robinson	R66	20130728X45845	N646AG	5				NONE
Robinson	R66	20111001X63448	N266CY	1				GRD
Robinson	R66	20141222X43102	N64HF				1	NONE
Robinson	R66	20141105X83801	N67GA				2	NONE

Fatality Reduction for 27/29.952 Compliance

For the non-compliant rotorcraft inclusive of both Parts 27 and 29, all fatalities during accidents with ground fires would not be prevented with introduction of a CRFS since an unknown portion of crashes are non-survivable. A recent FAA study evaluated the cause of pilot and pilot-certificated passenger fatalities in accidents where detailed autopsy data was available.[10] Pilots and pilot rated passengers were chosen because FAA only has autopsies performed on those individuals. Other passengers are not autopsied unless the local medical jurisdictional authority

[10] Roskop, Lee. "Post-Crash Fire and Blunt Force Fatal Injuries in U.S. Registered, Type Certificated Rotorcraft", Presentation by the FAA Safety Management Group, November 2015.

elects to perform additional autopsies at local expense. The accident data covered a five year span from October, 2008, to September, 2013, a representative subset of the same dataset reviewed for this project. The FAA study found at least 23.5% of the pilots and pilot-certificated passengers who were occupants in fatal accidents where the helicopter did not have a crash resistant fuel system and a post-crash fire occurred suffered fatal thermal injuries. Other occupants were not considered, but it was assumed that they would have approximately the same percentage of fatal thermal injuries. This analysis combines both Part 27 and Part 29 certified rotorcraft.

As previously discussed, a fully 27/29.952 compliant CRFS is expected to prevent post-crash fires up through the occupant survivable limit. Therefore, implementation of CRFS is expected to provide at least a 23.5 percent fatality reduction. This value is very close to the 26 percent reduction projected in the 27/29.952 Final Rule in 1994.[11] This result adds credibility to the Final Rule methodology of estimating the reduction in occupant fatalities by incorporating CRFS into rotorcraft. Filtering the dataset found a total of 104 fatalities in 50 accidents with ground fire where the rotorcraft was not fully compliant to 27/29.952 (Table 16). Implementation of full compliance to either 27/29.952 is expected to prevent 24 of these fatalities (23.5 percent of 104).

Table 16. Non-Compliant 27/29.952 Rotorcraft Accidents with Ground Fire and at least one Fatality

Event ID	Make	Model	F	S	M	Event ID	Make	Model	F	S	M
20140717X70001	Agusta	A109E	3			20080908X01405	Robinson	R44 II	2		
20151118X05037[4]	Airbus	AS350B3E	2			20080925X01525	Robinson	R44 II	2		
20150703X00859	Airbus	AS350B3E	1	2		20120119X92431	Robinson	R44 II	2		
20100728X92614	Airbus	AS 350 B3	3			20090920X34134	Robinson	R22 BETA	2		
20131022X92949	Airbus	AS 350 B3	3			20091017X64138	Robinson	R22 BETA	2		
20060813X01237	Airbus	AS-350-B3	4			20110627X51003	Robinson	R22 BETA	1		
20100325X93604	Airbus	AS-350-B3	3			20120910X05133	Robinson	R22 BETA	2		
20081013X24743	Bell	206	2			20071119X01805	Robinson	R44	3		
20080715X01051	Bell	407	3[(1)]			20090724X05537	Robinson	R44	4		
20061220X01815	Bell	412SP	3			20100705X12909	Robinson	R44	1		
20130102X35708	Bell	407	3			20110926X50902	Robinson	R44	2		
20150128X02848	Enstrom	280FX	2			20140910X82654	Robinson	R44	2		
20090626X94114	Enstrom	480B	1			20141202X73240	Robinson	R44	2		
20131007X44153	MDHI	369	1			20100205X21110	Robinson	R44 II	2		
20090724X13440	MDHI	369FF	0[(2)]	0[(2)]		20100717X71900	Robinson	R44 II	1	3	
20080201X00130	Robinson	R22 BETA	1			20100806X55641	Robinson	R44 II	2		
20080321X00357	Robinson	R22 Beta II	1			20121126X75106	Robinson	R44 II	1		
20060111X00044	Robinson	R44	3			20130525X61706	Robinson	R44 II	2		
20060208X00181	Robinson	R44	1			20140529X73728	Robinson	R44 II	1		

