October 22, 2018

Ms. Lirio Liu
Director, Office of Rulemaking
Designated Federal Official for the Aviation Rulemaking Advisory Committee
Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591

RE: Transport Airplane Crashworthiness and Ditching Working Group Recommendation Report; Approved Direction of ARAC at September 20, 2018, Meeting

Dear Ms. Liu,

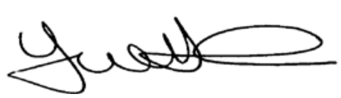
Attached is the Recommendation Report of the Transport Airplane Crashworthiness and Ditching Working Group (TACDWG), a Working Group established under the Transport Airplane and Engine (TAE) Subcommittee. This report was approved by the Aviation Rulemaking Advisory Committee (ARAC) on September 20, 2018, in accordance with the following stipulations:

1. Pages 2-3 of the report submitted to ARAC prior to the September 20, 2018, meeting were directed by ARAC to be removed.
2. The record was ordered to be kept open until October 20, 2018, to allow for the Association of Flight Attendants (AFA) to submit a dissent to the report's Executive Summary.
3. The AFA's dissent was ordered to be inserted into the report directly after the report's Executive Summary.

I have confirmed the actions directed by ARAC have been followed, therefore, on behalf of the ARAC members, please accept the attached TACDWG Recommendation Report and forward it to the relevant program offices within the Federal Aviation Administration (FAA). Please also accept the TACDWG's report as completion of its tasking, *See* 80 Fed. Reg. 31946 (June 4, 2015).

Please do not hesitate to contact me with any questions. Thank you very much.

Sincerely yours,



Yvette A. Rose
ARAC Chair

cc: David Oord, ARAC Vice Chair
Kevin Davis, Boeing, TACDWG Chair
Keith Morgan, Pratt & Whitney, TAE Chair
Chris Witkowski, Association of Flight Attendants, ARAC Member

Transport Aircraft Crashworthiness and Ditching Working Group Report to FAA

RELEASE/REVISION	RELEASE DATE
B	**20 September 2018**

CONTENT OWNER:

Transport Aircraft Crashworthiness and Ditching Working Group

All revisions to this document must be approved by the content owner before release.

Table of Contents

Executive Summary

This document provides record of data, discussions, decisions made by the Transport Aircraft Crashworthiness and Ditching Working Group (TACDWG). The TACDWG was tasked with addressing potential needs for new rules and or guidance related to ditching and crashworthiness of transport aircraft at the airframe level. The working group reached a general consensus on the content of new and revised crashworthiness and ditching rules and guidance, included in this report. On the general need for incorporating new crashworthiness requirements, the working group generally split between the manufacturers, opposed, and the Regulatory Authority and research communities, in favor. Additionally, the team addressed equipage and protocol related to emergency evacuation for crash and ditching events.

Major proposals presented in this document achieved a minimum of 2/3 majority agreement apart from the proposal to allow use of part 23 seat standards for small aircraft in lieu of the lumbar load requirement which achieved a simple majority and the equipage proposals which achieved full agreement.

There are three primary areas for proposed rules, rule revisions and/or guidance: 1) a proposed new general airframe level crashworthiness rule with guidance, 2) proposed revisions to existing ditching rules with associated guidance and 3) proposed harmonization revisions to numerous equipage and safety protocol rules for emergency events with associated guidance.

The working group obtained general consensus to adopt the proposed revisions to the ditching rules and the proposed new guidance material for ditching. Additionally the working group achieved full consensus in favor of adopting the proposed harmonization revisions for emergency equipage and protocol with associated guidance material. However, while the proposed guidance material for airframe crashworthiness achieved general consensus there were dissenting positions related to the proposed new airframe level crashworthiness rule. The dissenting positions are documented in detail in section 6.1.2 and are summarized as follows.

The Airline Flight Attendants (AFA) and the German Aerospace Center (DLR) were opposed to the use of similarity in certifying for crashworthiness. While DLR would accept use of similarity for conventional designs using conventional materials their organization felt that use of new materials e.g. composites should require full certification to the proposed new rule as opposed to use of similarity to an existing approved design. The AFA was opposed to the use of similarity for certification of any aircraft.

The major concern identified by AFA and DLR applies to derivative products and products of similar design to existing products. The team acknowledges that the FAA has an existing order and regulatory guidance to address the applicability of new regulatory requirements on derivative products. It is expected that the FAA would use existing policies to address new/changed regulatory requirements promulgated under this rulemaking activity. As with the previously applied special conditions, it is anticipated that the method of compliance negotiated between the applicant and the FAA would depend on the unique design features of the airplane under consideration. While the proposed rule contains the optional means of compliance utilizing design similarity the concept of guidance material describing the use of “change product rule” would also be acceptable.

The National Air and Space Administration (NASA) and DLR provided a dissenting position regarding vertical impact velocities to be used for certification.

The manufacturers and representative from the National Institute of Aviation Research (NIAR) provided design data and data from research that supported the velocity requirements included in the proposed rule. It is believed that sufficient data is provided in the report for the FAA to establish a proposed standard.

Finally, Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream and Textron had all voiced a general concern (also documented in section 6.1.2) regarding control of cost if the proposed rule were to be required for certification of all products.

The use of design similarity was paramount for gaining OEM acceptance of the proposed new rule. While the OEMs prefer the use of similarity in the rule it would be acceptable to include the same rational in the guidance material defining use of similarity in conjunction with change product rule for derivative aircraft or as an acceptable means of compliance of a new design that is appropriately similar to an existing design.

[This revised version of the Executive Summary to the Transport Aircraft Crashworthiness and Ditching Working Group Report to FAA *is submitted by the Association of Flight Attendants-CWA (AFA) to partially address the misuse of the term* General Consensus *as contained in this report. According to the following definitions found on p. 95 of* THE OFFICE OF RULEMAKING COMMITTEE MANUAL (ARM-001-015), Effective: February 2, 2015 *(*see https://www.faa.gov/regulations_policies/rulemaking/committees/arac/media/Comm_001_015.pdf*):*

> General consensus: Although there may be disagreement, the group has heard, recognized, acknowledged, and reconciled the concerns or objections to the general acceptance of the group. Although not every member fully agrees in context and principle, all members support the overall position and agree not to object to the proposed recommendation report.
>
> Dissent: A differing in opinions about the specific course of action. There may be times when one, some, or all members do not agree with the recommendation or cannot reach agreement on a recommendation.

Based on the above definition, it is clear that the term General Consensus *does not apply to specific recommendations; rather,* General Consensus *should only apply to the final report, and only when* all *working group members agree to go forward with publication and submittal of the document to the FAA despite having submitted dissents to specific recommendations. This was not the case with this report; AFA did not previously and does not now agree to final publication and submittal of this report to the FAA. Therefore, any and all uses of the term* General Consensus *in the body of this report as well as the preceding Executive Summary are factually incorrect and should be expunged.*

Finally, the following revised Executive Summary, in addition to addressing the significant issues related to misuse of General Consensus *in the preceding Executive Summary, includes several minor, primarily editorial corrections.]*

Executive Summary (AFA Dissent Version)

This document provides a record of the data, discussions, and decisions made by the Transport Aircraft Crashworthiness and Ditching Working Group (TACDWG). The TACDWG was tasked with addressing potential needs for new rules and or guidance related to ditching and crashworthiness of transport aircraft at the airframe level. The working group developed recommendations, with several written dissents, on the content of new and revised crashworthiness and ditching rules and guidance that are included in this report. On the general need for incorporating new crashworthiness requirements, the working group generally split between the manufacturers, opposed, and the Regulatory Authority and research communities, in favor. Additionally, the team addressed equipage and protocol related to emergency evacuation for crash and ditching events.

There are three primary areas for proposed rules, rule revisions and/or guidance: 1) a proposed new general airframe level crashworthiness rule with guidance; 2) proposed revisions to existing ditching rules with associated guidance; and 3) proposed harmonization revisions to numerous equipage and safety protocol rules for emergency events with associated guidance.

Major proposals presented in this document achieved a minimum of 2/3 majority agreement, still well short of consensus. Exceptions included a proposal to allow use of part 23 seat standards for small aircraft in lieu of the lumbar load requirement, which achieved only a simple majority, and the equipage proposals, which achieved full agreement.

The working group was able to achieve consensus in favor of adopting the proposed harmonization revisions for emergency equipage and protocol with associated guidance material. However, the working group was unable to obtain consensus to adopt the proposed revisions to the ditching rules and the proposed new guidance material for ditching; the report provides dissenting positions related to the proposed new airframe level crashworthiness rule. These dissenting positions are documented in detail in section 6.1.2 and are summarized as follows.

The German Aerospace Center (DLR) and the Association of Flight Attendants-CWA (AFA) were opposed to the use of similarity in certifying for crashworthiness. While DLR would accept use of similarity for conventional designs using conventional materials, they felt that use of new materials e.g. composites should require full certification to the proposed new rule as opposed to use of similarity to an existing approved design. The AFA was opposed to the use of similarity for certification of any aircraft.

The major concerns identified by AFA and DLR apply to derivative products and products of similar design to existing products. The majority of the team acknowledges that the FAA has an existing order and regulatory guidance to address the applicability of new regulatory requirements on derivative products, and expects that the FAA would use existing policies to address new/changed regulatory requirements promulgated under this rulemaking activity. As with the previously applied special conditions, the majority of the team anticipates that the method of compliance negotiated between the applicant and the FAA would depend on the unique design features of the airplane under consideration. While the proposed rule contains the optional means of compliance utilizing design similarity, the concept of guidance material describing the use of "change product rule" would also be acceptable to the majority of the team.

The National Air and Space Administration (NASA) and DLR provided dissenting positions regarding vertical impact velocities to be used for certification.

The manufacturers and representative from the National Institute of Aviation Research (NIAR) provided design data and data from research that supported the velocity requirements included in the proposed rule, and believe that sufficient data are provided in the report for the FAA to establish a proposed standard.

Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream and Textron all voiced a general concern (also documented in section 6.1.2) regarding control of costs if the proposed rule were to be required for certification of all products.

The use of design similarity was paramount for gaining OEM acceptance of the proposed new rule. While the OEMs prefer the use of similarity in the rule, they also believed that it would be acceptable to include the same rationale in the guidance material defining use of similarity in conjunction with a change product rule for derivative aircraft or as an acceptable means of compliance of a new design that is appropriately similar to an existing design.

Finally, as detailed in the AFA dissent statement included in Section 6.1.2, AFA did not agree to final publication and submittal to the FAA of this report. AFA was primarily concerned with misuse of the term *general consensus* in this report, stating that the report should "drop any mentions of general consensus with respect to recommendations that are rejected or challenged by one or more dissent statements [and,] where there is disagreement, should highlight differences in specific recommendations."

1 Introduction and Background

The Transport Airplane Crashworthiness and Ditching Working Group will provide advice and recommendations to the ARAC on airframe-level crashworthiness and ditching standards to incorporate into part 25 and any associated advisory material.

The current part 25 crashworthiness requirements may not adequately reflect the crash performance characteristics for the wide variation in part 25 aircraft configuration, architecture, and construction. For example, the emergency landing requirements of Title 14, Code of Federal Regulations (14 CFR) 25.561 apply equally to structure constructed from either metallic or nonmetallic materials, regardless of the design architecture and airplane size. Guidance material is mainly contained in FAA Advisory Circular (AC) 25–17A.

Assumptions in the current standards and guidance material have become increasingly outdated by advances in design and construction. While not explicitly stated in part 25, during the development of current airworthiness standards and published advisory circulars, the FAA assumed that airplane airframes would be constructed predominantly of metal, using skin-stringer-frame architecture. Therefore, some of the requirements either do not address all of the issues associated with nonmetallic materials, or have criteria that are based on experience with traditionally-configured large metallic airplanes.

In the absence of airframe level standards, the regulatory authorities have addressed the crashworthiness of non-traditional features through the use of program specific rules and guidance. The FAA has promulgated standards for occupant protection at the seat installation level, with the presumption that the airframe provides an acceptable level of crashworthiness. Thus when an applicant proposes to use unconventional fuselage structure (materials, design, or both), the FAA has written special conditions to ensure the level of crash protection is equivalent to that provided by a traditionally configured metallic airplane. These special conditions have been comparative in nature, and do not establish performance standards that are independent of traditional metallic skin stringer- frame architecture for airframe crashworthiness.

Current ditching standards and advisory material do not fully align with in-service experience of the modern transport fleet and do not adequately address the inherent variability of the ditching event. EASA has issued ditching means of compliance requirements for recent programs to define acceptable conditions for the structural planned ditching analysis.

In order to rationalize, modernize, and harmonize the regulatory environment, this report proposes new rulemaking and advisory material to incorporate updated crashworthiness and ditching standards. These recommendations address structures, seats, procedures and safety equipment per the specific working group tasking, incorporating generalizations of program specific requirements and guidance.

The proposed crashworthiness material focuses on occupant survivability for crash forces and accelerations. Other related and important crashworthiness aspects such as fuel tank integrity and flammability are outside the scope of this report.

2 TACDWG Tasking

TACDWG specific tasking as defined in the public register. TACDWG conclusions and issues with the findings are contained in Section 5. Lastly, Section 7 contains the TACDWG recommendations and documents any dissenting opinions.

The Transport Airplane Crashworthiness and Ditching Working Group was tasked to:

1. Specifically advise and make written recommendations on what airframe-level crashworthiness and ditching standards to incorporate into 14 CFR part 25 and any associated advisory material.

2. Evaluate §§ 25.561, 25.562, 25.563, 25.785, 25.787, 25.789, 25.801, 25.807, 25.1411, 25.1415, and associated regulatory guidance material (*e.g.,* ACs and policy memorandums) to determine what aspects need to be revised to maintain the current level of safety. Evaluate Special Conditions Nos. 25–321–SC, 25–362–SC, 25–528–SC, 25–537–SC, as a basis for future requirements. The Transport Airplane Crashworthiness and Ditching Working Group will specifically review the following factors in making its recommendations:

    a. Fuselage size effects as discussed in FAA report DOT/FAA/CT–TN90/23;

    b. Safety benefit considerations as identified in CAA Paper 96011 (and any subsequent revisions);

    c. Other non-traditional airplane level configurations or structural configurations (*e.g.,* non-skin, stringer, frame construction).

3. Make recommendations, using the information in FAA reports DOT/FAA/ TC–14/8 (draft), DOT/FAA/AR–95/54, DOT/FAA/CT–92/04, DOT/FAA/CT– 84/3, FAA policy memorandum PS– ANM100–1982–00124, and any other pertinent information that may be available on:

    a. Assumptions used in establishing the airplane configuration for ditching, both planned and unplanned;
    b. Validation of assumptions used for establishing airplane flight performance for planned and unplanned ditching scenarios;
    c. Procedures to be used to execute a successful ditching;
    d. Minimum equipment needed to address the likely ditching scenarios.

4. Consider the performance of existing-conventional metallic airframe structure in crash conditions (with consideration to size effects) when developing recommendations for airframe-level crashworthiness and ditching standards, such that conventionally configured airplanes fabricated with typical metallic materials and design details can be shown to meet the proposed regulations without extensive investigation or documentation.

5. Based on the Transport Airplane Crashworthiness and Ditching Working Group recommendations, perform the following:

a. Estimate what regulated parties will do differently as a result of the proposed regulation and how much it would cost;
b. Estimate the improvement (if any) in survivability of future accidents from this proposed regulation (cite evidence in the historical record as support if possible);
c. Estimate any other benefits (*e.g.,* reduced administrative burden) or costs that would result from implementation of the recommendations.

6. Develop a report containing recommendations on whether to incorporate airframe-level crashworthiness and ditching standards into 14 CFR part 25, the recommended requirements, and any associated advisory material.

7. Develop a report containing recommendations on the findings and results of the tasks explained above.

a. The 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 reason for the disagreement.

8. Consider EASA requirements, accepted means of compliance (AMC) and guidance material (GM) for harmonization to the extent possible.

9. The Transport Airplane Crashworthiness and Ditching Working Group may be reinstated to assist the ARAC by responding to the FAA's questions or concerns after the recommendation report has been submitted.

2.1 Working Group Members

The working group consisted of voting members, subject matter experts and regulatory members. The following individuals supported the tasking presented in this document:

Voting Members

1.	Akif Bolukbasi	Boeing Military Aircraft
2.	Jack Caughron	Gulfstream Aerospace Corporation
3.	Kevin R. Davis	Boeing Commercial Aircraft – Chairperson
4.	John van Doeselaar	Airbus
5.	Clóvis Augusto Eça Ferreira	Embraer
6.	Dan Hoverson	Textron Aviation
7.	Justin Littell	NASA Langley Research Center
8.	Vincent Jacques	Dassault Aviation
9.	Candace K. Kolander	Association of Flight Attendants (AFA)
10.	Milenko Milekic	Bombardier
11.	Heidi R. Moore	Naval Air Systems Command (NAVAIR)
12.	Gerardo Olivares Ph.D.	National Institute for Aviation Research (NIAR)
13.	Toru Sakagawa	Mitsubishi Aircraft Corporation

14. Matthias Waimer — German Aerospace Center (DLR)
15. Olena Zagoskina — Cascade Aerospace

Foreign Regulatory Members:

1. João Maria Antunes Leite — Agência Nacional de Aviação Civil (ANAC)
2. Wim Doeland — European Aviation Safety Agency (EASA)
3. Natasa Mudrinic — Transport Canada (TCCA)
4. Zhang Zhuguo — Shanghai Aircraft Airworthiness Certification Center (SAACC) of Civil Aviation Administration of China (CAAC)

Federal Aviation Administration Members:

5. Jeff Gardlin — FAA, AIR-115
6. Larry Ilcewicz — FAA, AIR-100
7. Joseph Pellettiere — FAA, AIR-100
8. Ian Won — FAA, ANM-115

2.2 Working Group Meetings

The working group held regular tele-coms and Face to Face meetings in support of this tasking activity. Additional meetings were held and managed by the four sub-teams described in the next section.

The full team meeting log is provided for reference below.

Table 2-1. Team Meetings

Date	All Team Tele-cons	Face to Face	Location	Host
12/8-9/2015		X	Everett, WA	Boeing
1/26/16	X			
3/8/2016	X			
4/5-7/2016		X	Melbourne, FL	Embraer
5/25/2016	X			
7/28/2016	X			
9/15/2016	X			
10/4-6/16		X	Wichita, KS	NIAR
1/25/2017	X			
3/8-10/2017		X	Mesa, AZ	Boeing
3/13/2017	X			
5/4/2017	X			
6/8/2017	X			

7/27/2017	**X**			
8/17/2017	**X**			
9/12-14/2017		**X**	Abbotsford, BC	Cascade Aerospace
10/12/2017	**X**			
10/26/2017	**X**			
11/21/2017	**X**			

2.3 Determination of Consensus[1]

The working group was comprised of 15 voting members. Nine members represented airframe manufacturers, three represented research organizations, one represented a U.S. military research organization, one represented an airframe modification organization and finally one represented a labor organization.

This document uses the terms full consensus and general consensus. General consensus implies greater than or equal to two thirds of the members who chose to vote were in agreement. Full consensus indicates that all members choosing to vote were in agreement with the decision made. Some members abstained from voting for issues that had no impact on their organization or no input to the issue.

[1] ARAC Manual, Ch. 4 Consensus (p. 95):

"General consensus: Although there may be disagreement, the group has heard, recognized, acknowledged, and reconciled the concerns or objections to the general acceptance of the group. Although not every member fully agrees in context and principle, all members support the overall position and agree not to object to the proposed recommendation report.

"Dissent: A differing in opinions about the specific course of action. There may be times when one, some, or all members do not agree with the recommendation or cannot reach agreement on a recommendation."

3 Working Group Team Structure and Goals

The tasking as specified by the FAA requested the TACDWG to address potential need for airframe level rules and guidance for crashworthiness and ditching. The bulk of work is in tasks 1 through 4. With an emphasis on maintaining the current level of safety for crash and ditching. Specifically, task 2 and task 4 focus on maintaining the current level of safety while recognizing a need to achieve this in the most cost-effective way practical.

The cost effectiveness of any recommendations recognizes the generally acceptable crashworthiness and ditching performance of conventionally configured airplanes with typical metallic construction and design details. Certification activities for future products should be able to rely and build upon similar design features without extensive investigation and documentation.

The working group established 4 teams to work the eight primary tasks.

3.1 Sub-Team 1 – In Service Data Evaluation

This team was established to collect data, reports, documents, and in-service data to aid the development of crashworthiness and ditching rules and guidance. A database was generated to facilitate the review and parsing of data.

3.2 Sub-Team 2 – Crashworthiness

Team 2 was established to address crashworthiness and review the potential need for an airframe level rule and associated guidance.

3.3 Sub-Team 3 – Ditching

Team 3 was established to address ditching and to review existing rules and guidance and determine if any new rules or changes to existing rules or guidance was to be recommended.

3.4 Sub-Team 4 – Equipage and Protocol

Team 4 was established to address cabin crew needs for equipment in an emergency and protocol for evacuating passengers for both ditching and in a survivable crash event.

4 Rule and Guidance Recommendations

4.1 Sub-Team 1 – In Service Data Evaluation

4.1.1 Data and Events Considered

Collection of data encompassed applicable testing performed and in-service events from 1983 to present day and includes 138 events or tests. There is an additional set of events identified as water related over that same time frame that have also been documented via the database.