[11] Department of Transportation, Federal Aviation Administration. Airworthiness Standards; Crash Resistant Fuel Systems in Normal and Transport Category Rotorcraft. 14 CFR Parts 27 and 29; Docket No. 26352; Amendment No. 27-30, 29-35, 1994

Table 16. Non-Compliant 27/29.952 Rotorcraft Accidents with Ground Fire and at least one Fatality											
Event ID	Make	Model	F	S	M	Event ID	Make	Model	F	S	M
20080128X00108	Robinson	R44	2			20150322X92548	Robinson	R44 II	3		
20080505X00592	Robinson	R44	1		1	20080722X01096	Sikorsky	269B	2		
20130403X65155	Robinson	R44	2			20150701X20227	Sikorsky	269C	2		
20060209X00187	Robinson	R44 II	1			20080710X01015	Sikorsky	269 C-1	2		
20060419X00461	Robinson	R44 II	2	2		20150702X24434	Sikorsky	269C	2		
20070405X00374	Robinson	R44 II	2			20130315X34542	Sikorsky	S-76A++	3		
20070808X01151	Robinson	R44 II	4			Total			104	7	1

1) Was a mid-flight collision, 3 occupants aboard rotorcraft with ground fire
2) This accident was found to not have a ground fire. 3 fatalities and 1 serious injury removed
3) Part 29 aircraft are shaded; Sikorsky S-76A and Bell 412A. All others are Part 27.
4) Further information on this crash indicates that there were only sparks and not a post-crash fire. Elimination of this crash does not change the final statistic of 24 lives saved.

Injury Reduction for 27/29.952 Compliance

Review of the dataset showed only 10 accidents for non 27/29.952 compliant rotorcraft that had a ground fire and included at least one serious injury (Table 17). As any second degree burn or more severe is considered a serious injury, these 10 accidents should include all potential thermal injuries that did not result in a fatality

Table 17. Non-Compliant 27/29.952 Accidents with Ground Fire and Serious Injury					
Event ID	Make	Model	Fatal	Serious	Minor
20150703X00859	Airbus	AS350B3E	1	2	0
20140110X63030	Airbus	AS350B3	0	1	2
20130728X04056	Enstrom	F-28A	0	1	1
20130729X84808	MDHI	369E	0	2	0
20090724X13440(1)	MDHI	369FF	0(1)	0(1)	0
20080529X00755	Robinson	R22 Beta II	0	1	1
20060419X00461	Robinson	R44 II	2	2	0
20100717X71900	Robinson	R44 II	1	3	0
20100917X24222	Robinson	R44 II	0	2	0
20080603X00779	Sikorsky	S-76A(2)	0	2	0
Total			4	16	4

(1) Accident review found no ground fire for this case
(2) In this table, only the S-76A is certified to Part 29

A detailed review of these accidents showed that eight of the 16 serious injuries were thermally related (remaining eight were blunt trauma). MAIS scores were assigned for the eight thermally injured occupants, and the MAIS cost values previously shown in Table 10 were applied to determine the injury cost as illustrated in Table 18.

Table 18. Injury Value			
Event ID	Occupant No.	MAIS	Injury Value
20150703X00859	1	5	$5,574,200
20130728X04056	1	3	$987,000
	2	3	$987,000
20080529X00755	1	3	$987,000
20060419X00461	1	5	$5,574,200
	2	6(1)	$11,778,200(1)
20100917X24222	1	2	$441,800
	2	3	$987,000
Total			**$27,316,400(2)**

Notes:

1) Occupant died after 18 months in the hospital. Valuation based on value of NTSB serious injury ($2,378,200) plus fatality value ($9,400,000).
2) Average cost per thermal injury calculated to be $3,414,550, however, due to the wide range of types of thermal injuries, the costs can range from the approximate equivalent of MAIS 3, $987,000, to costs associated with prolonged hospitalization in a Burn ICU, which can reach tens of millions of dollars.

As described previously, all fires are expected to be prevented for survivable accidents with the introduction of 27/29.952 compliance. Therefore, all eight thermal injuries should be prevented by implementation of full 27/29.952 compliance.