This time frame was chosen because most aircraft would reflect the more current state of the CFRs such as the later 14 CFR 25.561(b) and 25.562 which could have a significant effect on survivability and injuries.

It should be noted that the database was frozen by the end of 2016, for practical reasons. A diminutive number of inconsistencies, e.g. duplicate records, dummy records, and typographical mistakes, still exist in the database. These quality escapes do not preclude the use of the information "as is" and do not invalidate the overall findings.

4.1.1.1 In Service Events

In service event information was collected and stored in a database to support teams 2 and 3 in assessing crash and ditching history. The events considered start in 1980 and reflect in service through late, 2016. It was decided to not go further back in history as there were several significant changes to rules in the 1980's improving crash capability of the aircraft.

Some of this data was used to establish what a survivable crash is. There was no consistent definition available for the team to use. It was decided that NASA had a definition for "survivable crash" that matched the in-service observations and which has been accepted by a number of agencies worldwide.

Survivable Accident: An accident in which the forces transmitted to the occupant through the seat and restraint system do not exceed the limits of human tolerance to abrupt accelerations and in which the structure in the occupant's immediate environment remains substantially intact to the extent that a livable volume is provided for the occupants throughout the crash sequence.

Team 1 used a definition of survivability from DOT/FAA/TC-13/46 when reviewing in-service crash data. The FAA document defines survivable as:

- Non-survivable Accident: "A Nonsurvivable Accident is one in which all occupants sustain fatal injuries."
- Survivable Accident: "An Accident that is not Non-survivable, but involves at least one Fatal Injury or the aircraft was destroyed."

The team elected to use the NASA definition as it is better aligned with the key crashworthiness characteristics.

Similarly for ditching, the FAA and NTSB records were searched for ditching events of interest starting in 1980 up to present time, 2017.

See appendix A for a listing of the crash and ditching databases developed as part of this ARAC activity.

4.1.1.2 Applicable Tests

Large scale component and full scale aircraft crash testing has been accomplished by a number of research facilities and government agencies. A list of references and reports used in investigating the potential need for new rules or changes to existing rules can be found in appendix A.

4.2 Sub-Team 2 – Crashworthiness

This section summarizes the studies and investigations made during the ARAC exercise.

4.2.1 Detail Investigations

This section will collect the information created and evaluated as part of the various studies conducted in support of the proposed rule and guidance.

4.2.1.1 Configuration Assessments

Team 2 also evaluated the general configuration differences found in the fleet today as well as considering potential unique configurations possible for the future, specifically; fuselage size effects, non-traditional skin, stringer and frame configurations (e.g. honeycomb), blended wing body etc.

Items considered relative to airframe configuration:

1) Multiple decks
2) Cargo below the passenger floor - crush space reduction
3) Engine location - wing/fuselage/tail mount,
4) Unique structural architectures
5) Aircraft size and weight
6) New material systems
7) Wing configuration - high, low, blended.

A copy of the data collected is included in appendix B as excel files.

Even though all of the OEMs have long range studies looking at non-traditional designs for the future they all agree that conventional tube wing designs are what is to be expected for the foreseeable future. Unique designs such as the blended wing body are very far off in the future and likely will require consideration of a special condition even if an airframe level crashworthiness rule existed.

4.2.1.2 Determination of Vertical Impact Velocity Requirements

The grouping of Part 25 aircraft for crash sink rate requirements specified in airframe crashworthiness rule 25.XXX were based primarily on aircraft maximum take-off weight.

It was recognized that there is direct correlation between aircraft gross weight and the available crushable airframe structure that provides energy absorption during the crash.

The required sink speed capability for three groups representing the small, narrow-body, and wide-body Part 25 aircraft was established by using the following information:

(a) Aircraft accident study conducted by the ARAC working group

(b) FAA accident study conducted by Lance Labun

(c) FAA document DOT/FAA/CT-TN90/23 cited in the ARAC tasking for the working group.

(d) OEM's self-assessment of the vertical impact capability of their products

The vertical impact velocities for the accident data evaluated by the ARAC working group and the FAA are shown in Figure 1 thru Figure 3. The data is shown as a plot of the vertical impact velocity percentile distribution. The airframe level vertical impact velocity was identified by subtracting the 12 ft/sec energy absorption contribution of the landing gears from the overall aircraft vertical impact velocity obtained from the accident databases.

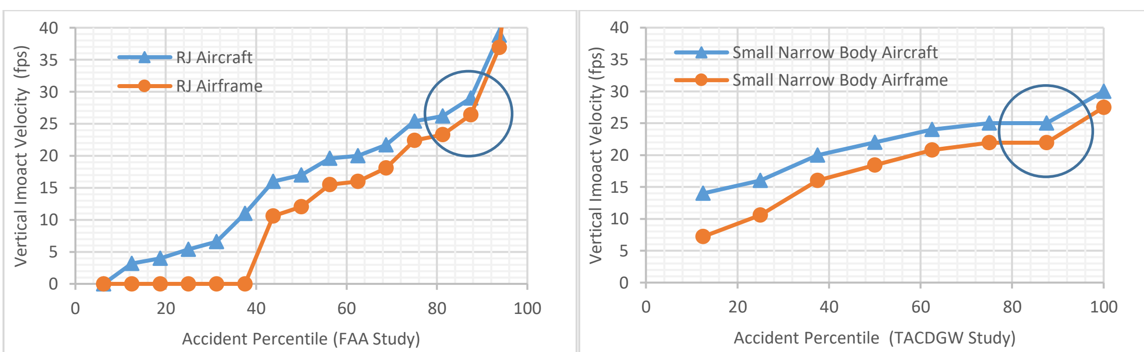


Figure 1. Small Part 25 Aircraft Vertical Impact Velocity Percentile Distributions

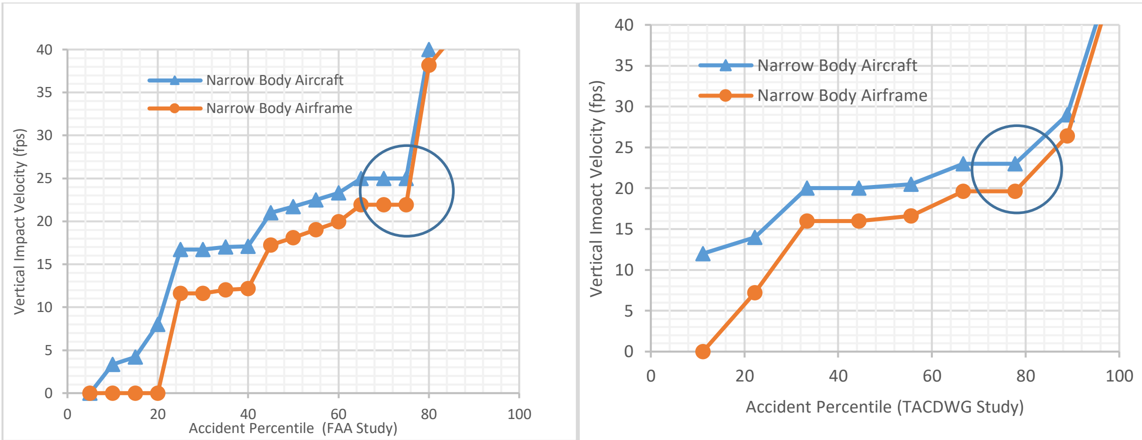


Figure 2. Narrow Body Part 25 Aircraft Vertical Impact Velocity Percentile Distributions

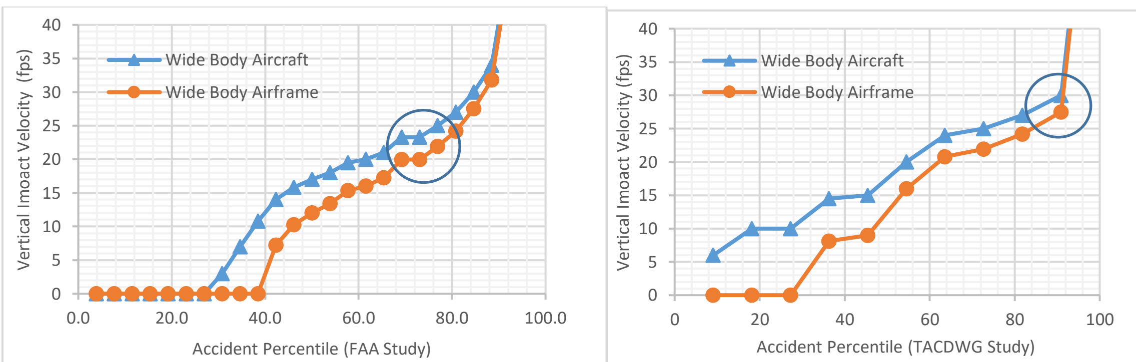


Figure 3. Wide Body Part 25 Aircraft Vertical Impact Velocity Percentile Distributions

The focus was to identify the optimum airframe vertical impact velocity levels for the three Part 25 airplane groupings that cover a majority of the accidents without weight impact on the airframe design. The accidents with higher impact velocities are typically fewer in number and result in higher weight impact on the airframe design. The transition point in vertical impact velocity is typically associated with a rapid change in the slope of the cumulative vertical impact velocity curve beyond the optimum vertical impact velocity. This transition point is within the region highlighted with a circle on the vertical velocity distribution charts (Figures 1 – 4). Designing the aircraft for higher vertical impact velocities beyond the transition point would result in significant increase in aircraft weight without any significant increase in the number of survivable accidents.

The vertical impact velocity data from FAA document DOT/FAA/CT-TN90/23 cited in the ARAC tasking for the working group is shown in Figure 4. The plot of vertical impact velocity versus crush depth was derived based on accident data as well as drop tests of the fuselage sections of transport aircraft. The airframe level vertical impact velocity was again identified by subtracting the 12 ft/sec energy absorption contribution of the landing gears from the overall aircraft vertical impact velocity.

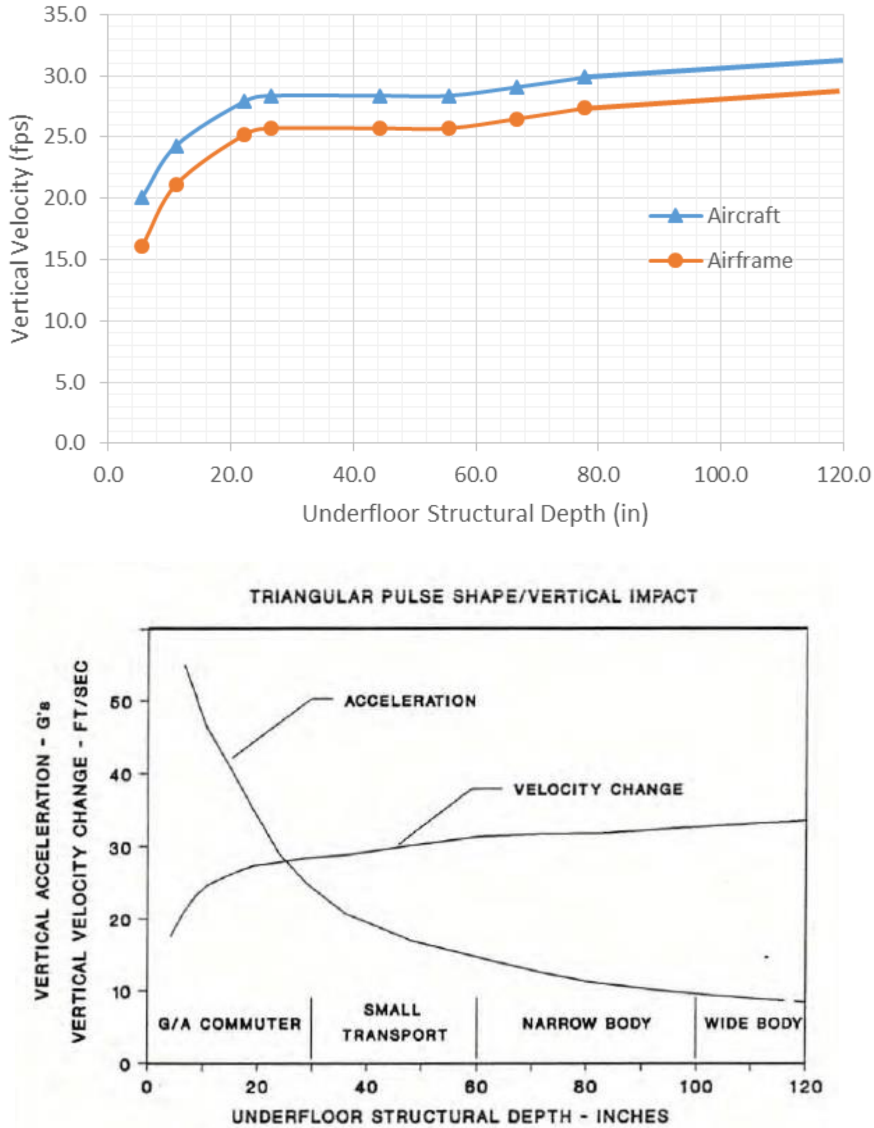


Figure 4. Part 25 Aircraft Vertical Impact Velocity based on Subfloor Depth

Review of the ARAC working group and FAA accident studies as well as the data from DOT/FAA/CT-TN90/23 as modified for the 12 ft./sec landing gear capability indicates that the optimum vertical impact velocity requirements range from 22 ft./sec for the small Part 25 aircraft to about 26 ft./sec for wide body Part 25 aircraft.

OEM's self-assessment of the vertical impact capability of their products is shown in Table 1. It should be noted that for small Part 25 aircraft, the survivable vertical impact capability is limited by the seats and the lumbar load injury criteria to about 18 ft. /sec. due to the limited subfloor crush space. The small Part 25 airframe structures do have vertical impact capability of about 22 ft. /sec on average.

Table 4-1. OEM's self-assessment of the vertical impact capability of their products

Aircraft OEM	Aircraft Size	Vertical Impact Capability (fps)
Airbus	Narrow Body	22 - 23
Airbus	Wide Body	25 - 28
Boeing	Narrow Body	22 - 24
Boeing	Wide Body	25 - 26
Bombardier	Small Transport	18 - 30
Dassault	Small Transport	18 - 23
Embraer	Small Transport	18 - 24
Gulfstream	Small Transport	28
Mitsubishi	Small Transport	19 - 23
Textron	Small Transport	21

Notes

1) Textron's capability number of 21 fps is based on geometry and Figure 4 data. There is no company data to show 21 fps is survivable for a passenger. Company tests at 30 fps show the fuselage meets the criteria for survivable volume and egress path but lumbar loads are significantly above the 1500 lbs. limit for survivability.
2) Bombardier's estimation for Vertical Impact capability of the fleet is based on A/C geometry and Figure 4 data, except for 18 ft/sec which is associated to smaller business aircraft (ex. Learjet). The 18 ft/sec was based on fuselage drop simulation analysis for metallic (Lear 60) and composite (Lear 85) where the lumbar loads has exceeded 1500 lbs limit for survivability. Recent NIAR testing of Hawker 4000 fuselage (similar to Lear 85) has confirmed 18 ft/sec as limitation for lumber load criteria.

The recommended vertical impact velocity capabilities for the Part 25.XXX Airframe Crashworthiness Rule shown in Figure 5 was then based on the accident studies, DOT/FAA/CT-TN90/23, and the OEM's self-assessment of the vertical impact capability of their products.

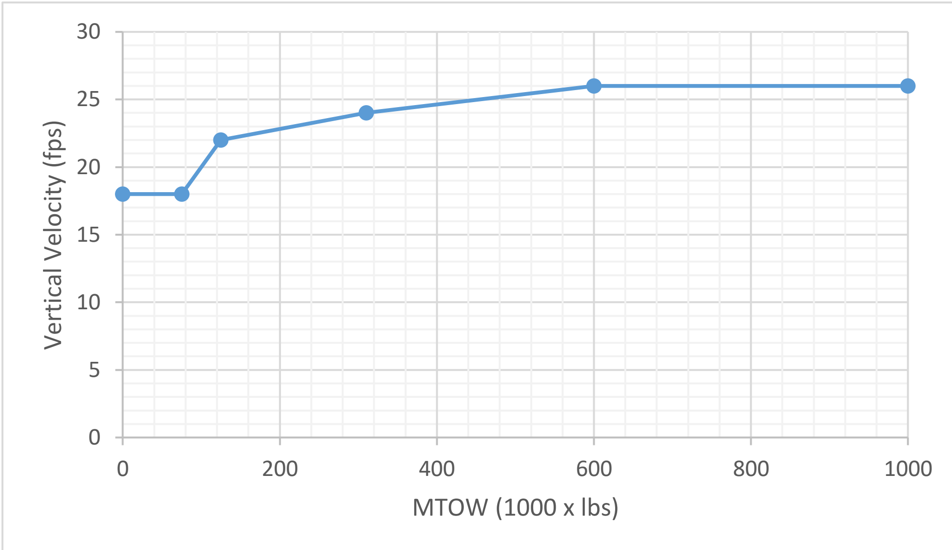


Figure 5. Recommended Vertical Impact Velocity Capabilities for Part 25 Aircraft

Specifically, for small Part 25 aircraft less than 75,000 lbs. the vertical impact velocity of 18 ft. /sec was selected to reflect the constraints associated with the Part 25 crashworthy seats and the lumbar load criteria when the aircraft has very limited subfloor structural crush space available. As shown in both experimental and analysis models validated by tests the lumbar load criteria may still be unachievable at 18fps in business jets with crush depths less than a foot. [Reference: NIAR Presentation I: NIAR ARAC March 2017 - Vertical Impact Velocity Study Business Jet (Page 268-300) ; NIAR ARAC September 2017 Presentation: Composite Fuselage Drop Test] That is why an enhanced seat requirement was developed (See appendix B.1 section 5.1 "Maintenance of Acceptable Loads experienced by the Occupants") in lieu of the lumbar load requirement when there are less than 19 passengers. The vertical impact velocity then increases to 22 ft. /sec for up to 125,000 lb. small part 25 aircraft as greater subfloor crush space becomes available with increasing aircraft gross weight. The vertical velocity further increases from 22 ft./sec to 24 ft./sec as the aircraft gross weight increases to 310,000 lb. reflecting the typical narrow- body Part 25 aircraft. Finally, the vertical impact velocity increases from 24 ft. /sec to 26 ft. /sec as the aircraft gross weight increases to 600,000 lbs. reflecting typical wide-body Part 25 aircraft. The vertical impact velocity remains 26 ft. /sec for Part 25 aircraft with gross weight higher than 600,000 lb.

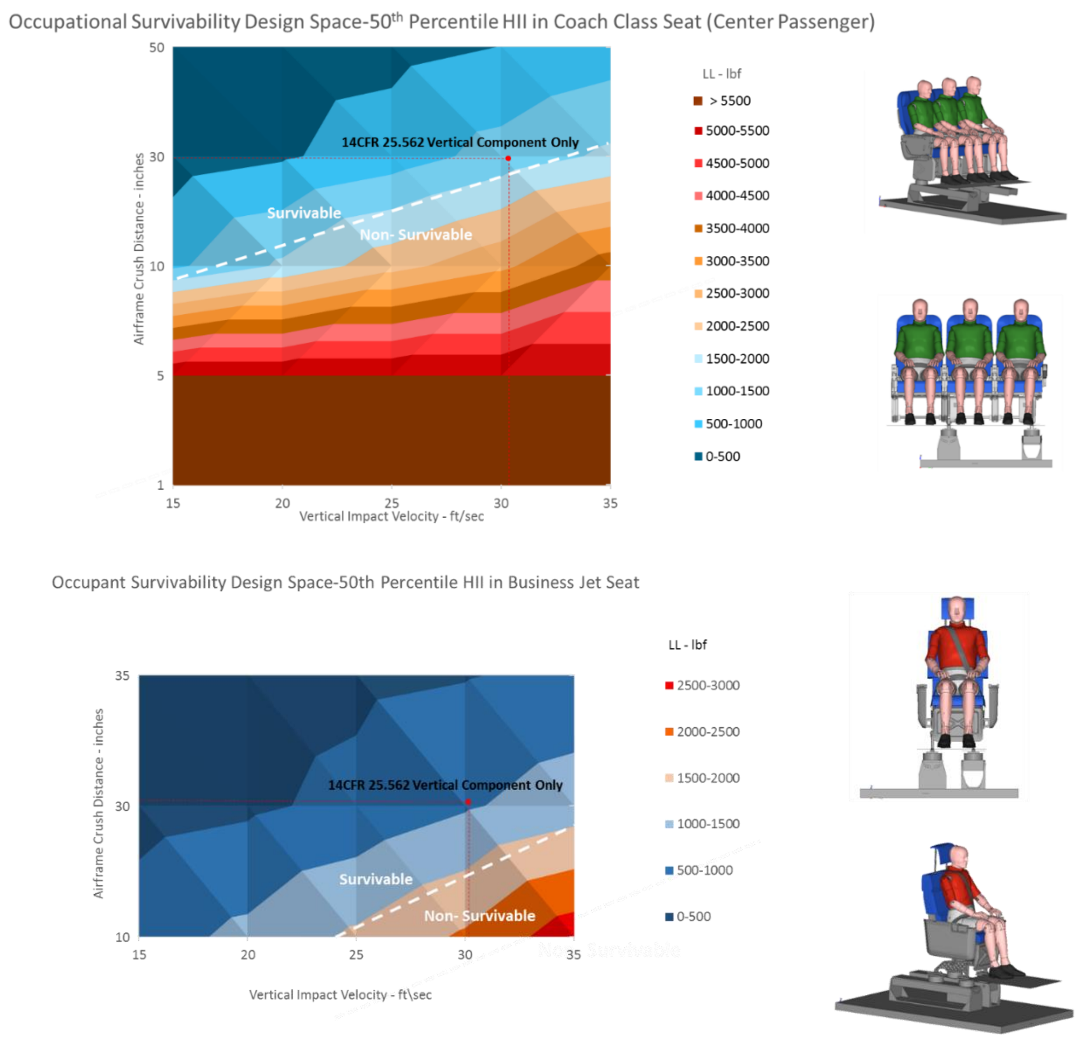


Figure 6. Passenger Survivability Curves for Typical Part 25 Coach and Business Jet Aircraft Seats Based on Vertical Impact Velocity and Airframe Subfloor Effective Crush Distance

Limit of Reasonable Survivability (LRS)

During earlier discussions about the structural capability of conventional large transport aircraft with respect to vertical impact velocity, it was deemed that higher values, up to 30 ft/s, better reflected the vertical impact velocity capability of traditional metallic aircraft.