Benefit of Implementing 27/29.561, 27/29.562, and 27/29.785 Compliance

There was insufficient data to permit division of Part 27 and Part 29 certified aircraft in this analysis. Simply put there are just a few rotorcraft certified to Part 29: Bell 412, Airbus H-155, H-215, H-225 and the Sikorsky S-76 representing less than one percent of the total airframe count. Combining the two certification standards (Part 27 and Part 29) still did not yield sufficient information in the current NTSB crash database to estimate the benefit of implementing the subject safety upgrades. Detailed information of the crash kinematics and occupant injuries will be required to make this assessment. Even if the improved data collection were to begin now, it may take several years to obtain the desired number of crash data points as there are relatively few fully compliant rotorcraft in operation today. For these reasons and because there is no new detailed crash data, ROPWG recommends that the injury reduction projections presented in the 27/29.562 Final Rule be utilized. Note that in the current analysis projections are based on the upgrades to 27/29.561, 27/29.562, and 27/29.785 inclusive.

The injury reduction projections presented in the 1994 Final Rule were based on years of research, and the methodology was well vetted by crash safety experts and industry representatives. Unfortunately, the projection has a broad range of 30 to 85 percent reduction in fatalities and injuries. Benefit values will be presenting for the extremes, with the understanding that a more precise value cannot be determined at this time.

Benefit Summary Calculations

The projected benefit value is calculated for all not fully compliant rotorcraft based on the expected net change in occupant injuries by implementation of full compliance to the current safety standards. Care must be taken to insure all occupants are accounted for. Table 19 and Table 20 provide the net benefit calculations for blunt trauma and thermal trauma utilizing the following procedure:

1. The NTSB occupant injuries were classified as thermal or blunt (all non-thermal considered blunt). Based on previously presented analysis, 23.5 percent of all fatalities in accidents with ground fire were expected to be thermally caused resulting in 24 thermal fatalities. There were eight serious injuries estimated to be thermally caused.
2. The benefit of introducing a CRFS was then applied. All thermally related fatalities became blunt severe injuries, and all thermal serious injuries became minor blunt injuries.
3. The benefit of introducing the Crash Resistant Seat and Structure (CRSS) was then applied at the FAA derived reduction value of 30 to 85 percent reduction in fatalities and injuries by calculating injuries at the two extremes (30% and 85%). The procedure of applying this benefit was as follows (using the 30 percent values in this example):
   a. 30 percent of fatalities were reduced to serious injuries.
   b. 30 percent of serious injuries were reduced to minor injuries.
   c. No additional adjustments were made to minor injuries.
   d. Serious thermal injuries estimated to be reduced to serious and minor blunt trauma were added into the blunt trauma calculation.
4. The net change in number of injuries was calculated by comparing the change in each injury category between the originally reported injuries and the calculated reduction in injuries incurred by introducing CRFS and CRSS (Tables 19 and 20).

Minor injuries were not reduced by introduction of CRSS based on the following rationale:

- Minor injuries are expected to be caused during low severity crashes by occupant flail and loading due to the deceleration of the crash event.
- During low severity crashes where non-CRSS helicopters produce minor injury, the CRSS will provide minimal benefit and will not eliminate most minor injuries, which are usually incurred through loading of the restraint system or limbs flailing into surrounding structure.

Table 19A. Calculated Blunt Trauma Benefit Value with 30% Injury Reduction

Injury NTSB		Classification		Add CRFS	Add CRSS (30%)	Net	Value (EA)	Total Net Value
Fatal	226	Blunt Trauma	202	202	141	-61	$9,400,000	-$573,400,000
Serious	146	Blunt Trauma	138	162	174	36	$2,378,200	$85,615,200
Minor	272	Blunt Trauma	272	280	329	57	$28,200	$1,607,400
None	937	NO injury	937	937	937	0	$0	$0
Total	1581		1581	1581	1581	**Blunt Trauma Total Benefit**		**-$486,177,400**

CRFS = Crash Resistant Fuel System (full compliance to 27/29.952)
CRSS = Crash Resistant Seat and Structure (full compliance to 27/29.561, 27/29.562, and 27/29.785)

Table 19B. Calculated Thermal Benefit Value with 30% Injury Reduction								
Injury NTSB		Classification		Add CRFS	Add CRSS (30%)	Net	Value (EA)	Total Net Value
Fatal	226	Thermal	24	0	0	-24	$9,400,000	-$225,600,000
Serious		Thermal	8	0	0	-8	$3,414,5501 (1)	-$27,316,400
Minor	272	Thermal	272	280	329	57	$0	$0
None	937	No Injury	937	937	937	0	$0	$0
Total	1581		1581	1581	1581	**Thermal Total Benefit**		**-$252,916,400**

CRFS = Crash Resistant Fuel System (full compliance to 27/29.952)
CRSS = Crash Resistant Seat and Structure (full compliance to 27/29.561, 27/29.562, and 27/29.785)
(1) Note: The average cost of a burn injury is based on Table 10.