Worldwide fleet survivable accidents review and recent certification projects (i.e. including fuselage drop tests using test specimens that are well representative of certified designs) have shown that this value is hardly achievable by a/c structure and moreover has never been recorded for survivable crash event.

Therefore, as a reference for new aircraft under certification, the values of Limit of Reasonable Survivability (LRS) were define based on real capability of similar size a/c of current conventional fleet.

The values of LRS were defined based on maximum capability of given a/c configuration with respect to all 4 crashworthiness criteria (i.e. those criteria that form part of the Special Conditions for B787 & A350).

As agreed with the certification Authorities, the impact at the vertical descent rate representing the Limit of Reasonable Survivability (LRS), related to structural behaviour during survivable crash event, should be considered.

Evaluation of a range of Vz, indicating the LRS was considered as baseline for comparison of new a/c crash performance.

The results have shown that the range of 18-26 ft/s represents current maximum LRS for Large Transport fleet. In that respect, 30ft/s is not achievable for the reasonably certifiable a/c configurations.

These values were confirmed by analysis supported by test evidences.

The summary table, gathered from the industry by ARAC team2 and presented to the group, reflects that fact.

These values also match well with OEM’s self-assessment of the vertical impact capability of their products provided in the Table 4-2.

The Limit of Reasonable Survivability defined for similar transport aircraft shall be accepted as an “acceptable means of compliance” by the Administrator as a basis for compliance demonstration with new proposed airframe crashworthiness rule.

<u>Dynamic Response Index (DRI)</u>

One of the key attributes of fuselage structure crashworthiness performance is the “Maintenance of Acceptable Loads experienced by the Occupants”. The primary purpose of this attribute is to make sure the occupant can exit the aircraft after the crash event.

The focus is on bodily injury and the applicant must establish acceptable load levels where the passenger would have minimum injuries and still be able to exit the aircraft. The injury threshold for the lumbar loads may be used as specified in 14 CFR 25.562(c)(2).

Alternatively, the applicant may utilize other occupant injury criteria as acceptable means of compliance, including the Dynamic Response Index for their design, in particular when showing similarity to previously certified aircraft.

The Dynamic Response Index (DRI) is the Authorities agreed injury risk criterion, used in the past certification exercises, as a suitable measure of “acceptable accelerations and loads experienced by the occupant”. It covers the accelerations and body loads experienced by passenger at each seat location.

DRI value is calculated using acceleration levels as experienced by passengers, measured at passenger seat attachment to floor level.

Full details of the DRI are formally documented in a US Army Systems Command document USAAVSCOM TR 89-D-22B “Aircraft Crash Survival Design Guide – Volume II – Aircraft Design Crash Impact Conditions and Human Tolerance”.

As a summary from above document, the key information about DRI is further described.

The most relevant risk for the passenger in case of vertical acceleration is the spinal injury and a correlation has been established between the DRI level and the probability of spinal injury, as follows:

- DRI of 16 represents a 1% probability of passenger spinal injury
- DRI of 18 represents a 5% probability of passenger spinal injury

Dynamic Response Index (DRI) equal to or less than 16 was considered as the acceptable limit in previously certificated products.

The aforementioned DRI values do not have direct correspondence to “g” level, as latter is an instantaneous metric parameter. It describes the maximum acceleration level along the event, but does not include any information about the duration of the acceleration.

DRI is obtained from a model of the upper human body. The DRI output is an integrated metric parameter, accounting for the acceleration levels (g) and their duration.

It gives a better indication of the consequences of the event on the passenger (i.e. risk of injuries is dependent on [acceleration level] x [duration]).

The accelerations transmitted to the passenger (from CS 25.562(b)) can be extracted based on: [g] – [seat damping]

This gives a peak level but with no reference to the time duration. In the realistic Fuselage Crash Survivability calculation, the acceleration transmitted to the seats and therefore to the passengers is much complex. The complexity is linked to real structure configuration and impact phenomena (i.e. the impact on the ground, fuselage crushing, cargo and passenger crossbeam bending, etc.). All these phenomena contribute to the acceleration transmitted to the passenger with different periods and phases.

Therefore, an integrated indicator such as the DRI, based on both acceleration peaks and also the duration of those acceleration peaks, better represents the loads experienced by the passengers.

DRI is a well-established parameter and is regarded as an “acceptable means of compliance” to the thresholds specified in 25.562 and as alternative measure, for showing compliance with Airframe crashworthiness rule.

4.2.1.3 Assessment of Passenger Compartment

Analysis and testing performed in support of showing compliance to previous special conditions for crashworthiness or for this proposed new airframe crashworthiness rule are anticipated to represent the typical passenger cabin. It is not necessary for the applicant to evaluate every seat in the aircraft including flight crew and cabin crew to determine that a new or revised product behaves globally in an acceptable fashion or similar to previous designs. The intent of this proposed rule as well as previous special conditions has been to demonstrate that the general design of the aircraft performs similar to the existing modern metallic fleet in terms of airframe crashworthiness and passenger safety. This had been accomplished by evaluating, by analysis or analysis supported by test, the performance of the typical passenger cabin area. This is acceptable for a number of reasons:

1) The typical passenger cabin area tends to be of lightest general construction providing a minimum of general energy absorption.
2) Typical passenger cabin is intended to represent the majority of the passenger seating.
3) The economy cabin of part 25 aircraft usually have the least energy absorbent seat structure.
4) The flight and cabin crew utilize restraint systems superior to the typical passenger thereby being equivalently or better protected.
5) If the typical passenger section performs acceptably the other sections may be assumed to respond in a similar way or better.

There was also significant discussion regarding retention of items of mass in the passenger compartment. It was decided 14 CFR 25.561(b) is sufficient for current and new designs. This is based on service experience for aircraft certified to the current version of 14 CFR 25.561(b) and by the results for analysis and testing performed by applicants complying with the recent airframe crashworthiness special conditions. Investigations of in service crash events has confirmed that failure of overhead bin structure is not adding injuries or deaths in accidents. Reference 14 cites quantitative analysis to suggest that improvements to an Equipment Retention Survivability Factor are "unlikely to yield significant benefits in terms of fatality or injury reduction," which leads one to conclude there may be no measurable benefit to changing the rules for overhead bin structure. The team reached general consensus on this point with AFA, EASA, DLR and NASA taking a dissenting position.

4.2.1.4 Aircraft Applicability

Previous special conditions for airframe crashworthiness have been applied to part 25 passenger aircraft. The majority of this working group discussion focused on passenger aircraft. There are, however, other part 25 aircraft where consideration for airframe crashworthiness may be applied. For example;

1) Cargo or freighter aircraft.
2) Modified special purpose aircraft.
    a. Water lifters (firefighting)
    b. Emergency medical transport, etc.

3) “Combi” aircraft that carry passengers and cargo on the main deck.
4) Commercial derivatives of military aircraft.

This group of aircraft is very small relative to the general population of part 25 passenger transports. These aircraft also have a greater likelihood of containing atypical or unusual design features due to their mission requirements. The proposed rule and guidance may be extended to these aircraft where deemed appropriate by the FAA although it was not deemed necessary by the task group due to the small quantity of such aircraft and the limited exposure due to the limited number of passengers involved.

4.2.1.5 Use of Similarity

Current worldwide fleet records show that the compliance with current set of crashworthiness requirements (561, 562, 721, 963, etc.) and their interaction, results in demonstrated acceptable level of safety. There were major updates to a number of these rules in the early to mid-1980s. Several recent studies have been conducted on crash events most notably studies performed by the Ray Cherry Group on behalf of the FAA and CAA-UK, reference 14. One of the primary conclusions is that accidents since adoption of these current rules have been very successful at protecting passengers and reducing fatalities.

For recent certification projects the applicants demonstrated via a combination of test and analysis that a level of crash survivability, for aircraft constructed using composite materials are comparable to that achieved on previously certificated large transport aircraft of similar size and structural configuration. The effort expended to comply with the special conditions was significant. These efforts resulted in minor and in some cases no changes to the design of the new type certificated products yet still demonstrated comparable performance to the existing fleet.

The proposed crashworthiness rule (25.5XX) targets to maintain the current level of safety as demonstrated by the worldwide fleet, which has been established by the state-of-the-art crashworthiness designs of already certificated conventional aircraft.

The applicants’ extensive knowledge through service experience and substantial amount of compliance data cumulated within certification projects represents a significant advantage that applicants should benefit from for future derivative model certification of similar design.

In-service experience and testing has shown that conventionally configured large transport aeroplane configurations with the energy absorption capability of typical structural frame/stringer/skin design, manufactured of light metal alloy or in some cases composites, demonstrated inherent structural robustness with regard to crash survivability.

The working group has proposed, for aircraft based on such conventional fuselage/cabin design, that the applicant may show compliance with CS 25.5xxx by design review.

The design review summary may detail the key design features, crashworthiness relevant, in comparison with already certificated transport category aircraft designs. It may include comparison/equivalence of materials, design/construction principals, assembly details, load paths and energy absorption features if any, etc.

Absence of design features that would require additional investigation with respect to energy absorption capability or as potential threats to occupants in a crash may be a starting point of a similarity assessment.

This assessment summary, together with engineering statements, may constitute the means of compliance "statement", justifying a similar design, with respect to crashworthiness capability of fuselage/cabin design. Ultimately the end result should conclude that if the fuselage is sufficiently similar to the previous acceptable model then it can be assumed the design provides similarly acceptable crashworthiness protection to the passengers. It is paramount that the level of effort for the applicant be commensurate with the level of safety improvement.

4.2.2 Proposed Rule Recommendation

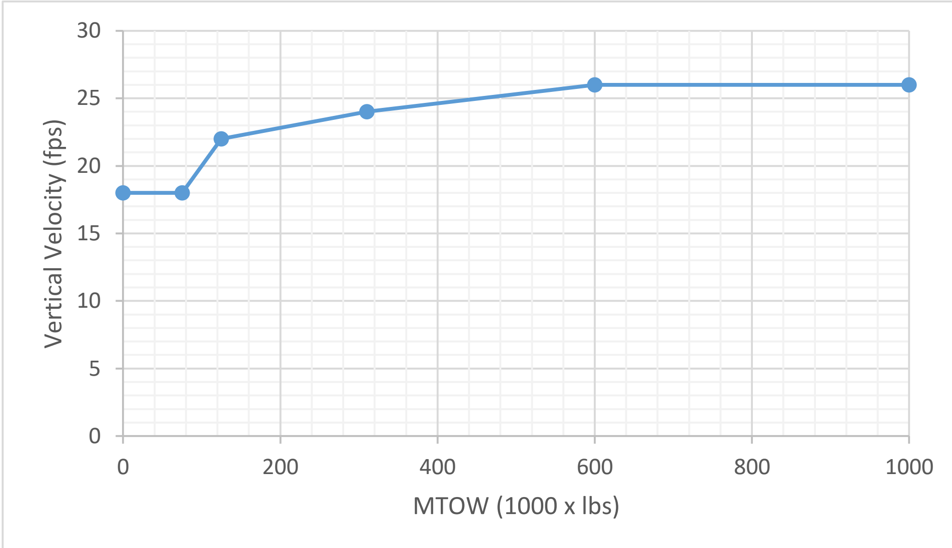
There is no airframe level crashworthiness rule in the Code of Federal Regulations currently. The tasking was established, in part, to determine if a new rule for airframe crashworthiness was needed. Initially there was much disagreement between the voting members. The airframe manufacturers did not believe a rule was necessary whereas most of the government and research organizations believed a new airframe level rule was appropriate. Ultimately a general consensus was reached as long as an option for using similarity to previous designs considered to be acceptable could be used to establish equivalence to the proposed new rule. The key to this being viable for applicants is keeping the level of effort to demonstrate compliance commensurate to the level of safety improvement expected.

Data shows that aircraft certified to more recent rules established in the mid 1980's and later (e.g. 14 CFR 25.562, 16 g seats etc.) are very safe with a relative few fatalities in crashes considered survivable. It would be difficult to satisfy a cost benefit analysis if all applicants had to perform a substantiation similar to the B787 and A350 products for every derivative and new design seeking certification.

The rule established by Team 2 that obtained general consensus is as follows:

25.XXX Airframe Crashworthiness Rule

(a) The fuselage structure, although it may be damaged in emergency landing conditions on land, must be designed as prescribed in this paragraph to provide for adequate occupant survivability during survivable crash events. In order to demonstrate adequate occupant survivability, compliance must be shown with the four criteria specified in subparagraph (b) under the following vertical impact conditions:



(b) Under the impact condition specified in subparagraph (a), compliance must be shown with the following four criteria addressing occupant survivability:

(i) Retention of Items of Mass: All occupants must be protected during the crash impact event from the release of seats, overhead bins, and other items of mass due to the impact loads and resultant structural deformations of the supporting airframe and floor structures.

(ii) Maintenance of Acceptable Loads Experienced by the Occupants: During the crash event the occupant injury criteria thresholds must not be exceeded for the load levels experienced by the occupants.

(iii) Maintenance of a Survivable Volume: All areas of the fuselage occupied by passengers for takeoff and landing must provide a survivable volume during the crash impact. Fuselage structural deformation will not result in infringement of the occupant's normal living space so that passenger survivability will not be significantly affected.

(iv) Maintenance of the Occupant Egress Paths: After the crash event, the fuselage structure must provide suitable egress paths to evacuate the occupants.

(c) As an alternative to subparagraphs (a) and (b), adequate occupant survivability can be demonstrated by showing an equivalent level of occupant survivability to those provided by previously certified transport category aircraft of similar size, design architecture, and material systems under survivable vertical crash events, provided that:

(i) The airplane does not have any design features or characteristics that have shown to be unsatisfactory with regard to occupant survivability;

(ii) The previously certified transport category aircraft does not exhibit an unsatisfactory service experience with regard to occupant survivability.

4.2.3 Proposed Guidance Recommendation

See appendix B for complete proposed guidance.

4.2.4 Considerations for Harmonization with NAA

This working group engaged regulatory agencies from Brazil, Canada, China, Europe, and Japan. While the different agencies provided varying levels of participation, all were engaged and it is hoped that all will try to harmonize their rules and guidance consistent with what this body recommends.

4.2.5 Cost / Benefit Assessment

Each member is requested to assess the costs and benefits of complying with the newly proposed rule. The summary of changes for applicants certifying their product to 14 CFR Part 25 is summarized in the following section.

4.2.5.1 Changes in requirements affecting applicant cost/benefit

There are three basic scenario that need to be considered for cost benefit.

1) Conventional design with traditional metallic materials
    a. No FAA issue paper/special condition expected
        i. No airframe rule – no compliance showing/finding
    b. Certify by similarity in the future (14 CFR 25.XXX(c))
        i. Applicant will show compliance by design review and document

Current

- No regulatory requirements or applicant action. No anticipated special condition.

Proposed

- Certify by similarity 14 CFR 25.XXX(c)
- Perform design comparison to previous similar conventional designs.
- Compare:
    - General structural arrangement
    - Materials
    - General gages
    - Construction techniques
- Document design comparison to establish similarity to show compliance

2) Conventional design with composite materials
    a. Conventional design implies similar to previous design that may have been certified via special condition
    b. FAA issue paper/special condition expected
        i. Significant effort in showing compliance
    c. Certify by similarity in the future (14 CFR 25.XXX(c))

        i. Applicant will show compliance by design review and document (similar to conventional derivative to design described above)
    d. Alternatively show compliance by 25.XXX(a) and (b) for the applicant with not able to utilize comparison to a previous accepted model.

Current

- FAA would create an IP/SC similar to B787, A350
    - Applicant might be able to demonstrate equivalence or similarity to previous similar product certified to a Special Condition.
- Alternatively an applicant would have to show compliance via the Special Condition.

Proposed

- Certify by similarity 14 CFR 25.XXX(c)
    - Perform design comparison to previous similar conventional designs
    - Compare:
        - General structural arrangement
        - Materials
        - General gages
        - Construction techniques
    - Document design comparison to establish similarity to show compliance

Or,

- Show compliance via 14 CFR 25.XXX(a)(b) for the cases where an applicant does not have previous acceptable design for similarity.

3) New and/or novel design or material system
    a. Assumes no similarity to previous certificated design
    b. FAA issue paper/special condition expected
        i. Significant effort in showing compliance
    c. Certify by new rule in the future (14 CFR 25.XXX(a))
        i. Significant effort in showing compliance

Current

- FAA would create an IP/SC similar to B787, A350
- Significant effort

Proposed

- Certify per 14 CFR 25.XXX(a)(b) or FAA IP/special condition if the design warrants
- Significant effort

4.2.5.2 Cost Benefit Assessment for Crashworthiness

Airbus

Airbus cost assessment.

Airbus cost data associated with new proposed crashworthiness rule compliance demonstration will be provided to directly FAA.

The cost assessment considers the new proposed airframe crashworthiness rule and associated guidance material, and based on the following assumptions:

- There is no airframe level rule currently in the CFRs
- The changes for the new rule as provided in section 4.2.4.1.
- Aircraft fuselage/cabin designs comprising significantly novel/unusual features, affecting the crashworthiness, are outside the scope of the proposed rule / guidance material. Those designs will be covered by Special Conditions, on a product-by-product basis, according to Part21.A.16B

2 scenarios below are covered by the cost assessment:

- New type certification project with fuselage/cabin designs that exhibit either significantly different crashworthiness characteristics and/or strength and stiffness characteristics (configuration, materials, etc..),
- Type certification project of conventional airframe configuration aircraft, or derivative, or Major change to Type design, using Means of compliance “similarity” and design review.

Where applicable, per scenario, the cost estimate will include:

- Engineering cost of developing crashworthiness design principles & Means of Compliance
- Engineering Certification cost, including documentation, analysis, resolution of issues with Authorities, etc…
- Type Certification Validation cost with National AAs.
- Engineering, simulations and structural analysis cost to support Means of Compliance (all levels of test pyramid and certification),
- Computing simulations costs for production article and test articles.
- Overall tests cost, including test engineering, instrumentation cost, test buildup, test articles manufacturing, manpower, test plans, test setup, test conformity, post test data management, test lab cost and test execution.
- Similarity assessment and documentation
- Design review and documentation

Qualitative Assessment conclusions

Based on the results of cost assessment conducted by Airbus, the following facts can be mentioned:

- Today, without new rule, for a conventional airframe configuration and the derivatives, a special condition is not needed; so no industry effort would be expended, as no specific crashworthiness compliance demonstration would be made.
- For recent certification projects the applicants demonstrated that the level of crash survivability is comparable to one achieved on previously certificated Large Transport aircraft of similar size.
- Significant effort was made both in terms of simulations and testing, resulting in no or minor change to design for new aircraft, but allowed to demonstrate equivalent level of safety comparable to current worldwide fleet of *Certificated Large Transport Category Aircraft*

- Fleet records show today that the compliance with current set of crashworthiness and structural strength requirements and their interaction, results in acceptable level of safety
- To meet a new airframe rule for conventional airframe configurations, the complexity of compliance demonstrations will need to be further increased, which will lead to significant efforts and cost for industry and would not be commensurate with expected safety benefit.

Association of Flight Attendants

AFA lacks access to detailed technical design/analysis information necessary to provide a cost/benefit assessment.

Boeing Commercial / Military

Boeing performed a cost benefit assessment of the new proposed airframe crashworthiness rule and associated guidance material. The assessment is based on the summary of changes provided in section 4.2.4.1 above. There is no airframe level rule currently in the CFRs. New and novel designs currently would anticipate a special condition similar to those applied to the B787 and A350 which were equivalent to the airframe rule proposed in this document. A special condition would not be expected today for a conventional derivative so no showing of compliance would be made and no engineering effort expended. In the future, the applicant would be expected to utilize the option of showing similarity to current acceptable aircraft.

The data provided to FAA addressed 3 scenarios:

1. A conventional new type certification project,
2. A new or novel new type certification project,
3. A conventional derivative (either composite or metallic).

Where applicable, each estimate includes:

<u>Cost Impact</u>

- Engineering
  - Development of means of compliance and supporting test program.
  - Certification documentation, analysis, resolution of issues with FAA, regulatory administration (ODA) support
  - Similarity assessment and documentation.
  - Type Certification Validation with NAAs.
- Engineering analysis: simulations and detail hand analysis
- Computing costs for simulations (production article and test articles)
- Manufacturing for test articles
- Test lab engineering
  - Test plan, test setup, test conformity, test execution, data reduction, reports, test article disposition
- Test lab materials; strain gages, wiring, other instrumentation
- Test lab technicians
- Test lab manufacturing

Benefit – Cost Reduction:

- Reduced Regulatory Administration for Special Condition
  - Supporting engineering Subject Matter Expert input
  - Engineering Certification coordination and approvals
- Future societal benefit for potential lives saved in a survivable crash event

A cost and benefit for each of the three scenario was provided to the FAA directly.

Qualitative Assessment of the Cost vs. benefit

Boeing Commercial Aircraft has assessed the cost of certifying the three scenario listed above vs. the expenses potentially saved having an airframe level rule for crashworthiness and the potential societal benefit for lives saved in a survivable crash due to the new proposed rule.

Boeing believes the minor improvements in safety that may result from the new proposed rule is not commensurate to the financial impact to industry due to the proposed rule.

Bombardier

Due to the proprietary nature of our cost data Bombardier has provided quantitative assessment to FAA directly.

The data provided to FAA address 3 design categories:

1) Conventional design with traditional metallic materials
2) Conventional design with composite materials
3) New and/or novel design or material system

Showing compliance by similarity will have the smallest impact when compared with compliance by Analysis / Simulation or testing validation. However the similarity approach would need to be agreed with design authorities (typically more than one) in the early stage of program development when the design maturity is still not achieved.

Showing compliance by test only (for BA passenger and larger business aircraft) would require multiple expensive drop tests to address four criteria defined in the new rule. This would be very expensive.

Showing compliance by analysis/simulation would significantly increase the cost associated to manpower required for extensive FEM/LSDYNA simulation (iterative process). Additional effort and associated cost increase would come from performing and/or processing test data required for FEM validation.

In general, Bombardier believes that the new proposed rule changes would cause **a large** additional certification effort and thus **significantly** increase costs.

Cascade Aerospace

Cascade Aerospace will abstain from providing detail cost data. It is difficult to determine a detail impact due to the variable nature of our business.

Dassault Aviation

Dassault Aviation cost data associated with proposed crashworthiness new rule compliance demonstration will be provided directly to FAA.

Currently, there is no airframe level crashworthiness rule in the regulation, but it is assumed a SC similar to those applied to B787 and A350 would apply for a new and novel configuration.

The assessment is based on section 4.2.4.1 of this document.

Two scenarios are evaluated:

- A conventional design certification
- A new and novel design certification

The third scenario proposed in this document (conventional design with composite material) is considered as a new and novel design.

When available, the assessment includes related research and development, engineering, certification, production, operation and test costs.

Conventional design:

It is assumed compliance would be shown by similarity with previous type certificate.

The nature and level of details expected by the authorities to be compared is today not clearly defined and would require an effort to be converged. This would imply a need for additional development, engineering, certification and test activities to demonstrate similarity for crashworthiness not required for the current regulations.

There would not be any benefit neither from a cost point of view neither from a safety point of view as the actual conventional aircrafts are considered to provide an acceptable level of safety, and therefore the demonstration would not lead to any significant change in design.

New and novel design:

It is assumed compliance would be shown by analysis supported by tests.

A significant effort in research and development, engineering, tests and certification would be required. This effort could be even more stringent for small part 25 aircrafts than for large part 25 aircrafts as there crashworthiness has been supported by only very limited research efforts during the past years.

The benefit would be limited to the reduction of regulatory administration compared to special condition.

For both scenarios, Dassault Aviation believes the limited benefits that may result from the proposed new rule would not be commensurate to the significant resulting costs.

Embraer

Embraer found that the new rule proposed for crashworthiness has a measurable impact on nonrecurring cost with negligible influence on survivability. A high-level cost estimate has been provided directly to the FAA, in order to safeguard proprietary and strategic data. In the assessment, one sample scenario was considered, involving a brand new

Part 25 airplane eligible to the vertical drop test (VDT) rule. The impacts were separated into two groups: a) basic knowledge acquisition and b) specific certification campaign.

German Aerospace Center (DLR)

DLR cost calculation. As a research organization DLR can provide high level cost estimation, but DLR is not in the position to provide substantiated data for a detailed cost calculation.

According to DLR's high-level cost estimate, there are no significant additional costs for the proposed rule 25.XXX compared to the certification process expected today.

1) Conventional design with traditional metallic materials

The demonstration of similarity by design review according to the proposed rule 25.XXX (c) results in increased effort compared to the certification process of today in terms of comparing the airframe designs and documenting the comparison.

According to DLR's estimate, this additional effort is limited and it is the essential basis for justifying the selected certification approach by design review according to 25.XXX (c).

2) Conventional design with composite materials

According to the proposed rule 25.XXX and related guidance material there will be significantly less effort for certification of conventional designs with composite materials as expected for the certification process of today.

Allowing an applicant the demonstration of compliance with the rule by design review for conventional designs with composite materials will result in significantly less costs compared to showing compliance with Special Conditions which is the certification process expected today.

3) New and/or novel design or material system

According to the proposed rule 25.XXX and related guidance material new and/or novel design or material systems must be certified based on 25.XXX (a) and (b).

According to DLR's estimate, there will be no additional costs for the proposed rule 25.XXX compared to the demonstration of compliance with Special Conditions expected today for such airframe designs.

Cost estimate for DLR's dissenting points:

DLR represents dissenting points to the proposed rule 25.XXX and related guidance material which are documented in Sections 6.1.2 and 6.1.4 of this present report.

According to DLR's estimate, most of these dissenting points would result in no or minor cost increase. Besides that, the dissenting points "DLR Item (2)" and "DLR Item (10)" may result in additional costs.

DLR's dissenting point "DLR Item (2)" is related to conventional designs with traditional metallic materials. DLR's position is that a consistent level of safety should be introduced with the proposed new rule 25.XXX, in a way that the "previously certified aircraft" used as reference for demonstration of similarity was certified according to the new rule 25.XXX (a) and (b), see Section 6.1.2 for the rationale. As a consequence, the applicant must show compliance with the new rule 25.XXX (a) and (b) at least once, to use that certified design as reference for future certification approaches based on 25.XXX (c).

Following this DLR position (DLR Item (2)) would result in one-off costs for certifying a traditional design according to 25.XXX (a) and (b).

DLR's dissenting point "DLR Item (2)" is additionally related to conventional designs with composite materials. DLR's position is that conventional designs with composite materials can solely demonstrate compliance with the rule by 25.XXX (a) and (b), demonstration of similarity by design review according to 25.XXX (c) should not be allowed for such airframe designs (see Section 6.1.2 for the rationale).

Following this DLR position (DLR Item (2)) would result in similar costs as expected today for showing compliance with Special Conditions.

DLR's dissenting point "DLR Item (10)" is related to the means of compliance by analysis supported by test, and requests at least one large structure test for demonstration of compliance, see Section 6.1.4 for the rationale.

Following DLR's dissenting position (DLR Item (10)) would result in significant cost increase as the performance of a large structure test, like a fuselage barrel drop test, is cost intensive.

<u>DLR benefit calculation.</u> DLR's benefit estimate is related to the level of safety provided by the proposed rule 25.XXX and related guidance material.

According to DLR's benefit estimate, the proposed rule 25.XXX and related guidance material partly provides a reduced level of safety compared to the certification process expected today.

1) Conventional design with traditional metallic materials

The demonstration of similarity by design review according to the proposed rule 25.XXX (c) results in the same level of safety as expected for the certification process of today. The airframe is not explicitly designed for crashworthiness and provides a certain level of crash safety solely by its structural nature.

Dependent on the individual airframe design details the level of crash safety may vary within not negligible ranges. Small design details, like fixed or articulated attachments of vertical stanchions, may significantly change the crash performance even for traditional metallic designs.

In this sense, with the proposed rule 25.XXX the level of safety would be similar to the certification of today, but further on not fully consistent.

For that reason, DLR represents a dissenting position (DLR Item (2)) as documented in Section 6.1.2.

2) Conventional design with composite materials

The proposed rule 25.XXX and related guidance material allows demonstration of similarity by design review for certification of conventional designs with composite materials.

According to DLR's benefit estimate, this would result in a reduced level of safety.

Airframe designs using composite materials typically require a specific crash concept with design features intended to absorb energy or to fail in a specific manner. Crashworthiness for the airframe is obtained by a controlled failure sequence of several design features. Such airframe designs can be robust if proper designed! However, robustness is not provided simply by the airframe structural nature as it is the case for conventional designs with traditional metallic materials. Structural crashworthiness is a complex discipline and the global response of large structures subjected to crash loads can typically be driven by small design details. This is specifically true for airframe designs that need structural features to achieve a crashworthy safety level that comply with the rule. The transfer of such a specific crash concept from one design to another design that is similar in size, design architecture, and material systems solely by design review implies uncertainties that might not end up in similar structural crashworthiness.

For that reason, DLR represents a dissenting position (DLR Item (2)) as documented in Section 6.1.2.

3) New and/or novel design or material system

According to the proposed rule 25.XXX and related guidance material new and/or novel design or material systems must be certified based on 25.XXX (a) and (b).

According to DLR's estimate, this represents a safety level similar to the one expected for the certification process of today based on Special Conditions.

Benefit estimate for DLR's dissenting points:

DLR represents dissenting points to the proposed rule 25.XXX and related guidance material which are documented in Sections 6.1.2 and 6.1.4 of this present report.

According to DLR's estimate, the level of safety expected for certification of today can be MAINTAINED when considering DLR's dissenting points (see Sections 6.1.2 and 6.1.4 for the rationale of the individual dissenting points):

1) DLR Item (1): 25.XXX (a); Determination of Vertical Impact Velocity Requirements
    a. Consider higher impact velocities up to 30 ft/s for the impact conditions specified in the proposed rule 25.XXX (a).
2) DLR Item (2): 25.XXX (c); Similarity/ Design Review

   a. Limit the demonstration of similarity by design review to conventional aircraft with traditional metallic materials.
   b. Demonstrate equivalent level of safety based on the impact conditions specified in 25.XXX (a).
3) DLR Item (4): 25.XXX (b); Maintenance of the Occupant Egress Paths
   a. Demonstrate non-permanent deformation of the emergency exit structure based on the impact conditions specified in 25.XXX (a), in addition of using the static loads defined in 14 CFR 25.561.
4) DLR Item (5): 25.XXX (b); Maintenance of Acceptable Loads Experienced by the Occupants
   a. Link the occupant injury criteria thresholds in 25.XXX (b) to 14 CFR 25.562 (c)(2) and specify the lumbar loads as sole criteria accepted for demonstration of compliance.
5) DLR Item (6): Robust Crashworthiness
   a. Demonstrate robust crashworthiness for maintaining the level of safety provided today by the fleet of conventional aircraft with traditional metallic materials.
6) DLR Item (7): Consistency in Means of Compliance by Test and by Analysis
   a. Harmonize the guidance material for means of compliance by test and by analysis in a way that all important issues are conform to a maximum, to ensure a consistent level of safety.
7) DLR Item (8): Limit of Reasonable Survivability
   a. Demonstrate compliance with the rule mandatorily up to the impact velocities specified in 25.XXX (a).
8) DLR Item (9): Alternative Demonstration of Adequate Occupant Crash Survivability for Smaller Transport Category Aircraft
   a. Demonstrate compliance with occupant crash injury criteria thresholds for all transport aircraft categories including the small transport category aircraft.
9) DLR Item (10): Means of Compliance by Analysis Supported by Test
   a. Demonstrate compliance with the rule by a large structure test.

According to DLR's estimate, the level of safety expected for the certification process of today can be reasonably INCREASED when considering DLR's dissenting points (see Sections 6.1.2 and 6.1.4 for the rationale of the individual dissenting points):

10) DLR Item (2): 25.XXX (c); Similarity/ Design Review
    a. Only such "previously certified aircraft" can be used as reference for comparison that were certified according to the new rule 25.XXX (a) and (b).
11) DLR Item (3): 25.XXX (b); Retention of Items of Mass
    a. Demonstrate compliance with the rule based on the impact conditions specified in 25.XXX (a), in addition of using the static loads defined in 14 CFR 25.561.

Gulfstream Aerospace Corporation

Mitsubishi Aircraft Corporation

National Aeronautics and Space Administration

NASA will abstain from comment on cost/benefit, since NASA does not act as an applicant in certifying structure.

Naval Air Systems Command

National Institute of Aircraft Research

Three basic scenarios that need to be considered for cost benefit:

1) **Conventional design with traditional metallic materials**
    a. No FAA issue paper/special condition expected
        i. No airframe rule – no compliance showing/finding
    b. Certify by similarity in the future (14 CFR 25.XXX(c))
        i. Applicant will show compliance by design review and document

    - **BENEFIT:** Will maintain the current level of safety for conventional metallic aircraft. This approach will enable current manufacturers to certify conventional design configurations without additional work. Need to pay attention to the level of documentation required to certify by similarity, guidance material should be developed to minimize the engineering effort to create the appropriate documentation.
    - **COST:** NIAR has no cost data for this scenario.

2) **Conventional design with composite materials**
    a. Conventional design implies similar to previous design that may have been certified via special condition
    b. Certify by similarity in the future (14 CFR 25.XXX(c))
        i. Applicant will show compliance by design review and document (similar to conventional derivative to design described above)
    c. Alternatively show compliance by 25.XXX(a) and (b) for the applicant with not able to utilize comparison to a previous accepted model.

    - **BENEFIT:** Will maintain the current level of safety for composite materials aircraft given that the manufacturer has gone in the past through the special condition to show compliance. This approach will enable current manufacturers to certify conventional composite design configurations without additional work. Need to pay attention to the level of documentation required to certify by similarity, guidance material should be developed to minimize the engineering effort to create the appropriate documentation.
    - **COST:**
        - NIAR has no cost data for this scenario B. Certify by Similarity
        - For scenario C the cost estimate based on previous Business jet type aircraft experience plus cost of test articles, a cost based on experience has been submitted to the FAA]

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  1. Testing Costs
     a. Building Block Testing to support Certification by Analysis: Coupon, Joints Component
     b. Full Scale Test Article 10 foot section – Cost Depends on Design
     c. Full Scale Test 10 foot section – Planning, testing data analysis
     d. Instrumentation, Conformity, Test Lab Materials
     e. Facilities and Equipment: External Facility with all the equipment in place. If the OEM has to make the investment to develop the facilities and equipment necessary for testing this will significantly increase the cost
  2. Computational Costs may vary depending on the engineering cost per hour across OEMS, plus basic software and cluster infrastructure)
     a. Methodology Development: 4 Senior Full Time Simulation Engineer 1 Year.
     b. Building Block Validation to support Certification by Analysis: Coupon, Joints Component – 3 Senior FTE for 1 Year
     c. Full Scale Test Article Model Development Metallic– Cost Depends on Design – 3 Senior FTE for 1 Year
     d. Baseline Studies Metallic Fuselage – 2 Senior FTE for 1year
     e. Seat Model Development and Validation – 1 FTE 1 Year
     f. Composite Studies Fuselage - 3 Senior FTE for 1 Year.
     g. Documentation – 3 FTE Senior Engineers 1 Year
     h. License and Computational Resources

3) New and/or novel design or material system

a. Assumes no similarity to previous certificated design
b. FAA issue paper/special condition expected
   i. Significant effort in showing compliance
      a. Certify by new rule in the future (14 CFR 25.XXX(a))
   ii. Significant effort in showing compliance

- **BENEFIT:** Will maintain the current level of safety.
- **COST:**
  - The cost estimate based on previous Business jet type aircraft experience plus cost of test articles, a cost based on experience has been submitted to the FAA]
    1. Testing Costs (factors considered man power cost, plus the cost of the test article, may vary depending on the engineering cost per hour across OEMS, assumes the facilities and equipment are already available or external)
       a. Building Block Testing to support Certification by Analysis: Coupon, Joints Component (Testing cost including test Engineer)
       b. Full Scale Test Article 10 foot section – Cost Depends on Design

   c. Full Scale Test 10 foot section – Planning, testing data analysis
   d. Instrumentation, Conformity, Test Lab Materials
   e. Facilities and Equipment: External Facility with all the equipment in place. If the OEM has to make the investment to develop the facilities and equipment necessary for testing this will significantly increase the cost
2. Computational Costs(may vary depending on the engineering cost per hour across OEMS, plus basic software and cluster infrastructure)
   b. Methodology Development: 4 Senior Full Time Simulation Engineer 1 Year.
   c. Building Block Validation to support Certification by Analysis: Coupon, Joints Component – 3 Senior FTE for 1 Year
   d. Full Scale Test Article Model Development Metallic– Cost Depends on Design – 3 Senior FTE for 1 Year
   e. Baseline Studies Metallic Fuselage – 2 Senior FTE for 1year
   f. Seat Model Development and Validation – 1 FTE 1 Year
   g. Composite Studies Fuselage - 3 Senior FTE for 1 Year.
   h. Documentation – 3 FTE Senior Engineers 1 Year
   i. License and Computational Resources

Textron Aviation

Textron believes all the changes will cause additional certification effort and time and thus increase costs.

Showing compliance by similarity will have the least impact assuming the design review is a one day affair with power points/Catia presentations showing how the new design is similar to the previous acceptable design. If the standard for this to show compliance becomes an extensive FEM/LSDYNA review with multiple load cases on each aircraft, the cost could go up quickly. To minimize program risk, this comparison would need to be completed and approved when the design is complete but before much of the construction has begun. We do not want to make a lot of changes to basic fuselage structure after they have been built.

Showing compliance by test only will take multiple expensive drop tests to show all 4 criteria are met for vertical drop with some variation for pitch and roll. If a test fails there could be significant impact to cost and schedule for redesign.

Showing compliance by analysis (or analysis combined with test) will be very expensive and add time to the schedule to do testing before the initial design to validate analysis methods. Once this has been done for the first new program subsequent programs that use similar materials and construction methods would not be as expensive because testing would not be required to prove the analysis methods are correct

Total cost / benefit summary for airframe crashworthiness:

Cost / benefit data provided by team members directly to FAA.

4.3 Sub-Team 3 – Ditching

4.3.1 Proposed Rule Recommendation

<u>The current 14 CFR 25.563 per amendment 0 and 14 CFR 25.801 at amendment 72.</u>

§25.563 Structural ditching provisions.

Structural strength considerations of ditching provisions must be in accordance with §25.801(e).

§25.801 Ditching.

(a) If certification with ditching provisions is requested, the airplane must meet the requirements of this section and §§25.807(e), 25.1411, and 25.1415(a).

(b) Each practicable design measure, compatible with the general characteristics of the airplane, must be taken to minimize the probability that in an emergency landing on water, the behavior of the airplane would cause immediate injury to the occupants or would make it impossible for them to escape.

(c) The probable behavior of the airplane in a water landing must be investigated by model tests or by comparison with airplanes of similar configuration for which the ditching characteristics are known. Scoops, flaps, projections, and any other factor likely to affect the hydrodynamic characteristics of the airplane, must be considered.

(d) It must be shown that, under reasonably probable water conditions, the flotation time and trim of the airplane will allow the occupants to leave the airplane and enter the life rafts required by §25.1415. If compliance with this provision is shown by buoyancy and trim computations, appropriate allowances must be made for probable structural damage and leakage. If the airplane has fuel tanks (with fuel jettisoning provisions) that can reasonably be expected to withstand a ditching without leakage, the jettisonable volume of fuel may be considered as buoyancy volume.

(e) Unless the effects of the collapse of external doors and windows are accounted for in the investigation of the probable behavior of the airplane in a water landing (as prescribed in paragraphs (c) and (d) of this section), the external doors and windows must be designed to withstand the probable maximum local pressures.

<u>The following proposed rules received general consensus with the group.</u>

§25.563 Structural ditching provisions.

If certification with ditching provisions is requested, the airframe structures that are necessary to maintain flotation shall withstand ditching loads, considered as ultimate, associated with a planned emergency landing on water. The airframe loads must account for reasonable variations in the flight parameters when the airplane enters the water.

§25.801 Ditching.

(a) Whether or not ditching certification is requested, it must be shown that, following an unplanned ditching, the flotation time and trim of the airplane will allow the occupants to leave the airplane.

(b) If certification with ditching provisions is requested, the airplane must meet sections §§ 25.563, 25.1411(a) and 25.1415(d) and the following:

1) Each practicable design measure, compatible with the general characteristics of the airplane, must be taken to minimize the probability that, in an emergency landing on water, the behavior of the airplane would cause immediate injury to the occupants or would make it impossible for them to escape.

2) The probable behavior of the airplane in an emergency landing on water must be investigated by model tests or validated analytical methods. Features likely to affect the hydrodynamic characteristics of the airplane must be considered.

3) It must be shown that, following a planned emergency landing on water, the flotation time and trim of the airplane will allow the occupants to leave the airplane and enter rafts. The flotation and evacuation assessment shall account for probable damage resulting from the conditions prescribed in § 25.563.

4.3.2 Proposed Guidance Recommendation

See appendix C for a complete listing of the recommended guidance.

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4.3.3 Detail Investigations

What follows is a description and conclusions related to the various studies and investigations made supporting development of the proposed rule and guidance.