Total Benefit for combined Blunt Trauma and Thermal CRFS AND CRSS: -$739,093,800

Table 20A. Calculated Blunt Trauma Benefit Value with 85% Injury Reduction								
Injury NTSB		Classification		Add CRFS	Add CRSS (85%)	Net	Value (EA)	Total Net Value
Fatal	226	Blunt Trauma	202	202	30	-172	$9,400,000	-$1,616,800,000
Serious	146	Blunt Trauma	138	162	196	58	$2,378,200	$137,935,600
Minor	272	Blunt Trauma	272	280	418	146	$28,200	$4,117,200
None	937	No Injury	937	937	937	0	$0	$0
Total	1581		1581	1581	1581	Blunt Trauma Total Benefit		**-$1,474,747,200**

CRFS = Crash Resistant Fuel System (full compliance to 27/29.952)
CRSS = Crash Resistant Seat and Structure (full compliance to 27/29.561, 27/29.562, and 27/29.785)

Table 20B. Calculated Thermal Benefit Value with 85% Injury Reduction								
Injury NTSB		Classification		Add CRFS	Add CRSS (85%)	Net	Value (EA)	Total Net Value
Fatal	226	Thermal	24	0	0	-24	$9,400,000	-$225,600,000
Serious	146	Thermal	8	0	0	-8	$3,414,550(1)	-$27,316,400
Minor	272	Thermal	272	280	418	$0	$0	$0
No Injury	937	No Injury	937	937	937	$0	$0	$0
Total	1581		1581	N/A	N/A	Thermal Total Benefit		**-$252,916,400**

CRFS = Crash Resistant Fuel System (full compliance to 27/29.952)
CRSS = Crash Resistant Seat and Structure (full compliance to 27/29.561, 27/29.562, and 27/29.785)
Note: The average cost of a burn injury is based upon Table 13.
Total Benefit for combined Blunt Trauma and Thermal CRFS AND CRSS = -$1,727,663,600

As can be deduced from Tables 19 and 20, the total reduction in injury costs realized by full compliance of newly manufactured rotorcraft with current regulations over a 10-year period ranged from $739M to $1.7 billion based on the extremes of the predicted range of effectiveness of the CRSS estimated by the FAA (30% and 85%). Table 21 shows a simplified summary of costs and benefits.

Table 21. Cost/Benefit Summary

- **There were 763 accidents in 2006-2015 in the NTSB data set for non-compliant helicopter models still in production resulting in 226 fatalities and 146 serious injuries.**
- **There were only 21 crashes of fully compliant Rotorcraft resulting in 19 fatalities and 1 serious injury.**

Benefits	**Costs**
CRFS Pt. 27/29: $253 Million	**One-time Development Costs: >$109.2 Million**
CRSS Pt. 27/29: $739 Million (30%) to $1.7 Billion (85%)	**One time Development Costs: >$143 Million**
	Recurring Costs: >$167,000 per aircraft

Note: All costs supplied by OEM's. See Table 5.

Other Benefits

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

1. Fully compliant rotorcraft that crash will probably sustain less damage than non-compliant rotorcraft in some cases allowing the rotorcraft to be repaired and returned to operation at a fraction of the total loss cost.
2. *"Many fixed-wing aircraft were parked on apron & 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.

3. *"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.

CONCLUSIONS/RECOMMENDATIONS

1. Primarily based on input from OEM's and suppliers, it is estimated that in implementing current Part 27/29 standards into all newly manufactured rotorcraft, each OEM would incur the following costs (Table 5):
   a. The total one-time cost of complying with the current regulations for rotorcraft currently in production would be greater than $252M.
   b. Recurrent costs would be in excess of $167,000 per rotorcraft produced.
   c. This estimate includes only OEM costs.
   d. Operators would also incur additional costs that are quite variable from operator to operator. In some cases, the operator costs would be considerable, if not unsustainable.
2. Most currently manufactured rotorcraft can meet the requirements of 27/29.952, however some rotorcraft will require structural changes and the increased weight and/or loss of fuel capacity that may render them obsolete.
3. A number of currently manufactured rotorcraft will require substantial structural modifications to meet the requirements of Part 27/29.561 and 27/29.562 (CRSS).
   a. Such modifications may be too impractical and costly for the OEM to continue manufacturing some rotorcraft.
   b. Discontinuation of a current model may force the involved OEM's to undergo the considerable expense and time required to design, test, and produce a replacement rotorcraft.
   c. Loss of a current model rotorcraft may have a dramatic operational and/or economic impact on current operators of the discontinued models.
4. Adding the full CRSS requirements to existing production helicopters will be difficult, if not impossible for some platforms. However, the potential benefit may be significant. A systems approach to crash safety enhancement is required to achieve maximum benefit, i.e., installing an EA seat alone may not provide a significant benefit if the surrounding structure is not also enhanced.
5. Based on the ROPWG benefits analysis, the total reduction in injury and fatality costs realized by full compliance of newly manufactured rotorcraft with current regulations over