4.3.3.1 Hazard Assessment

An assessment was made of potential in service incidents that could lead to a potential ditching of an aircraft. The table below summarizes the different phases of a ditching and the key aspects for consideration. No power and reduced power scenarios are addressed by additional instructions in the Aircraft Flight Manual (AFM). The resulting hazard assessment was used to evaluate the revised ditching considerations to determine if the general threats are reasonably addressed.

Table 2-1. Team Meetings

Summary of 25.563 and 25.801 Ditching Considerations			
Type	**Planned**	**Unplanned**	**Inadvertent**
Applicability	Aircraft certified for ditching	All aircraft	All aircraft
Principle	• Complete analysis, including approach and impact variation	• Basic flotation and evacuation capability	• Addressed by crashworthiness
Approach	• Ditching performed in accordance with AFM procedure	N/A	N/A
Impact	• Engine power available • Powered systems available • Weight not less than MLW • Calm water state (fresh water) • Variation of parameters	N/A	N/A
Deceleration	• Ensure appropriate hydrodynamic behavior	N/A	N/A
Structural Assessment	• Local loads (pressures) • General distributed pressures • Load factors • Ditching exit integrity • No structural leaks	N/A	N/A
Flotation	• MLW reduced by detached components • Structural leaks accounted for • All system openings closed in accordance with recommended ditching procedures	• MTOW • Systems in Take Off Mode	N/A
Evacuation	• All occupants leave the airplane and enter rafts (life rafts or slide rafts)	• All occupants leave the airplane and enter a slide raft, the water or step onto the wing	N/A

The following table summarizes the typical safety hazards/threats considered in the aircraft design, that have the potential to lead to a ditching event and the likely capability for a successful controlled intentional water landing. These water landings are considered for two categories, planned and unplanned, which correspond both to the state of the aircraft and the time to prepare for landing and are distinct from crashes such as runway overruns or inadvertent landings into the water. It will be seen in the assessments that most of these hazards are associated with unplanned ditching scenarios, but that the likely control power and structural capability should be satisfactory.

The ditching hazard is primarily, but not always, related to loss of engine power to continue to a suitable destination. Total engine power loss can arise from situations arising in the aircraft itself, encounters with external threats, and human error. Other situations may arise where the flight crew attempts a ditching because of a dire and immediate situation in the aircraft, such as uncontrollable smoke, fire, fumes.

Of all these situations, the aircraft is quite resistant to certification hazards arising within the aircraft itself and no significant improvements in this area may be reasonably expected. Electrical, mechanical, and flight control systems and structural reliability and redundancy requirements insure that system or structural failures necessitating an emergency landing are reduced to an extremely improbable level.

On the other hand, engine technology is not at and is not anticipated to attain reliability to the systems and structures level. One example is the high energy uncontained engine fragment from one engine damaging all the remaining engines. There is no practical design approach for complete mitigation of this hazard. For the conventional fuselage/wing arrangement, this event would likely damage the structural integrity and ability to withstand the ditching loads, even if the aircraft remains flyable.

External threats and human error still remain the most likely causes of ditching incidents. External threats to the engine power are primarily ingestion of external objects. The Hudson River bird ingestion incident has highlighted this threat. The current engine bird ingestion standards for continued flight roughly correspond to an extremely remote condition and it is not anticipated that engines can be designed and manufactured to resist a bird threat approaching extremely improbable.

Human error, including maintenance errors and flight crew errors, always persist and are still likely, in the sense of lifetime fleet exposure, to result in exposure to ditching events. Unapproved dangerous cargo also adds to this exposure.

In conclusion, there may be extremely remote but survivable situations, meaning that occupants do not suffer extreme loadings, where the execution of recommended ditching procedures is not possible e.g. loss of engine power sufficient to provide recommended flaps and fuel jettison functionality. Fuselage damage may result in substantial flooding into occupied areas. Examples of these scenarios include loss of engine power due to extremely remote hazards beyond the engine certification requirements for bird strikes and rain and hail ingestion; unanticipated fuel exhaustion, inability to relight following ash cloud encounters, and fuel contamination. Modern fleet experience has shown that aircraft global integrity is usually maintained in these extremely remote unplanned ditching events, and floatation and evacuation characteristics, even with substantial skin damage and flooding, allow for survival rates generally consistent with a hazardous condition as understood in system safety assessments.

In the following table, threats and hazards are assessed for ditching exposure to a single event, categorized as the planned or unplanned, and the hazard scenario described along with the applicable design configuration. Comments note the expected structural capability for the event. Where applicable, in service events are noted, including near misses. The assessment of a particular hazard assumes that no unknown unsafe design feature exists for a properly designed and certified product. In other words, the design is assumed to perform as intended.

Table 4-4. Hazard assessment for Issues that could lead to ditching

Threat or Hazard	Single event may lead to ditching	Planned	Un-planned	Ditching Hazard	Ditching configuration	Comments
Threats/Hazards originating in the airplane						
Brake Overheat/Failure	No			• Precluded by design.		
Chemical Spills	No			• Precluded by design.		
Electrical Faults • Wire bundle fire or overheat • Equipment or junction box fires • Connector Shorting and De-Coupling • Wire Breakage • Wire Chafing • Faulty Ground/Bond/Shield Connections • Flight Test Instrumentation Incompatibility • Crossed Wiring	No			• Precluded by design, see also item fire.		
Electrical Power Failure	No			• Precluded by design.		
Engine and Nacelle Separation	No			• Precluded by design. • In service event: El-Al 1862 Amsterdam lost two engines on one wing. Fail safe and damage tolerant design changes since then. Ditching not attempted.		
Equipment Failure	No			• Precluded by design.		
Excessive vibration	No			• Precluded by design, e.g. wind milling.		

Threat or Hazard	Single event may lead to ditching	Planned	Un-planned	Ditching Hazard	Ditching configuration	Comments
Explosions • Passenger and Cargo Areas • Other Areas	No			• Explosion renders aircraft flyable but unable to reach suitable landing field. • Flyable but with no engine power is highly unlikely. • No known in service events.		
Fire • Contamination of cockpit and/or cabin by toxic fumes	Yes		Yes	• Last resort to deal with cabin fire, borderline condition. • In service event: Swissair 111 crash in water due to uncontrollable cockpit smoke/fire. Ditching not attempted.	• Engine power available • Landing flaps. • Limited time for fuel jettison.	• Leaks allowed • loads approaching planned ditching levels • Anticipate global integrity maintained • In service events show adequate flotation
Fluid Contamination	No			• Precluded by design.		
High Pressure Device • Duct Rupture • Accumulator Rupture	No			• Precluded by design.		
Hydraulic Failure	No			• Precluded by design.		
Oxygen/Flammable fluid leakage	No			• Precluded by design.		
Ram-Air Turbine Blade Loss	No			• Note: RAT will deploy during dual engine fail, can cause further damage during ditch		

Threat or Hazard	Single event may lead to ditching	Planned	Un-planned	Ditching Hazard	Ditching configuration	Comments
Rotor Burst (main engine and APU)	No			• Dual engine failure, possible but extremely remote – would involve uncontained 1/3 disc fragment penetrating fuselage and other engine. Catastrophic scenario included in the 1/20 analysis. • Not survivable.		
Structural Damage • Rapid decompression • Skin rupture • Bulkhead failure • Missing portion of wing • Missing portion of vertical tail • Missing portion of horizontal stabilizer • Floor collapse	No			• Precluded by design. • Floor damage resulting from ditching needs to be considered. Covered by the Crashworthiness team. • No known in service events.		
Wheel and Tire Burst/Fragmentation	No			• Should be contained by design.		
Threats/Hazards external to the airplane - environments						
Bird Strike – within Part 33 engine requirements	No			• Bird strikes disabling all engines occur after point of no return or prior to attainable suitable landing field. • Time and power requirements in CFR 33.76 are intended to provide for return to land so planned ditching need not be considered.		

Threat or Hazard	Single event may lead to ditching	Planned	Un-planned	Ditching Hazard	Ditching configuration	Comments
Bird Strike – beyond Part 33 engine requirements	Yes		Yes	• Bird strikes disabling all engines occur after point of no return or prior to attainable suitable landing field. • Unavoidable external event. • In service event: US Airways 1549 Hudson River. Flock of non-standard birds beyond engine certification requirements and above current/foreseeable engine design capability.	• Loss of engine power • APU available • Flaps Available • No jettison • MTOW-burn • Minimum acceptable control (MAC)	• Leaks allowed • Anticipate global integrity maintained • Analysis shows loads approaching planned ditching levels • In service events show adequate flotation
Electromagnetic Environment • Electromagnetic Incompatibility • High Intensity Radio Frequency (HIRF) • Electromagnetic Interference (EMI) - Internal - External • Electrostatic Discharge (ESD)	No			• Precluded by design.		
Fuel system contamination	Yes		Yes	• In service event: British Airways 38, near miss, landing short due to fuel system icing.	• Loss of engine power • APU not available • Flaps not available • MLW • Minimum acceptable control (MAC)	• Leaks allowed • Load levels likely 1.5 to 2.2 times normal • global integrity likely not maintained
Icing – within Part 25 and/or Part 33 requirements	No			• Precluded by design.		

Threat or Hazard	Single event may lead to ditching	Planned	Un-planned	Ditching Hazard	Ditching configuration	Comments
Icing – above Part 25 or Part 33 requirements	Yes		Yes	• Part 25 – Aircraft likely not controllable or • Part 33 – Total and unrecoverable engine power loss from ice ingestion • No known in service events	• Loss of engine power • APU available • Flaps Available • No jettison • MTOW-burn • Minimum acceptable control (MAC)	• Leaks allowed • likely global integrity maintained • loads approaching planned ditching levels • In service events show adequate flotation
Lightning – within Part 25 requirements • Direct • Induced	No			• Precluded by design.		
Lightning – above Part 25 requirements • Direct • Induced	No			• Lightning strike renders aircraft flyable but unable to reach suitable landing field. • Highly unlikely event • No known incidents		
Mid-Air Collision	No			• If flyable and controllable, then should have power to land.		
Missiles, MANPADS	No			• If flyable and controllable, then likely to have power to land.		

Threat or Hazard	Single event may lead to ditching	Planned	Un-planned	Ditching Hazard	Ditching configuration	Comments
Rain/hail causes dual flame within Part 25 requirements.	Yes		Yes	• Service event: Garuda Flight 421. Crew errors during relight procedures and other factors. Should have been avoidable. • Most likely to happen towards end of flight.	• Loss of engine power • APU available • Flaps available • MLW • Minimum acceptable control (MAC	• Leaks allowed • loads approaching close to planned ditching levels • global integrity likely • In service events show adequate flotation
Rain/hail causes dual flame out above Part 25 or Part 33 requirements	Yes		Yes	• Rain and hail events strong enough to force airplane down should be beyond certification requirements. • Transient loss of power for beyond certification level events likely to occur in landing configuration only. Storms at takeoff and en-route should be avoidable.	• Loss of engine power • APU available • Flaps available • MLW • Minimum acceptable control (MAC)	• Leaks allowed • loads very close to planned ditching levels • Anticipate global integrity • In service events show adequate flotation
Volcanic Ash	Yes		Yes	• Engine flame out from inadvertent encounters with ash cloud usually at cruise. Primarily an engine restart issue which seems to have an acceptable service history. Volcanic ash ingestion is typically avoidable.	• Loss of engine power • APU available • Flaps Available • No jettison • MTOW-burn • Minimum acceptable control (MAC)	• Leaks allowed • loads approaching planned ditching levels • anticipate global integrity • In service events show adequate flotation
Human error						

Threat or Hazard	Single event may lead to ditching	Planned	Un-planned	Ditching Hazard	Ditching configuration	Comments
Improper operation results in loss of critical mission fuel due to improper operations, head winds etc.	Yes	Yes		• Most likely scenario for planned ditch. • In service event: ALM Flight 980, poor fuel management and poorly executed ditching.	• Landing flaps. • Airplane will be near zero fuel weight, assume MLW • High lift available.	Addressed by planned event Intact airframe, no skin ruptures in pressurized areas.
Rough/Unsafe Installation/Maintenanc e • Shortcuts • Poor Documentation • Process Changes • Undocumented Changes • Untrained Maintenance Personnel • Undetected Corrosion	Yes	Yes		• Fuel leak results in mission critical fuel loss but with enough time to prepare for ditching.	• Landing flaps. • Airplane will be near zero fuel weight, assume MLW • High lift available.	• Addressed by planned event • Intact airframe, no skin ruptures in pressurized areas.
Rough/Unsafe Installation/Maintenanc e	Yes		Yes	• Undetected leak results in total fuel loss. • Avoidable event. • In service event: Air Transat 236, (ETOPS mission) flame out and near miss for ditch near Azores, dead stick landing at Lajes, Azores. Caused by poor maintenance and mismanagement of remaining fuel	• Loss of engine power • No APU • Flaps up • Airplane at zero fuel weight. • Minimum acceptable control (MAC)	• Leaks allowed • Load levels likely 1.5 to 2.2 times normal • global integrity likely not maintaine d
Tail Strike/Hard Landing	No			• Precluded by design.		

4.3.3.2 Large Breach

The TACDWG spent significant time evaluating flotation with a large fuselage breach. The majority of the ditching events have not been executed according to the procedures defined in the Aircraft Flight Manuals. Many of these events, for a variety of reasons, have led to some form of fuselage breach often significant in size. The working group members representing aircraft manufacturers made an attempt to evaluate flotation of these events. The primary means to providing safety in a ditching event is to:

1) Keep the general fuselage and wing intact.
2) Float sufficiently long to allow occupants to evacuate the aircraft and enter rafts or to get onto the wing to await rescue.

All applicant evacuations occur in minutes. In service events has shown that even when the aircraft sustained significant damage they continued to float for a substantial amount of time, many times for hours. The Flotation analysis performed by applicants has been shown to be very conservative. There could be a great benefit if flotation analysis yielded results more consistent with in service experience. The team considered a version of the ditching rule where the applicant would:

1) Provide preferred ditching instructions for the flight crew.
2) Assess the airframe to make sure the fuselage and wing would likely remain intact (avoid general break-up of the aircraft).
3) Perform a flotation analysis to demonstrate adequate time to evacuate and enter rafts.

No evaluation of local or distributed pressures would be necessary if the flotation analysis showed adequate flotation time while assuming a significant fuselage breach. The significant breach could be as large as 100 ft^2 based on large part 25 aircraft in service data and the actual flotation times observed.

Unfortunately, no OEM has a flotation analysis method that reasonably predicts flotation times with that level of significant damage. Current flotation analysis used by applicants appears to be very conservative.

Applicants with a more accurate flotation analysis and using a rule of this form could put the focus on the important aspects of a ditching event. The aircraft remains intact and sufficient flotation time exists for a safe evacuation of the aircraft getting all occupants into rafts.

It is suggested that applicants work to improve the current state of the art for flotation analysis and that regulators consider this approach as a viable option for showing compliance to the ditching requirements in the future.

4.3.3.3 Controlled Ditching

The TACDWG considered an additional ditching category, controlled ditching, as an intermediate condition between planned and unplanned. This category was intended to capture the general fleet ditching experience of emergency landings that were not planned, but intentional with some preparation, and often associated with loss of engine power. It is evident from the hazards summary table and fleet service, that the planned ditching scenario does not cover the majority of emergency water landings. Consequently, most of the intentional emergency water landings are unplanned and there are no structural requirements for these events.

The controlled ditching, bridging the gap between planned and unplanned, would consider global structural integrity requirements for a landing that is not fully executable per the AFM instructions. This additional category would allow for large breaches and leaks, but would require that global integrity be maintained and inertial loads to the occupants be survivable.

The expectation would be that even with large fuselage breaches, as long as the airplane remained largely intact, i.e. global integrity, floatation and evacuation would be sufficient to minimize occupant fatalities. The service history generally shows that if the aircraft does not break up, there is a reasonable chance of occupant evacuation.

The Hudson River US Airways flight 1549 [ref. 5] ditching would be an example of a controlled ditching. Because the aircraft lost engine power, it was forced to glide into the water and suffered damage to the fuselage and flooding of occupied areas. However, the aircraft was largely intact and floated well beyond expectations providing sufficient time for the aircraft to be evacuated.

As the working group considered this scenario, it became apparent that similar to the large breach evaluation, the predicted aircraft structural capability generally did not match fleet experience. For the critical fuselage areas, predicted ditching loads would likely significantly exceed the ultimate design envelope and it was evident that the structure possessed more capability than required by the usual subpart C loading requirements.

Since the tasking background accepts that the current fleet ditching performance is generally acceptable, the creation of a new analysis burden was judged to be beyond the scope of the tasking and would not increase the level of safety. Furthermore, controlled ditching are partially considered in the new variation of parameters requirements associated with planned ditching.

4.3.3.4 No Engine Power or Reduced Engine Power

After the A320 ditching in Weehawken New Jersey safety investigations were completed, the NTSB (Ref. 5) released safety recommendations stating that manufacturers should include instructions for the flight crew for cases where there is significantly reduced engine power or no engine power.

There was an action given to the applicants to assess what reduced engine power or no engine power means for a ditching event. Is it practical to design for conditions where little to no power is available? The aircraft are designed to fly and land safely with the loss of one engine functionality. They are also designed to be able to return safely on land with no engine power for many parts of the flight profile. There are some portions of the departure flight profile where safely landing with no engines or engines damaged beyond certification requirements might not be recoverable. However, it was recognized that many of the ditching events are related to some significant loss of engine power. How does significant engine power loss or having no engine power affect ditching?

The OEMs collected data on the effect of reduced engine power on the ditching loads. Four scenarios were evaluated; planned ditching (reference load event), reduced power with flap authority, no power with flap authority, no power with no flap authority. It became apparent that the dominant factor was the amount of flap control available to the flight crew. If the crew has the ability to achieve the flap position desired the ditching pressures would be expected to be very near those for a planned ditching event. If the flight crew does not have the ability to achieve the flap position desired the loads will increase by the square of the velocity change. This could yield ditching pressures in excess of double normal ditching pressures. It would be a significant weight penalty to size the fuselage skin, stringers and frames to accommodate loads double the normal ditching pressures.

Table 4-5. Relative Ditching Pressures for Various Conditions

		Bombardier			Boeing***		Embraer	Dassault	Mitsubishi
		70 Pax	Business Jet	110 Pax Jet	737-10MAX	787-8	ERJ-145	Business Jet	MRJ-200
Planned Ditching per AFM MLW *	Pres. Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0
	Speed Kts.	95	100	110	146	146	111	100	135
	Pitch Angle	15	11	11			7	14	11
Reduced Power Full Flap MLW *	Pres. Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0
	Speed Kts.	95	100	110	146	146	111	100	135
	Pitch Angle	14	11	11			7	14	11
No Power Available Flap** MZFW	Pres. Ratio	1.10	1.00	1.00	2.10	1.80	1.00	1.20	
	Speed Kts.	100	100	110	211	195	111	100	
	Pitch Angle	13	11	11			7	13	
No Power No Flap MZFW	Pres. Ratio	1.70	2.25	2.10	2.10	1.80	1.60	2.20	
	Speed Kts.	122	150	160	211	195	163	160	
	Pitch Angle	9	4	5			7	5	

* 737 analysis performed at MTOW less 30 min of fuel burn

** RAT is not capable of providing flap for Boeing aircraft

*** Loads and pressures based on "sea plane" formulas

This information made it clear that while may not be practical to size for no flap control it would be appropriate to provide additional direction in the AFM for the flight crew. The

AFM should indicate that, in a ditching scenario, the crew should make sure the APU is running to ensure there is sufficient power to operate the high lift system.

The team also investigated the ability of the Ram Air Turbine (RAT) and other secondary power supplies for powering the high lift devices. Currently, most Part 25 aircraft use the secondary power systems to provide alternate power to the primary flight controls to achieve the most controllability of the aircraft for the flight crew. Some Part 25 aircraft are small or light enough that the RAT can provide sufficient power to operate the high lift devices. However, for most of the aircraft the RAT system is unable to provide sufficient power to the hydraulics to extend the flaps. The power requirement for flaps on the larger Part 25 aircraft (737 or larger) is 9 to 10 times what the RAT can provide, hence the need for the APU to be running.

OEMs also investigated what it would take to provide more power to the flaps in these reduced or no power ditching scenarios. The Flight Control specialists have made it clear that it would be a significant impact to the design of the aircraft power and control systems. The flaps on many large Part 25 aircraft require the equivalent of 8 to 10 times the power the RAT can provide. The APU is the only practical means of adding the necessary amount of power for the larger Part 25 aircraft. Alternate power systems for emergencies might be considered in the future however, the cost and impact to current system architecture design would be significant.

4.3.3.5 Variation of Parameters

The team was also given an action to evaluate the variation of flight parameters affecting the ability to ditch the aircraft as prescribed in the aircraft flight manual. EASA recognizes applicants have performed structural strength analysis for planned ditching based on loads and water pressures developed from conservative assumptions or some adaptation of the optimum configuration and conditions for a planned ditching. However, as a result of the ditching of an ATR 72 in August 2005 and an Airbus A320 in January 2009, and a subsequent review of several applicants' compliance with ditching requirements, EASA determined the optimum ditching configuration and conditions are unlikely to be sufficient to cover probable ditching scenarios.

EASA has been applying a Certification Review Item on recent certification projects asking applicants to perform structural ditching substantiation based as a minimum on the Maximum Design Landing Weight, consistent with 14 CFR 25.721 for emergency landings on land. Acceptable minimum values or variation for three other key parameters for ditching (descent rate, forward speed at impact and aircraft attitude) are also suggested. Descent speed is proposed to be based on 14 CFR 25.721 for emergency landings on land for consistency. For speed at impact the selected value considers likely exceedences in approach speed, offset by the probable deceleration in the flare. For aircraft attitude at impact a variation around the optimum attitude is prescribed. All of these parameters are related as one increases others increase or decrease accordingly based on aircraft flight mechanics.

The team worked with the flight mechanic experts and loads organization to establish a reasonable variation of parameters based on our product designs. The results are summarized below:

Table 4-6. Variation of Parameters

	Airplane Pitch Angle[2]	Forward Airplane Speed	Vertical Descent Rate	Airplane Weight	Center of Gravity[4]	Flap Setting[4]	Landing Gear extended/ retracted	Engine Power[4]	Loss of Structural Components[5]
Large Part 25	+/- 3°	up to Vref[7]	5 fps[1]	MLW	full range	landing	retracted	idle	included
Small Part 25	+/-1°	< Vref fps[6] or (typical Vref-10kt)	< 5 fps[6] +/-1 ft/s	MLW	typical range	landing	retracted	idle	included

Notes:

Green indicates a parameter that may logically vary based on design limitations of the aircraft

Orange indicates a basic design parameter that will not vary, a parameter that has little effect on loads or is not an issue as we assume we have APU power at minimum and full flap control.

An applicant propose lower values if justified.

1) up to 5 fps
2) Variation on nominal planned ditching pitch angle.
3) Forward velocity not less than Vref as established by 14 CFR 25.125(b)(2)(i) at MLW, corresponding to the prescribed flap setting. This is conservative and an applicant can propose something less if justified.
4) Assumes aircraft has power which implies any desired flap setting available amount of thrust not an issue as long as there is fuel (APU/RAT available).
5) Loss of gear, engines, flaps etc. are accounted for in the flotation analysis. Is function of design and planned ditching event and should not be a variation parameter.
6) Regular approach at Vref, touch-down horizontal and vertical velocities reduced according to flare.
7) Including higher speed validation of sensitivity.

The guidance material proposed for ditching addresses variation of parameters but does not make a distinction between the large and small part 25 aircraft for pitch angle shown above. There does not appear to be a benefit to distinguish between aircraft for pitch angle as long as the applicant considers some reasonable variation of parameters. Therefore, it was decided that the guidance can propose, as a minimum, +/- 1° of pitch variation must be considered.

4.3.3.6 Assessment of In Service Events

The Hudson River US Airways flight 1549 [ref. 5] ditching event was a significant water impact event with loads far exceeding the normal expected ditching pressures. This event cannot be considered as a typical ditching event but it does provide a severe condition to evaluate the proposed changes for ditching compliance and determine if the proposed changes improve the conditions for ditching, flotation and evacuation.

The subject ditching occurred with significantly reduced engine thrust. Fortunately, the crew was able to get some flap control to help control velocity. Unfortunately, the final flare procedure is highly variable and in this case the aircraft impacted with relatively high vertical descent and forward velocity.

The proposed changes in this document would provide optimized instructions for ditching with reduced or no engine power. The improved instructions should assist the flight crew in focusing on the most important aspects of aircraft attitude and speed to control the forces of impact. Additionally, instructions to ensure a running APU would help to make sure the crew should be able to achieve the desired flap settings, as well, to control forward and vertical velocity.

Ultimately the proposed changes in this document support the recommendation from the NTSB report of the US Airways event and they go further to help improve crew ability to maximize control of velocity by making flap control more readily available.

4.3.4 Considerations for Harmonization with NAA

This working group engaged regulatory agencies from Brazil, Canada, China, Europe, and Japan. While the different agencies provided varying levels of participation, all were engaged and it is hoped that all will try to harmonize their rules and guidance consistent with what this body recommends.

4.3.5 Cost / Benefit Assessment

4.3.5.1 Changes in requirements affecting applicant cost/benefit

Current

- Loads
    1. Develop distributed and local pressures for planned ditching event
- Stress
    1. Evaluate fuselage structure for distributed and local pressures
- Flotation
    1. Assess flotation characteristics for planned and unplanned ditching with appropriate assumptions
    2. Make determination on hydrodynamic behavior
- Evacuation
    1. Evaluate evacuation for planned and unplanned ditching event
- Certification
    1. Resolve Issue Papers and CRIs
        - Variation of parameters CRI
        - Various evacuation IP, CRI
- AFM

Procedure for planned ditching

<u>Proposed</u>

Loads

1. No change, extent of methods better defined

Stress

1. No change

Flotation

1. No change, unplanned ditching as standard if certification is not requested

Evacuation

1. No appreciable change. May be able perform one evacuation assessment that conservatively covers both planned and unplanned events.

Certification

1. No variation of parameter CRI
2. No evacuation IPs

AFM

1. Procedure for planned ditching
2. Procedures for reduced power
    1. No engine power
    2. Reduced power engines

4.3.5.2 Cost Benefit Data from Team 3

Airbus

<u>Cost Assessment.</u>

The cost assessment considers the new proposed airframe ditching rule and associated guidance material, and is based on the following assumptions:

- The new rule clarifies the means for showing compliance
- The new rule consolidates the today's level of safety
- The new guidance supports clarification of water contact scenarios with respect to the classification as ditching

2 scenarios below are covered by the cost assessment:

- New type certification project which includes ditching
- New type certification without ditching

Qualitative Assessment conclusions

Based on the results of cost assessment conducted by Airbus, the following facts can be mentioned:

- Today a new certification project has to show compliance for a ditching CRI. Now these rules requirements are transferred to a rule, which does not create cost for Airbus.
- The introduction of a new certification project which not requires a ditching certification is not the typical scenario for Airbus. A cost effect of the new §801(a) is neutral.
- These statements are valid for new development projects only. Prerequisite is that for current programmes and derivatives the existing methodology can be continued to be used by showing similarity with already certified design This point is crucial to limit the additional costs.

Association of Flight Attendants

AFA lacks access to detailed technical design/analysis information necessary to provide a cost/benefit assessment.

Boeing Commercial / Military

Boeing collected cost and benefit data for the proposed revised ditching rules and associated guidance. It is anticipated that most of these changes will result in an overall benefit of a small cost savings. There is not expected to be significant changes to calculation of ditching loads, stress analysis, flotation analysis or evacuation analysis.

Many of the accepted means of compliance issue papers are being proposed for codifying into the rule and in the proposed guidance. This would provide a benefit of reduced engineering and certification work in development of issue papers and resolution of issue papers.

There will be no anticipated change to aircraft weight.

There will be additional effort to develop instructions in the AFM for reduced power and no engine power ditchings. It is expected that this increased effort will be minimal.

Qualitative Assessment of the Cost vs. benefit

Boeing believes the proposed revised rule and associated guidance will result in a neutral to minor reduction in costs in certifying future products. There is no anticipated adverse impact and minimal effect or societal impact due to the very rare occurrences of ditching events and even rarer fatalities related to ditching events.

Due to the proprietary nature of the data, Boeing provided the cost benefit data to the FAA directly.

Bombardier

Bombardier believes that proposed revised rule and associated guidance will be cost neutral for the certification of the new A/C in the future.

Consequently, no cost benefit analysis was provided to FAA.

Cascade Aerospace

Cascade Aerospace will abstain from providing detail cost data. It is difficult to determine a detail impact due to the variable nature of our business.

Dassault Aviation

Currently, part 25 regulations are completed by a CRI on ditching issues.

Proposed changes to rules and guidance in this document are mainly understood as a clarification of the current rule incorporating main CRI issues. However, the allowance for "comparison to airplanes of similar configuration for which ditching characteristics are known" has been removed from the rule.

Therefore, it will result in a minor reduction in certification efforts without any impact on research and development, engineering, production, operation or test efforts. Subsequently, no impact on the actual level of safety (deemed acceptable) is expected.

Dassault Aviation believes a cost benefit analysis is not needed.

Embraer

Embraer found that the revised rule proposed for ditching does not have a measurable impact on design, certification, production or operation of future aircraft. No influence is expected on survivability, but the regulations are rendered more clear – what is positive. A cost benefit analysis is not justified.

German Aerospace Center (DLR)

DLR's main contribution to the working group is related to crashworthiness. DLR has no cost/benefit information to provide for the proposed ditching rule revisions or guidance.

Gulfstream Aerospace Corporation

Mitsubishi Aircraft Corporation

National Aeronautics and Space Administration

NASA will abstain from comment on cost/benefit, since NASA does not act as an applicant in certifying structure.

Naval Air Systems Command

National Institute of Aircraft Research

Textron Aviation

Since Textron does not certify its airplanes for ditching there is no cost impact to us. If all Part 25 aircraft were required to show compliance for ditching there would be a large cost to develop the analytical methods for water impact loads and validate the analysis by test. Textron currently meets the requirement to show adequate floatation time to allow all persons to exit the aircraft.

Total cost / benefit summary for airframe revised ditching rule/guidance:

Roll up the total cost/benefit

4.4 Sub-Team 4 – Equipage and Protocol

Team 4 was established to address cabin crew needs for equipment in an emergency and protocol for evacuating passengers.

4.4.1 Proposed Rule Recommendations

Below is a high-level overview of the Team 4 recommendations.

Description
The FAA harmonize 14 CFR 25.809(a) with EASA CS 25.809(a) to clarify that certain emergency exits may not be able to permit viewing of the evacuee ground contact area. The intent of the requirement is to enable a person to ascertain whether to open an exit, and whether it is safe to evacuate through the exit, based on an assessment of the outside conditions. The recommendations are related to viewing from certain overwing exits and flight crew emergency exits. Further, EASA should reorder their paragraphs in 25.809(a) to reflect the reorder recommended to the FAA for harmonization purposes.
Harmonize 14 CFR 25.810(a)(1)(ii) with EASA CS 25.810(a)(1)(ii) to reflect the reference to 10 seconds deployment time for assist means.
The requirements for stowage provisions and emergency descent means in § 25.1411(c) is obsolete and redundant since the same requirement is contained in 14 CFR 25.810, therefore the requirement in 25.1411 (c) should be deleted.
Harmonize US regulations sections 25.811(g), 25.812(b)(1) and (2) which specify the use of the word “exit” and the signs dimensions of exit locator signs, exit identifiers

and exit marking to harmonize with EASA to allow the use of **symbolic symbols** as an alternative to red exit signs.
We recommend the FAA delete the reference to the requirement for **life line** stowage provisions as stipulated in §25.1411(g) for new design aircraft.
We recommend the FAA delete the requirement for life lines in §91.509(b)(5) as part of required survival equipment for overwater operations for new design aircraft.
For current in-service aircraft with life lines included, we recommend the FAA finalize the FAA activity to update advisory guidance material to relay information to passengers on the availability, stowage and use of life lines on aircraft equipped with life lines.
We recommend the FAA revise 14 CFR 25.1415(c) to allow **survival equipment** to be stowed adjacent to each liferaft. Guidance would reflect that remote **stowage** of the equipment for slide/rafts would be permitted as a means of compliance with the regulation.
Codify airbag standard, special conditions and guidance material related to inflatable seatbelt restraints and/or airbags; and expand the information to include all active restraints. It is also recommended that EASA adopt the harmonization into CS 25 regulations and guidance material.
Utilize the term "active restraints" into the regulations and guidance material including the proposed definition: *Active Restraint: A device that operates as the result of certain inputs (such as acceleration or velocity) to trigger a mechanism that is intended to protect an occupant (such as an airbag or pretensioner). By their very nature, devices of this type can have two protection environments, one prior to the device being triggered and one subsequent.*
It is proposed that 14 CFR 25.1411 be revised to require that an approved life preserver must be provided for each airplane occupant, regardless of whether the aircraft is certified for ditching or not. The FAA should also provide additional guidance to enhance the stowage provisions and accessibility of life preservers as required in 25.1415.
14 CFR parts 25.1411 and 25.1415 have been reordered for simplification. Included in the proposal is the deletion of requirement for life lines and reference to seat cushion floatation in favor of life preservers for each occupant.
It is recommended that FAA harmonize with EASA related to the stowage or attachment of survival equipment to life rafts. Clarification and modifications were also incorporated in relation to the contents of such kits.
Revise 25.1415 related to non-portable rafts: The rafts shall have a combined **overload capacity** to accommodate all occupants of the airplane in the event of a loss of: (i) one portable raft with the largest overload capacity, and (ii) 50% of the non-portable rafts

4.4.1.1 Outside viewing requirements for emergency exits – 14 CFR 25.809(a)

Recommendation Summary:

Harmonize 14 CFR 25.809(a) with CS 25.809(a), Amendment 18

Statement of the Issue:

Having an appropriate means to assess outside conditions is needed to determine whether or not a hazard exist outside of the airplane during a land or ditching evacuation situation. In some cases it may be necessary to avoid opening certain otherwise useable emergency exits in order to prevent injury to the evacuees. In this context, a viewing window or other means of assessing the outside conditions and determining whether an exit should be opened is extremely valuable. Although exterior emergency lighting is an explicit requirement of § 25.812 to address evacuation in darkness this regulation also references outside illumination conditions since evacuations can take place at night.

The outside viewing requirements adopted in CS 25.809(a) at Amendment 12 incorporated lessons learned from the version of the outside viewing requirements that was previously adopted by the FAA in 14 CFR 25.809(a) at Amendment 25-116. It is believed that the requirements in CS 25.809(a) are consistent with the FAA's original intent.

Harmonizing 14 CFR 25.809(a) with CS 25.809(a) will ensure appropriate outside viewing means are provided at emergency exits and it will reduce the certification costs for the airframe manufacturers and the FAA. It will greatly reduce or eliminate the need for exemptions, issue papers and/or exceptions that are currently needed to clarify the FAA's intent. The intent of the following proposed changes are to clarify the requirement, there is no change to the level of safety provided.

Proposed Recommendation(s)

1) It is recommend that the FAA harmonize 14 CFR 25.809(a) with EASA CS 25.809(a) to clarify that certain emergency exits may not be able to permit viewing of the evacuee ground contact area. The intent of the requirement is to enable a person to ascertain whether or not to open an exit, and whether or not it is safe to evacuate through the exit, based on an assessment of the outside conditions.

2) It is also recommended that EASA reorder the paragraphs in CS 25.809(a) to reflect the reorder recommended to the FAA for harmonization purposes.

Rationale for Recommendation(s)

Prior to 1996, although a viewing window was commonly provided in most exits on aircraft in service it was not specifically required by the FAA. In 1996, a rulemaking initiative[2] was undertaken to harmonize with the Joint Airworthiness Authorities (JAA) and other airworthiness authorities. That rulemaking change required a means (e.g. a window in the exit itself, or in an adjacent frame bay) that provided a view of the ground area where evacuees will make contact upon leaving the airplane in an emergency evacuation. That rulemaking change resulted in the current language of 14 CFR

[2] Notice of Proposed Rulemaking (NPRM), Notice No. 96–9, which was published in the Federal Register on July 24, 1996 (61 FR 38552).

25.809(a). The purpose of the requirement is to ensure that there is a means to assess outside conditions to determine whether or not a hazard exists outside of the airplane during a land or ditching evacuation situation.

The lessons learned addressed in the outside viewing requirements adopted in CS 25.809(a) at Amendment 12 were related to the overwing passenger exits and flight crew exits. Specifically, the lessons learned related to the overwing exits where viewing of the evacuee ground contact was impossible. This was due to aircraft design features that included overwing exits that are complemented by off wing slides. Because of the exit location above the wing, it is impossible to see the ground contact area from the door, whether the door is closed or open. This is generally true with all aircraft with an overwing exit.

The lesson learned related to flight crew emergency exits and, in specific, to top hatch installations (e.g. B747-8, B787, A350, etc.). With this design configuration, it is also not possible to see the “likely areas of evacuee ground contact” from the exit.

It is believed that the requirement language in CS 25.809(a) is consistent with the FAA’s original intent and therefore the lessons learned and incorporated with Amendment 12 of CS 25.809(a) should also be incorporated into 14 CFR 25.809(a). This can result in reduced certification costs and eliminate the need for exemptions, issue papers and/or exceptions that are currently needed to clarify the FAA’s intent.

Current FAA Regulation: 14 CFR 25.809(a)

a) Each emergency exit, including each flight crew emergency exit, must be a movable door or hatch in the external walls of the fuselage, allowing an unobstructed opening to the outside. In addition, each emergency exit must have means to permit viewing of the conditions outside the exit when the exit is closed. The viewing means may be on or adjacent to the exit provided no obstructions exist between the exit and the viewing means. Means must also be provided to permit viewing of the likely areas of evacuee ground contact. The likely areas of evacuee ground contact must be viewable during all lighting conditions with the landing gear extended as well as in all conditions of landing gear collapse.

Proposed Change to the FAA Regulation: 14 CFR 25.809(a), Amendment TBD

(a) Each emergency exit, including each flight crew emergency exit, must be a movable door or hatch in the external walls of the fuselage, allowing unobstructed opening to the outside.

(1) Each emergency exit, including a flight crew emergency exit, must have a means to permit viewing of the conditions outside the exit when the exit is closed, in all ambient lighting conditions, with the landing gears extended or in any condition of collapse. The viewing means may be on or adjacent to the exit provided no obstructions exist between the exit and the viewing means.

(2) For non-over-wing passenger emergency exits, a means must also be provided to permit viewing of the likely areas of evacuee ground contact when the exit is closed with

the landing gears extended or in any condition of collapse. Furthermore, the likely areas of evacuee ground contact must be viewable with the exit closed during all ambient lighting conditions when all landing gears are extended.

4.4.1.1.1 FAA – EASA Harmonization

Current EASA Regulation: CS 25.809(a)
(a)

(1)Each emergency exit, including a flight crew emergency exit, must be a movable door or hatch in the external walls of the fuselage, allowing unobstructed opening to the outside.

(2) Each emergency exit, including a flight crew emergency exit, must have means to permit viewing of the conditions outside the exit when the exit is closed, in all ambient lighting conditions with the landing gears extended or in any condition of collapse. The viewing means may be on or adjacent to the exit provided no obstructions exist between the exit and the viewing means. (See AMC 25.809(a))

(3) For non-over-wing passenger emergency exits, a means must also be provided to permit viewing of the likely areas of evacuee ground contact when the exit is closed with the landing gears extended or in any condition of collapse. Furthermore, the likely areas of evacuee ground contact must be viewable with the exit closed during all ambient lighting conditions when all landing gears are extended.

Proposed Recommendation to EASA:

Reorder CS 25.809 to put text in the vacant (a) section and re-number the subsequent paragraphs. The intent of the regulation does not change, the purpose is for harmonization of paragraph numbers. The language proposed to EASA would be the same as proposed above to the FAA to change 14 CFR 25.809(a).

4.4.1.2 Escape Slide Deployment Time Requirements – 14 CFR 25.810(a)(1)(ii)

Recommendation Summary:

Harmonize 14 CFR 25.810(a)(1)(ii) with CS 25.810(a)(1)(ii)

Rationale:

Section 25.810(a)(1)(i) specifies that the assist means must be deployed automatically and that deployment must begin during the interval between the time the exit opening means is actuated from inside the airplane and the time the exit is fully opened. For exits other than Type C, §25.810(a)(1)(ii) requires the assist means be automatically erected within 6 seconds after deployment is begun and § 25.809(b)(2) requires the exit be openable within 10 seconds. Taking the maximum time intervals permitted, the regulations allow up to 16 seconds for an assist means to be erected after the exit opening means is actuated. When The FAA introduced Type C exits at FAA Amendment 25-88, a new more rigorous 10 second exit preparation time requirement was required for this new exit type. The exit preparation time is measured from the time the exit opening means is actuated to when the assisting mean is fully erected and ready for use.

The total time it takes to prepare the exit and assist means is more important than the portion of time that is allocated to erecting the assist means. Therefore, allowing an exit to be opened and its assist means to be fully erected within 10 seconds provides a level of safety that is at least equivalent to the 16 second exit preparation time that is allowed by the current regulations. This equivalency is documented in numerous FAA Equivalent Level of Safety (ELOS) issue papers that have been granted since the 6 second deployment time requirement was adopted.

Harmonizing 14 CFR 25.810(a)(1)(ii) with CS 25.810(a)(1)(ii) will allow the more rigorous 10 second exit preparation time requirement for Type C exits to be applied to other exit types. This will reduce the certification costs for the airframe manufacturers and the FAA, since it will greatly reduce or eliminate the need for ELOS issue papers and/or exceptions that are currently needed. The intent of this proposed change is to make the requirement consistent with how it is being applied via ELOS issue papers.

Current FAA Regulation: 14 CFR 25.810(a)(1)(ii)

Except for assisting means installed at Type C exits, it must be automatically erected within 6 seconds after deployment is begun. Assisting means installed at Type C exits must be automatically erected within 10 seconds from the time the opening means of the exit is actuated.

Proposed Change to the FAA Regulation: 14 CFR 25.810(a)(1)(ii), Amendment TBD

Except for assisting means installed at Type C exits, it must be automatically erected within 6 seconds after deployment is begun or within 10 seconds from the time the opening means of the exit is actuated. Assisting means installed at Type C exits must be automatically erected within 10 seconds from the time the opening means of the exit is actuated.