a 10-year period ranged from $739M to $1.7B based on the range of effectiveness of the CRSS (30-85%) estimated by the FAA (Tables 19 and 20).

   a. The ROPWG considers that costs of injuries and fatalities determined by the DOT grossly underestimate the actual costs of hospitalization, continued medical care and support to accomplish activities of daily living required by many injured patients.
   b. A significant finding of this project is that implementation of a CRFS compliant with 27/29.952 should eliminate most, if not all post-crash fires in survivable accidents. However, data for only three rotorcraft models in known high severity crashes was captured in the current database filter.
   c. Implementing CRFS alone would have saved over $253M in thermal injury costs. This is based on an FAA study that showed that CRFS produces an estimated 23.5% reduction in fatalities (reduced to serious blunt trauma injury) as well as elimination of serious thermal injuries (reduced to minor trauma injuries). Thermal injuries require very long term and expensive medical care, suggesting that the "Relative Disutility Factors" may significantly understate the actual cost of such injuries. The non-economic factors of chronic pain and disfigurement also cannot be overstated. In addition, there are potential benefits to reducing ground fires, including limiting the damage to airframes and reducing collateral damage at the crash location. But even with possible underestimates of benefits, the cost-benefit analysis appears to be favorable with respect to CRFS alone. Implementation of CRFS is recommended.
   d. This analysis also does not include the huge psychological and physical burden placed on the patient, family and friends when an individual is seriously injured in a crash.

6. It is recommended that rotorcraft with partially compliant CRFS also be reviewed, to determine if partial 27/29.952 compliance is acceptable, and/or what portions of 27/29.952 compliance are most critical to preventing post-crash fire. Unfortunately, lack of crash kinematic data as well as specific injury data may make this task extremely difficult.
7. The current NTSB accident data collection is inadequate to accurately determine benefits provided by the introduction of crash safety upgrades. Detailed information on crash kinematics, occupant injuries, and injury causation for each crash will be required to make this determination. It is strongly recommended that the NTSB and/or FAA accident collection system be upgraded to allow more precise evaluation of crash safety performance.
8. The lack of impact data for the rotorcraft as well as detailed injury data for all occupants of the crash greatly inhibited the ROPWG analysis and, indeed, will undermine any cost/benefit analysis expected to determine reasonable new regulations to improve aircraft safety. The lack of data inhibits the identification of crashworthiness problems associated with specific aircraft and prevents effective rulemaking to improve safety in newly designed aircraft. If you cannot identify the problems, how can you fix them? Consequently, current regulatory changes are based more on anecdotal data and personal bias than on scientific, epidemiological data. The current system is totally inadequate for supporting meaningful rulemaking decisions!
9. Automotive safety has increased dramatically over the past decades compared to aviation safety. This is primarily because NHTSA has a vigorous surveillance program where a

statistical sample of crashed cars are studied in detail. Injuries, impact conditions and vehicle deformations are all carefully analyzed and recorded. Design and manufacturing problems are determined rapidly, although not always acted upon in a timely manner. NTSB/FAA should adopt a crash investigation/data collection process similar to that used by NHTSA, specifically the National Automotive Sampling System-Crashworthy Data System (NASS-CDS).