4.4.1.2.1 FAA – EASA Harmonization

Current EASA Regulation: CS 25.810(a)(1)(ii)
Except for assisting means installed at Type C exits, it must be automatically erected within 6 seconds after deployment is begun or within 10 seconds from the time the opening means of the exit is actuated. Assisting means installed at Type C exits must be automatically erected within 10 seconds from the time the opening means of the exit is actuated.

Proposed Recommendation to EASA: None

Recommended Changes to FAA Guidance:

Define deployment time, including what constitutes the start of deployment of an escape slide.

4.4.1.3 Emergency Exit Descent Device Stowage – 14 CFR 25.1411(c)

Recommendation Summary: Delete this redundant and obsolete requirement

Rationale:

14 CFR 25.1411(c) specifies that the "stowage provisions for the emergency exit descent devices required by § 25.810(a) must be at each exit for which they are intended." This requirement, which dates back to CAR-4b (predecessor to the 14 CFR Part 25 requirements), was initially adopted at a time when the descent devices were not required to be inflatable escape slides and were not required to be automatically deployed. Today, § 25.810(a)(1) requires the assisting means (descent device) at a passenger emergency exit to be a self-supporting escape slide or equivalent. It also requires the assisting means be automatically deployed when the door is opened [in an emergency], and maximum deployment times are specified.

> *§ 25.810(a)(1) The assisting means for each passenger emergency exit must be a self-supporting slide or equivalent; … In addition, the assisting means must be designed to meet the following requirements—*
>
> *(i) It must be automatically deployed and deployment must begin during the interval between the time the exit opening means is actuated from inside the airplane and the time the exit is fully opened. …*
>
> *(ii) Except for assisting means installed at Type C exits, it must be automatically erected within 6 seconds after deployment is begun. Assisting means installed at Type C exits must be automatically erected within 10 seconds from the time the opening means of the exit is actuated.*

For flight crew exits, § 25.810(a)(2) specifies the assisting means may be a rope or other suitable means (e.g., emergency descent device (EDD)) and that it must be attached to fuselage structure above the exit.

> *§ 25.810(a)(2) The assisting means for flightcrew emergency exits may be a rope or any other means demonstrated to be suitable for the purpose. If the assisting means is a rope, or an unapproved device equivalent to a rope, it must be—*
>
> *(i) Attached to the fuselage structure at or above the top of the emergency exit opening, or, for a device at a pilot's emergency exit window, at another approved location if the stowed device, or its attachment, would reduce the pilot's view in flight;*

Prior to the advent of inflatable escape slides, the emergency descent devices could be stowed away from the exit. At that time, the stowage requirement in § 25.1411(c) was warranted to ensure the descent device was stowed at the exit where it was intended to be used in order to expedite its retrieval during an evacuation. With the requirements in § 25.810, this § 25.1411(c) requirement is obsolete and should be deleted.

Current FAA Regulation: 14 CFR 25.1411(c)
Emergency exit descent device. The stowage provisions for the emergency exit descent devices required by Sec. 25.810(a) must be at each exit for which they are intended.

Proposed Change to the FAA Regulation: 14 CFR 25.1411(c), Amendment TBD

4.4.1.3.1 FAA – EASA Harmonization

Current EASA Regulation: CS 25.1411(c)
Emergency exit descent device. The stowage provisions for the emergency exit descent device required by CS 25.810(a) must be at the exits for which they are intended.

Proposed Recommendation to EASA: CS 25.1411(c) should be harmonized with the above proposed change to the FAA regulation (i.e., the obsolete requirement should be removed).

4.4.1.4 Symbolic Symbols – 14 CFR §§ 25.811(g), 25.812(b)(1) and (2) Amdt 25-128

Recommendation Summary: Harmonize 14 CFR 25.811(g), 25.812(b)(1)(i) and (ii) with CS 25.811(g), 25.812(b)(1)(i) and (ii), Amdt 18 to allow the use of symbolic exit signs as an alternative to red exit signs.

Rationale:

Sections 25.811(g), 25.812(b)(1) and (2) specify the use of the word “exit” and the dimensions of exit locator signs, exit identifiers and exit marking signs.

In March 2003, the Joint Aviation Authorities (JAA) of Europe adopted Notice of Proposed Amendment (NPA) 25D-327 allowing the use of symbolic exit signs as an alternative to language based signs. This type of sign is currently permitted by EASA certification specifications as a means of complying with CS 25.811(g), 25.812(b)(1) and (2) since the CS-25 Amdt. 3 requirements were adopted by EASA NPA No 04/2006.

At the time of the implementation of NPA No 04/2006, the FAA and EASA had a different standard for ‘equivalency’, based on the inherent language differences between the United States and Europe. As such, EASA was able to accept a level of symbol recognition that the FAA did not believe would demonstrate equivalency for the English speaking population of the United States.

Since then, symbolic exit signs have been found to be equivalent to the text signs required by the existing FAA regulations, and this equivalency is documented in numerous FAA Equivalent Level of Safety (ELOS) issue papers that have been granted for most of the large transport airplanes certified in this past decade. In these documents, the FAA has acknowledged that since not all passengers are English speaking, and may not understand the word “Exit,” the use of symbolic exit signs can increase safety by providing a common exit symbol that does not require knowledge of the English language. It has also been noted that research has shown that exposure to such symbols significantly increases comprehension. This exposure has been more frequent as an increasing number of the airplanes, of all major aircraft manufactures, are being equipped with these symbolic signs. Research has also shown that a green-colored symbolic sign is more visible than a red-colored symbolic sign in smoke conditions, as stated in the NPA No 04/2006 in its Safety Justification/Explanation.

Harmonizing 14 CFR / CS 25.811(g), 25.812(b)(1) and (2) will allow the use of the symbolic exit sign option on a voluntary basis and will have the added benefits of not only improving safety, but also simplifying the manufacturer's task of showing compliance with current national linguistic requirements whenever the symbolic sign option is used. This will reduce the certification costs for the airframe manufactures and the FAA since it will greatly reduce or eliminate the need for ELOS issue papers that are currently needed. The intent of this proposed change is to make the requirement consistent with how it is currently being applied via ELOS issue papers.

Current FAA Regulation:

14 CFR 25.811(g) Emergency exit marking.

Each sign required by paragraph (d) of this section may use the word "exit" in its legend in place of the term "emergency exit".

14 CFR 25.812(b) Emergency exit signs -

(1) For airplanes that have a passenger seating configuration, excluding pilot seats, of 10 seats or more must meet the following requirements:

(i) Each passenger emergency exit locator sign required by Sec. 25.811(d)(1) and each passenger emergency exit marking sign required by Sec. 25.811(d)(2) must have red letters at least 1½ inches high on an illuminated white background, and must have an area of at least 21 square inches excluding the letters. The lighted background-to-letter contrast must be at least 10:1. The letter height to stroke-width ratio may not be more than 7:1 nor less than 6:1. These signs must be internally electrically illuminated with a background brightness of at least 25 foot-lamberts and a high-to-low background contrast no greater than 3:1.

(ii) Each passenger emergency exit sign required by Sec. 25.811(d)(3) must have red letters at least 1½ inches high on a white background having an area of at least 21 square inches excluding the letters. These signs must be internally electrically illuminated or self-illuminated by other than electrical means and must have an initial brightness of at least 400 microlamberts. The colors may be reversed in the case of a sign that is self-illuminated by other than electrical means.

(2) For airplanes that have a passenger seating configuration, excluding pilot seats, of nine seats or less, that are required by Sec. 25.811(d)(1), (2), and (3) must have red letters at least 1 inch high on a white background at least 2 inches high. These signs may be internally electrically illuminated, or self-illuminated by other than electrical means, with an initial brightness of at least 160 microlamberts. The colors may be reversed in the case of a sign that is self-illuminated by other than electrical means.

Proposed Change to the FAA Regulation:

14 CFR 25.811(g) Emergency exit marking.

Each sign required by subparagraph (d) of this section may use the word "exit" in its legend in place of the term "emergency exit" or a universal symbolic exit sign. The design of exit signs must be chosen to provide a consistent set throughout the cabin.

14 CFR 25.812(b) Emergency exit signs –

(1) Airplanes that have a passenger seating configuration, excluding pilot seats, of 10 seats or more must meet the following requirements:

(i) Each passenger emergency exit locator sign required by CS 25.811 (d)(1) and each passenger emergency exit marking sign required by Sec. 25.811(d)(2) must have red letters at least 1½ inches high on an illuminated white background and must have an area of at least 21 square inches excluding the letters, or a universal symbol, of adequate size. These signs must be internally electrically illuminated with a background brightness of at least 25 foot-lamberts and a high-to-low background contrast no greater than 3:1.

(ii) Each passenger emergency exit sign required by Sec. 25.811(d)(3) must have red letters at least 1½ inches high on a white background having an area of at least 21 square inches excluding the letters or a universal symbol, of adequate size . These signs must be internally electrically illuminated or self-illuminated by other than electrical means and must have an initial brightness of at least 400 microlamberts. The colors may be reversed in the case of a sign that is self-illuminated by other than electrical means.

(2) Airplanes that have a passenger seating configuration, excluding pilot seats, of nine seats or less, that are required by Sec. 25.811(d)(1), (2), and (3) must have red letters at least 1 inch high on a white background at least 2 inches high or a universal symbol, of adequate size. These signs may be internally electrically illuminated, or self-illuminated by other than electrical means, with an initial brightness of at least 160 microlamberts. The colors may be reversed in the case of a sign that is self-illuminated by other than electrical means.

4.4.1.4.1 FAA – EASA Harmonization

Current EASA Regulation:
CS 25.811 (g) Emergency exit marking

Each sign required by subparagraph (d) of this paragraph may use the word "exit" in its legend in place of the term "emergency exit" or a universal symbolic exit sign (See AMC 25.812(b)(1), AMC 25.812(b)(2) and AMC 25.812(e)(2)). The design of exit signs must be chosen to provide a consistent set throughout the cabin.

CS 25.812 (b) Emergency exit signs

(1) For aeroplanes that have a passenger seating configuration, excluding pilot seats, of 10 seats or more must meet the following requirements:
(i) Each passenger emergency exit locator sign required by CS 25.811 (d)(1) and each passenger emergency exit marking sign required by CS 25.811(d)(2) must have red letters on an illuminated white background or a universal symbol, of adequate size (See AMC 25.812(b)(1)). These signs must be internally electrically illuminated with a background brightness of at least 86 candela/m2 (25 foot lamberts) and a high-to-low background contrast no greater than 3:1.

(ii) Each passenger emergency exit sign required by CS 25.811(d)(3) must have red letters on a white
background or a universal symbol, of adequate size (See AMC 25.812(b)(1)). These signs must be internally electrically illuminated or self-illuminated by other than electrical means and must have an initial brightness of at least 1.27 candela/m2 (400 microlamberts). The colours may be reversed in the case of a sign that is self-illuminated by other than electrical means.

(2) For aeroplanes that have a passenger seating configuration, excluding pilot seats, of 9 seats or less, each sign required by CS 25.811 (d)(1), (2), and (3) must have red letters on a white background or a universal symbol, of adequate size (See AMC 25.812(b)(2)). These signs may be internally electrically illuminated, or self-illuminated by other than electrical means, with an initial brightness of at least 0.51 candela/m2 (160 microlamberts). The colours may be reversed in the case of a sign that is self-illuminated by other than electrical means.

CS 25.812 (e) Emergency exit signs

(2) Readily identify each exit from the emergency escape path by reference only to markings and visual features not more than 1.2 m (4 ft) above the cabin floor (See AMC 25.812(e)(2)).

Proposed Recommendation to EASA: None

Recommended Changes to FAA Guidance: FAA guidance should be harmonized with the EASA Guidance AMC 25.812(b)(1), AMC 25.812(b)(2) and AMC 25.812(e)(2) to define the universal symbols that are considered acceptable to be used for the exit signs.

4.4.1.5 Active Restraints – 14 CFR 25.785

Recommendation Summary:

Codify airbag standard, special conditions, and guidance material, and expand to include all active restraints. It is also recommended EASA adopt harmonized CS 25 Regulations and related Guidance Material.

Rationale:

With NPA 2011-09 EASA incorporated a certain number of generic Special Conditions and AMC CRIs (Certification Review Items) in CS25. This was made effective with Amendment 13. The objective for EASA was to upgrade CS-25 by introducing generic CRI containing Special Conditions and/or Guidance Material, Means of Compliance and the intent was to reflect the current certification practices and to facilitate future certification projects.

The Crashworthiness & Ditching ARAC WG offers the opportunity to launch harmonization and publication as FAR and CS Regulations of the most recently published CRIs and IPs relative to Installation of inflatable seat belts.

Current FAA and EASA Regulations: 14 CFR / CS 25.785,
Existing Regulations do not contain adequate or appropriate safety standards for inflatable seat belts.

Proposed Change to the FAA and EASA Regulations:
Revise § 25.785(b) to include a reference to active restraint and create a new sub-paragraph in § 25.785 to address requirements for designs and installations involving active restraints. This new regulation, combined with the proposed guidance is intended to remain consistent with the current requirements that apply to active restraints via Special Conditions documented in various FAA Issue Papers addressing the installation of inflatable seat belts and other airbag systems (i.e., no new criteria for certifying active restraints are proposed).

§25.785 Seats, berths, safety belts, and harnesses.
(a) A seat (or berth for a non-ambulant person) must be provided for each occupant who has reached his or her second birthday.
(b) Each seat, berth, safety belt, active restraint (e.g., airbag), harness, and adjacent part of the airplane at each station designated as occupiable during takeoff and landing must be designed so that a person making proper use of these facilities will not suffer serious injury in an emergency landing as a result of the inertia forces specified in §§25.561 and 25.562. [CS25: *However, berths intended only for the carriage of medical patients (e.g. stretchers) need not comply with the requirements of CS 25.562.]*
(c) Each seat or berth must be approved.
….
Add a new section (m):
(m) If an active restraint is used, it must meet the following requirements -
(1) It must be designed to provide adequate protection for the occupant under the conditions specified in (b) above.
(2) The active restraint system shall not result in a hazardous condition to the aircraft, or cause injury to any aircraft occupant.

Recommended Changes to FAA and EASA Guidance (New dedicated AC or updated AC25-17A):

Incorporate the intent of the specific Special Conditions in the various inflatable lapbelt and airbag Issue Papers and provide additional clarify guidance material, as applicable.

The following Guidance Material is proposed to be added to FAA AC TBD.

The FAA considers the installation of active restraints to have two primary safety concerns: first, that they perform properly under foreseeable operating conditions, and second, that they do not perform in a manner or at such times as would constitute a hazard to the airplane or occupants. This latter point has the potential to be the more rigorous of the requirements, owing to the active nature of the system.

Active Restraint is defined as follows:

A device that operates as the result of certain inputs (such as acceleration or velocity) to trigger a mechanism (such as an airbag or pretensioner) that is intended to protect an occupant. By their very nature, devices of this type can have two protection environments, one prior to the device being triggered and one subsequent to the trigger.

When addressing compliance with § 25.785(b)(1), the following criteria shall apply:

1. It must be shown that the active restraint will deploy and provide protection under emergency dynamic load conditions (§25.562) where it is necessary to prevent serious head injury. The means of protection must take into consideration a range of stature from a two year old child to a 95th percentile male. The active restrain must provide a consistent approach to energy absorption throughout that range of occupants. In addition, the following situations must be considered:

a. The seat occupant is holding an infant.

b. The seat occupant is a child in a child restraint device.

c. The seat occupant is a pregnant woman.

(Applicable regulation: § 25.562).

Guidance:

a) For conditions of head contact with seats, or other structure (including airbags), it is acceptable if HIC ≤ 1000 (reference AC 25.562-1b, Change 1, Paragraph 12.d). If the calculated HIC is ≤1000, the test is successful. If HIC is >1000, and contact is made with the seat or other structure, regardless of airbag usage, the test has failed.

b) For conditions of head contact is with an airbag only, it is acceptable if HIC 15 ≤ 700 (reference 49 CFR 571.208). Use of HIC 15 is permitted as an alternate to HIC if the ATD head only contacts an airbag and makes no contact with the seat or other structure. ATD head contact with the seat or other structure, through the airbag, or contact subsequent to contact with the airbag requires the use of HIC.

HIC 15 is not applicable if head contact with seat or other structure has occurred. The following evaluations of the test data should be used to determine if this type of head contact has occurred:

i. A review of the dynamic test videos and evaluation of the ATD head path movement, head contact, and head reaction at contact should be made. There should be a noticeable change in the head movement at the time of contact.

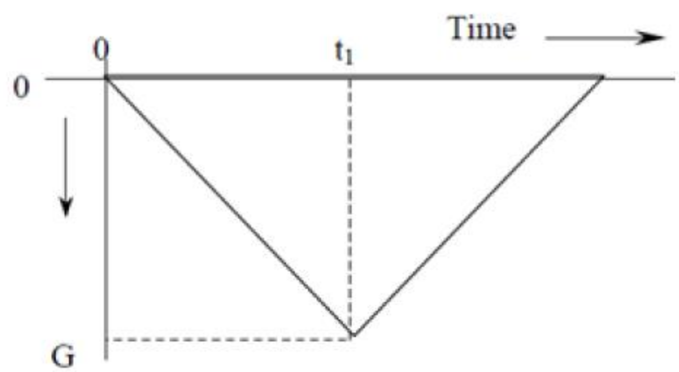
ii. A review and evaluation of the ATD head acceleration plots (x, y, z, and resultant) should be made. The resultant ATD head acceleration plot during the time period in which the critical HIC calculation was made should show an abrupt change in the head acceleration.

2. The restraint system, including the active restraint system, must provide adequate protection of occupants in conditions where the impact is below that at which the active restraint is designed to deploy *(applicable regulation: § 25.785(b))*.

Guidance: active restraint technology involves a step change in protection for impacts below and above that at which the device deploys. This could result in the HIC being higher at an intermediate impact condition than that resulting from the maximum impact condition. It is acceptable for the HIC to have such a non-linear or step change characteristic provided that the value does not exceed 1000 at any condition at which the active restraint does or does not deploy, up to the maximum severity pulse specified by the requirements.

The restraint system and surrounding configuration must be shown to produce HIC<1000 below the step change by test or a combination of test and analysis. When using test, an acceptable pulse shape prior to active restraint deployment is shown in the figure below. The pulse onset rate must be the same as the 16g pulse defined in AC 25.562-1B CHG1. The pulse parameters (G, t_1, velocity change) shall be selected based on the sensor parameters that activate the active restraint.

The magnitude of the required pulse shall not deviate below the ideal pulse by more than 0.5g until 1.33 t_1 is reached.



The ideal pulse is a symmetrical isosceles triangle

Note: conditions above that at which the active restraint *system deploys are addressed in Criterion 1 above.*

3. It must be shown that the active restraint provides adequate protection for each occupant regardless of the number of occupants of the seat assembly, considering that unoccupied seat places may have an active restraint *(applicable regulation: § 25.1301).*

No additional guidance needed.

4. It must be shown that the active restraint system is not susceptible to inadvertent deployment as a result of wear and tear, or inertial loads resulting from in-flight or

ground maneuvers or other operating and environmental conditions likely to be experienced in service *(applicable regulation: § 25.1309).*

Guidance: It should be shown that the active restraint functions properly after exposure to environmental conditions specified in a suitable industry standards such as DO-160. The following environmental test conditions should addressed:

- *Vibration*
- *Shock*
- *Extreme Temperatures*
- *Humidity*
- *Salt Spray*
- *Fungus*
- *Fluid Exposure*
- *Sand and Dust*

5. Deployment of the active restraint must not introduce injury mechanisms to the seated occupant or result in injuries that could impede rapid egress. This assessment should include an occupant who is in the brace position when the device deploys and an occupant whose belt is loosely fastened *(applicable regulation: § 25.1301).*

6. It must be shown that inadvertent deployment of the active restraint, during the most critical part of the flight, will either not cause a hazard to the airplane or its occupants, or it meets the requirement of § 25.1309(b). Both sitting and standing persons must be considered *(applicable regulation: § 25.1301)*.

Guidance: If an inadvertent deployment of the active restraint *could cause injury to persons, the airbag system is considered essential. If an inadvertent deployment of the airbag could cause a hazard to the airplane, the system is considered critical.*

7. If an airbag is used, it must be shown that it will not impede rapid egress of occupants 10 seconds after its deployment *(applicable regulation: § 25.803)*.

Guidance: Evaluation for occupant egress and life preserver retrieval may be accomplished using a completely empty airbag. The evaluation must show that the empty airbag may be readily moved to the side, if necessary, by the seated and belted occupant to retrieve a life preserver if installed. The evaluation for occupant egress must show that the empty airbag does not hinder the occupant from releasing the belt (if restraint includes the airbag) standing up and entering the main aisle, cross-aisle, or exit passageway. Furthermore, occupants using the aisles and passageways must be able to move without hindrance with empty airbags located in the likely positions resulting from occupants exiting the seats or positions resulting from post-deployment of an airbag at any unoccupied seat.

8. The active restraint system must be protected from lightning and HIRF *(applicable regulation: §§ 25.1316(b), 25.1317(c))*.

No additional guidance needed.