Membership Concurrence/Non-Concurrence with the ROPWG Report

All members of the ROPWG reported to the Chairman on concurrence/non-concurrence with the report. Eighteen (18) voting members gave full concurrence. One member representing Sikorsky, strongly non-concurred with the report. The following are the Sikorsky objections verbatim:

Sikorsky Aircraft strongly supports the goals of reducing helicopter accident rates and increasing survivability when an accident occurs. With those goals in mind, Sikorsky has reviewed the contents of the report, but does not concur. Please see the following comments:

- Sikorsky believes the report significantly understates implementation costs of the suggested changes;
- The Report has not demonstrated the basis of the purported derived safety benefits;
- The Report fails to consider and take into account the significant differences between Part 27 and Part 29 aircraft:

1. Part 27 Aircraft vs Part 29 Aircraft. Combining Part 27 and Part 29 aircraft does not promote accurate data analysis. To this point---Table 16 clearly highlights the significant difference between Part 27 and Part 29 aircraft statistics---only 6 of the 104 Fatalities are Part 29 aircraft. These may be attributable to other differences in the design (single vs dual engine, single vs dual pilot, larger aircraft, other safety related subsystems, etc.) or operational employment of the aircraft that should be considered as part of the overall fleet safety analysis and resultant conclusions/recommendations.

2. Statistical methods. The cost estimates exclude significant concerns, such as the operational impact of the reduced range/performance of the aircraft, requiring additional flights to accomplish the same mission requirements, leading to more exposure. Additionally, the reported statistics/metrics are not representative of the industry. Instead of a $/incident cost/benefit numeration, it would be more appropriate to present the data as the cost or benefit per incident per flight-hours ($/incident/Flight-hour) or the cost or benefit per incident per Seat-mile ($/incident/Seat-mile).

3. Total Cost Summary. Sikorsky Aircraft believes that the Cost Analysis summary (page 29) of One Time: $253M, Recurring cost: $167,000/ac/year and Amortized cost: $810,000/ac/year dramatically understates the actual cost of implementation notwithstanding the peripheral cost associated with replacement programs, DOC, etc. It would seem more appropriate to present a roll up of this cost. Assuming a 20 year total market of 300-400 aircraft/year, the total Cost is more accurately portrayed as $1.25-1.5B.

Sikorsky agrees that accident survivability is a key helicopter concern and we design with that in mind. Sikorsky also believes, however, that accident prevention should be the primary focus. There is no need to survive an accident that never occurs. It is understood that the ARAC tasking may not have included the cost-benefit analysis of preventing mishaps in the first place, but Sikorsky strongly believes that the cost benefit relationship of preventing rotorcraft mishaps through technologies such as EGPWS/HTAWS, health usage monitoring systems, flaw tolerant parts, reduced pilot workloads is a far more compelling cost/benefit relationship.

APPENDIX A

ROPWG COMMITTEE MEMBERS

	NAME	COMPANY/REPRESENTING	Task Group	Position
1	Dennis F. Shanahan	Injury Analysis, LLC		Chair
2	Robert J. Rendzio	Safety Research Corporation of America (SRCA)	Benefits	Voting Member
3	Harold (Hal) L. Summers	Helicopter Association International	Benefits	Voting Member
4	Jonathan Archer	General Aviation Manufacturers Association (GAMA)	Benefits	Voting Member
5	Daniel B. Schwarzbach, SPO	Airborne Law Enforcement Association's (ALEA)	Benefits	Voting Member
6	Krista Haugen	Survivors Network for Air & Surface Medical Transport	Benefits	Voting Member
7	Joan Gregoire	MD Helicopters, Inc.	Costs	Voting Member
8	John Wittmaak	Bell Helicopter Textron, Inc.	Costs	Voting Member
9	Matthew Pallatto	Sikorsky	Costs	Voting Member
10	William Taylor	Enstrom Helicopter Corporation	Costs	Voting Member
11	Pierre Prudhomme-Lacroix	Airbus Helicopters	Costs	Voting Member
12	David Shear	Robinson Helicopter Company	Costs	Voting Member
13	Chris Meinhardt	Air Methods	Costs	Voting Member
14	John Heffernan	Air Evac Lifeteam	Benefits	Voting Member
15	John Becker	Papillon Airways Inc	Costs	Voting Member
16	Christopher Hall	PHI Air Medical, LLC	Costs Chair	Voting Member
17	Bill York	Robertson Fuel Systems	Costs	Voting Member
18	Randall D. Fotinakes	Meggitt Polymers & Composites	Costs	Voting Member
19	Marv Richards	BAE Systems	Benefits Chair	Voting Member

20	Laurent Pinsard	EASA Structures Engineer	Benefits	Non-Voting Member
21	Rémi Deletain	EASA Powerplant & Fuel Engineer	Costs	Non-Voting Member
22	Martin R. Crane	FAA Structures Engineer	Advisor	Non-Voting Member