9. If an airbag is used, once deployed, it must not adversely affect the emergency lighting system For example, the airbag should not block proximity lights to the extent that the lights no longer meet their intended function *(applicable regulation: § 25.812)*.

Guidance: Evaluation of the effect on the emergency lighting system may be accomplished using a completely empty airbag. It should be assessed with the empty airbags located in the likely positions resulting from occupants exiting the seats or positions resulting from post-deployment of an airbag at any unoccupied seat.

10. It must be shown that the active restraint system will function properly after loss of normal airplane electrical power, and after a transverse separation of the fuselage at the most critical location *(applicable regulation: §§ 25.1301 & 25.1309)*.

Guidance: A separation at the location of the active restraint does not have to be considered

11. It must be shown that the airbag system will not release hazardous quantities of gas or particulate matter into the cabin *(applicable regulation: § 25.601)*.

Guidance: USCAR-24 and/or other applicable industry standard(s) may be used to show that the active restraint system will not release hazardous quantities of gas or particulate matter into the cabin.

12. The active restraint system installation must be protected from the effects of fire such that no hazard to occupants will result *(applicable regulation: § 25.601)*.

Guidance: Special conditions may apply if lithium batteries are used in the active restraint system.

13. For active restraint, there must be a means to verify the integrity of the activation system prior to each flight or it must be demonstrated to reliably operate between inspection intervals. The FAA considers the loss of the active restraint system deployment function alone (i.e., independent of the conditional event that requires the active restraint system deployment) is a major failure condition *(applicable regulation: §§ 25.1301 & 25.1309)*.

No additional guidance needed.

14. If an airbag is used, the airbag material may not have an average burn rate of greater than 2.5 inches/minute when tested using the horizontal flammability test as defined in part 25, appendix F, part I, paragraph (b)(5) (applicable regulation *§* 25.853).

No additional guidance needed.

15. If an airbag is used as part of the seat's occupant restraint (e.g., lap belt or shoulder harness), the design must prevent the airbag from being either incorrectly buckled or incorrectly installed such that the airbag would not properly deploy. Alternatively, it may be shown that such deployment is not hazardous to the occupant, and will provide the required head injury protection *(applicable regulation: § 25.601)*.

No additional guidance needed.

16. For structure-mounted airbags, the effects of the deflection and deformation of the structure to which the airbag is attached must be taken into account when evaluating deployment and location of the inflated airbag. The effect of loads imposed by airbag deployment, or stowed components where applicable, must also be taken into account *(applicable regulation: § 25.1301)*.

Guidance: If representative/production article is not used in dynamic test, then do static test at 9g to determine deformation/deflection - if deformation, run dynamic test with deformation represented in the test article.

17. For structure-mounted airbags, the applicant must provide installation limitations to ensure installation compatibility between the seat design and opposing monument or structure *(applicable regulation: § 25.1301)*.

Guidance: Any installation limitations should be documented in the applicable Instructions for Continued Airworthiness (ICA).

18. This guidance is not intended to be a comprehensive list of all regulations that could apply to an active restraint system. Therefore, all regulations that could apply to installed equipment should be assessed for their applicability to the active restraint systems. For example, some of the 17XX series regulations may apply.

Guidance: For these general regulations, there is no unique guidance that apply specifically to active restraint systems.

4.4.1.6 Life Preserver Requirement for Part 25 Aircraft 14 CFR §§ 25.1411, 25.1415

Recommendation Summary:

Given the current common practice of installing of passenger seats without flotation seat cushions and the need to continue to provide a method of flotation for all passengers, it is recommended that all part 25 aircraft, regardless of whether or not the aircraft is certified for ditching, have life preservers installed instead of just seat flotation cushion.

Statement of the Issue:

Passenger survivability in an aircraft accident is dependent on multiple factors including certification standards for crashworthiness and ditching, and cabin crew evacuation procedures. Passenger survival rates are improved when they are informed about the correct use of equipment and the actions they should take in the event of an emergency situation. Some aircraft currently carry only one type of personal passenger flotation equipment, other aircraft can carry both a life preserver and a seat flotation cushion. Often though, the required passenger safety information briefing card might depict both life preservers vests and seat cushions. This can create passenger confusion as to which type of equipment is actually provisioned on the aircraft if an explicit verbal emergency briefing is not provided. Adding to this confusion is the current practice that the safety briefing cards combine overwater (ditching) and non-overwater equipped aircraft on the same card. While the crew on board may know whether the aircraft is an overwater equipped aircraft, the average passenger does not.

To avoid confusion to passengers and improve occupant survivability, it is suggested that future aircraft be provisioned with one type of personal flotation equipment - specifically a life preserver which provides higher buoyancy and water stability than a seat cushion. This would alleviate passengers having to guess which type of equipment is provisioned on the aircraft.

In addition to enhancing passenger safety, the recommendation would provide a level of harmonization with other regulatory authorities' operational rules that require life preservers as their only acceptable flotation means.

Proposed Recommendation(s)

It is proposed that§ 25.1411 be revised to require that an approved life preserver be provided for each airplane occupant, regardless of whether the aircraft is certified for ditching or not. The FAA should also provide additional guidance to enhance the stowage provisions and accessibility of life preservers as required in §25.1415.

The current and proposed regulatory text that would require life preservers instead of seat flotation cushions is provided below.

Rationale for Recommendation(s)

The U.S. National Transportation Safety Board (NTSB) has conducted studies on overwater emergency equipment and made recommendations for improvements based on their study and accident investigation reports. One recommendation from the NTSB was that Parts 121 and 135 be amended to require that, for passenger carrying operations under these parts have both life preservers <u>and</u> flotation seat cushions installed. The merit in providing two means of individual flotation is recognized. The life preserver would act as the primary individual flotation method. Seat cushions would be a back-up flotation means.

There is substantial literature that describes the parameters of human survival in water. To generally summarize the subject, the colder the water temperature, the faster the body's core temperature will drop numbing the extremities to the point of uselessness. Eventually hypothermia (exposure) sets in, and without rescue and proper first aid treatment, unconsciousness and death follow. Many factors can influence survival, including the use of flotation equipment. If it is not possible to keep the body out of the water, another important aspect is keeping the body afloat, specifically keeping the head and mouth out of the water to reduce the likelihood of drowning. For purposes of survivability, although the seat cushions have merit, the life preserver provides superior flotation properties over seat cushions. And utilizing both devices at the same time would be difficult at best. Therefore it is recommended that all Part 25 aircraft be equipped with life preservers.

Current FAA Regulations

§ 25.1411

General.

(a) Accessibility. Required safety equipment to be used by the crew in an emergency must be readily accessible.
(b) Stowage provisions. Stowage provisions for required emergency equipment must be furnished and must—

> *(1) Be arranged so that the equipment is directly accessible and its location is obvious; and*
> *(2) Protect the safety equipment from inadvertent damage.*

(c) Emergency exit descent device. The stowage provisions for the emergency exit descent devices required by Sec. 25.810(a) must be at each exit for which they are intended.]
(d) Liferafts.

> *(1) The stowage provisions for the liferafts described in Sec. 25.1415 must accommodate enough rafts for the maximum number of occupants for which certification for ditching is requested.*
> *(2) Liferafts must be stowed near exits through which the rafts can be launched during an unplanned ditching.*
> *(3) Rafts automatically or remotely released outside the airplane must be attached to the airplane by means of the static line prescribed in Sec. 25.1415.*
> *(4) The stowage provisions for each portable liferaft must allow rapid detachment and removal of the raft for use at other than the intended exits.*

(e) Long-range signaling device. The stowage provisions for the long-range signaling device required by Sec. 25.1415 must be near an exit available during an unplanned ditching.
(f) Life preserver stowage provisions. The stowage provisions for life preservers described in Sec. 25.1415 must accommodate one life preserver for each occupant for which certification for ditching is requested. Each life preserver must be within easy reach of each seated occupant.
(g) Life line stowage provisions. If certification for ditching under Sec. 25.801 is requested, there must be provisions to store life lines. These provisions must—

> *(1) Allow one life line to be attached to each side of the fuselage; and*
> *(2) Be arranged to allow the life lines to be used to enable the occupants to stay on the wing after ditching.*

§ 25.1415

Ditching equipment.
(a) The following equipment is required for airplanes to be certificated for ditching under Sec. 25.801:
(b) Each life raft and each life preserver must be approved. In addition—

> *(1) Unless excess rafts of enough capacity are provided, the buoyancy and seating capacity beyond the rated capacity of the rafts must accommodate all occupants of the airplane in the event of a loss of one raft of the largest rated capacity; and*

(2) Each raft must have a trailing line, and must have a static line designed to hold the raft near the airplane but to release it if the airplane becomes totally submerged.
(c) Approved survival equipment must be attached to each life raft.
(d) There must be an approved survival type emergency locator transmitter for use in one life raft.
(e) For airplanes not certificated for ditching under Sec. 25.801 and not having approved life preservers, there must be an approved flotation means for each occupant. This means must be within easy reach of each seated occupant and must be readily removable from the airplane.

Proposed FAA Regulations

§ 25.1411

General.
(a) *Accessibility.* Required safety equipment to be used by the crew in an emergency must be readily accessible.
(b) *Stowage provisions.* Stowage provisions for required emergency equipment must be furnished and must—
(1) Be arranged so that the equipment is directly accessible and its location is obvious; and
(2) Protect the safety equipment from inadvertent damage.
(c) *Life preserver stowage provisions.* The stowage provisions for life preservers described in Sec. 25.1415 must accommodate one life preserver for each occupant.
(1) A life preserver must be within easy reach of each seated occupant.
….

§ 25.1415

Ditching equipment.
(a) An approved life preserver must be provided for each airplane occupant.
….

4.4.1.6.1 FAA – EASA Harmonization

It is suggested that EASA harmonize with this proposed FAA revision.

4.4.1.7 Life Lines – 14 CFR §§ 25.1411(g), 91.509(b)(5)

Recommendation Summary:

Given the lack of awareness related to the availability of the life line, the lack of actual use in multiple events, and the difficulties with the actual use of the life line in ditching events, it is recommended that the regulatory requirement for life lines and the associated attachment eyelet on the wing be deleted.

Statement of the Issue:

Life lines are required by 14 CFR 91.509(b)(5), "Survival Equipment for Overwater Operations." A life line is intended to be mounted to the airplane fuselage and then anchored to a point on the wing by an evacuee. This has been a requirement for overwater operations since June 26, 1979.

A life line is intended to be used by people who evacuate through an overwing exit to stabilize themselves while on the wing of the airplane following a ditching. Airplanes that do not have wings as evacuation routes are not required to provide a life line.

Section 25.1411(g) states that there must be provisions to store life lines and that these provisions must allow one life line to be attached to each side of the fuselage and arranged to allow the life lines to enable the occupants to stay on the wing after ditching. This has been a requirement since February 1965. Life line stowage provisions are not required for airplanes that do not have ditching exits that lead evacuees on to the wing.

There have been no relevant changes to these regulatory requirements since their introduction.

Proposed Recommendation(s)

1) The FAA should delete the reference to the requirement for life line stowage provisions as stipulated in §25.1411(g) for new design aircraft.
2) The FAA should also delete the requirement for life lines in §91.509(b)(5) as part of required survival equipment for overwater operations for new design aircraft.
3) For current in-service aircraft with life lines included, the FAA should finalize the FAA activity to update advisory guidance material to relay information to passengers on the availability, stowage and use of life lines on aircraft equipped with life lines.

While there have been a large number of accident that have involved a ditching, there were only two notable accidents that contained a reference to the use of life lines in the final accident reports. These included the Boeing 737 accident at LaGuardia on September 20th, 1989 and the Airbus A320 accident on the Hudson River on January 15th, 2009.[3]

> "On September 20, 1989, at approximately 2322, USAir Flight 5050, a Boeing 737-400, with six crewmembers and 57 passengers onboard overran the end of the runway 31 at LaGuardia airport, Flushing, New York, as a result of a rejected takeoff. The airplane collided with a wooden airport approach light stanchion and the waters of Bowery Bay off the end of the runway. The forward portion of the airplane came to rest on a portion of the elevated light stanchion

[3] DOT/FAA/TC-14/8, Review and Assessment of Transport Category Airplane Ditching Standards and Requirements, May 2015

> and the aft portion was partially submerged in the water. The fuselage separated into three sections. Two passengers were fatally injured."[4]

The National Transportation Safety Board (NTSB) Aircraft Accident Report NTSB/AAR-90/03 noted that the airplane had four type III overwing exits, two hatches on the left and two hatches on the right. During the examination of the overwing exit area it was noted that someone "…unstowed the fabric ditching line from above a left overwing exit and tied it to its wing fitting." About 20 passengers stood on the left wing which was out of the water and held onto the line as they awaited rescue. The right wing ditching line was unstowed but passengers did not know that it needed to be tied to the right wing fitting. Despite the line not being attached to the wing fitting, passengers held onto the line so they could stay out of the water. The forward portion of the right wing was out of the water.

The NTSB did not make any specific findings or recommendations regarding the use of life lines in this accident.

We also reviewed the most recent example of a ditching for references to the use of life lines – US Airways Flight 1549, NTSB Aircraft Accident Report NTSB/AAR-10/03.

> "On January 15, 2009, about 1527 eastern standard time, US Airways flight 1549, an Airbus Industrie A320-214, N106US, experienced an almost complete loss of thrust in both engines after encountering a flock of birds and was subsequently ditched on the Hudson River about 8.5 miles from LaGuardia Airport (LGA), New York City, New York. The flight was en route to Charlotte Douglas International Airport, Charlotte, North Carolina, and had departed LGA about 2 minutes before the in-flight event occurred. The 150 passengers, including a lap-held child, and 5 crewmembers evacuated the airplane via the forward and overwing exits. One flight attendant and four passengers were seriously injured, and the airplane was substantially damaged."[5]

The accident report indicates that the ditching was into calm water allowing many passengers to stand on the wing after evacuating the airplane. The report notes that about 87 occupants were rescued from the wings and off-wing ramp/slides, which were neither detachable nor considered part of the airplane's extended overwater emergency equipment, and that at least 9 passengers unintentionally fell into the water from the wings. Although the airplane continued to float for some time, many of the passengers who evacuated onto the wings were exposed to water up to their waists within 2 minutes. The NTSB concluded that if the rescue vessels had not been near the accident site, it is likely that some of the airplane occupants would have drowned due to cold shock or swimming failure.

Although all of US Airways' A320 extended overwater airplanes were equipped with life lines in accordance with 14 CFR 91.509(b)(5), neither the crew nor the passengers onboard the airplane attempted to utilize the life lines during the evacuation. The accident report states that "…it is unclear under what circumstances the life lines could

[4] NTSB/AAR-90/03, USAir, Inc., Boeing 737-400, LaGuardia Airport, Flushing, New York, September 20, 1989. Survival Factors Group Chairman's Factual Report of Investigation, Docket No. SA—791, Exhibit No. 6A.
[5] NTSB/AAR-10/03, US Airways, Airbus A320-214, Weehawken, New Jersey, January 15, 2009.

be used effectively..." and that "…the NTSB fails to see how life lines will be effectively used."[6] Overwing exits will typically be opened by passengers, as these exits are not considered a primary exit for flight attendants. Given that information about the life lines is generally not relayed to passengers during the pre-flight safety briefing or individual exit-row briefings and that flight attendants will be unable to reach the overwing exits during an unexpected emergency, the passengers will likely not see or understand the purpose of the life lines and they will go unutilized.

The accident report did suggest that if the life lines had been retrieved, they could have been used to assist passengers on both wings, possibly preventing passengers from falling into the water. However, unless adequate information is provided to passengers about the life lines, they will likely continue to not be effectively retrieved and used even if they are provided on the airplane. Therefore, the NTSB recommended that operators provide information about life lines, if the airplane is equipped with them, to passengers to ensure that the life lines can be quickly and effectively retrieved and used. (A-10-81)

As noted earlier, only one accident was found where the life lines were utilized, and even in that situation there was difficulty attaching the end of the life line to the attachment point on the wing. In the majority of the accidents, including events where the airplane was partially in water, the life lines do not appear to have been used. It is worth noting that even in some of the partial water/land events, there were instances where the complete wing structure was not visible due to water or impact damage, again making the location of the eyelet attachment point difficult to find.

During Team 4 discussions we also noted that existing life lines are typically so short and the geometry of their attachment points so shallow that their use could result in people staying close to the window exit instead of moving further out on the wing. This could result in a crowd near the exit that could block others from evacuating out of the aircraft. In relation to its current design, it was discussed that very few people would likely be able to make use of the life line due to its short length and that once the life line is attached to the wing it could also pose a tripping hazard to the evacuees on the wing. However, there could still be some benefit to evacuees of smaller airplanes that may be more susceptible to wave action while at rest in the water.

The team noted that should the FAA not agree with the recommendation to remove the requirements for life lines on future design aircraft, the FAA should at a minimum begin research and development of a better designed life lines including the attachment point on the wing.

Proposed Changes to the FAA Regulations:

Delete the references to life lines in the two regulations noted below.

Current FAA Regulation: 14 CFR 91.509(b)(5)

[6] NTSB/AAR-10/03; page 110.

This regulation requires that there be survival equipment for overwater operations, specifically that a life line be stored in accordance with §25.1411(g).

§91.509 Survival equipment for overwater operations.

(b) Except as provided in paragraph (c) of this section, no person may take off an airplane for flight over water more than 30 minutes flying time or 100 nautical miles from the nearest shore, whichever is less, unless it has on board the following survival equipment

….

~~(5) A lifeline stored in accordance with §25.1411(g) of this chapter.~~

Current FAA Regulation: 14 CFR 25.1411(g)

This regulation addresses the stowage provisions of the life line, specifically if certification for ditching under §25.801 is requested.

§25.1411 General.

(a) *Accessibility*. Required safety equipment to be used by the crew in an emergency must be readily accessible.

….

~~(g) *Life line stowage provisions*. If certification for ditching under §25.801 is requested, there must be provisions to store life lines. These provisions must –~~

~~(1) Allow one life line to be attached to each side of the fuselage; and~~

~~(2) Be arranged to allow the life lines to be used to enable the occupants to stay on the wing after ditching.~~

4.4.1.7.1 FAA – EASA Harmonization

Current EASA Regulation: CS 25.1411(g)

This regulation addresses the stowage provisions of the life line, specifically if certification for ditching under CS 25.801 is requested.

Proposed Recommendation to EASA: CS 25.1411(g) should be harmonized with the above proposed change to the FAA regulation (i.e. the requirement for life line stowage provisions should be removed).

4.4.1.8 Survival Equipment for Rafts– 14 CFR § 25.1415(c)

Recommendation Summary:

Harmonize with the European Aviation Safety Agency (EASA) CS 25.1415(c) related to the stowage or attachment of survival equipment as referenced in the life raft TSO-C70b, including *SAE International Aerospace Standard (AS) AS1356, Life Rafts, dated July 2012, as modified by Appendix 1 of this TSO."* The life raft equipment needed to support survival of occupants following a ditching event is defined in these documents. This recommendation defines appropriate stowage locations for the survival kit contents on or in slide/rafts attached to emergency exits; and the survival kit contents for rafts stowed remotely. Nothing in this document shall prohibit the air carrier from providing additional equipment in either the slide/raft or rafts.

Statement of the Issue:

The current FAA regulations related to ditching go back to the early 1950s and are focused on planned ditching events that occur in open seas on extended overwater fights. Regulations[7] also focused on equipment necessary for survival on the open seas, specifically life rafts and associated survival equipment for use in the life rafts to enhance the possibility of survival. The approved survival equipment was required to be attached to each liferaft. A list of suggested items that should be carried during extended overwater operations is provided in Appendix A. A single long-range signaling device was also required to be available for use in one of the rafts. In the 1960s the combination emergency escape slide and life raft, known as the "slide/raft" was designed and demonstrated. Although slide/rafts are not currently specifically addressed in the regulations, they are required to be equipped with the same survival equipment as life rafts when utilized on extended overwater operations as the designated life rafts for that flight. Slide/raft size can be limited by the mounting space available on the door. This also results in limited packing space for the contents of a survival kit inside the slide/raft. One option is to limit the amount of items required to be packed inside the slide/raft. This would not affect the items in a life raft.

EASA CS 25.1415(c) allows the survival kit to be installed adjacent to a life raft. The FAA also allows this on a case by case basis via an ELOS or exemption. Because the term slide/raft has yet to be codified, some regulatory language references "life raft" but can imply "slide/raft" in relation to equipment. Team 4 proposes to harmonize with EASA related to remote stowage of the survival kits in limited circumstances. However, the team also noted that remote stowage of the survival kit increases the likelihood that it will not be retrieved after a water landing resulting in the contents not be usable or available and can result in loss of life.

Ultimately, the best solution is that the survival kit should always be stowed inside or attached to the raft or slide raft. Raft stowage remote from an exit, i.e., ceiling compartment, overhead stowage bin, has adequate space for inclusion of full survival kit packed inside the raft or attached directly to the raft. This requirement would not change.

[7] Doc. No. 5066, 29 FR 18291, Dec. 24, 1964

In the situation of slide/rafts, the limited door and packing space has resulted in approval of "pre-positioning" survival kits for a ditching impact. Some of the survival kit items are packed in the slide/raft while some of the other remaining survival kit items are stowed remotely from the slide/raft and are manually attached to the slide/raft by a hook or other method at the specific emergency exit. This document will clarify which items must be packed in the slide/raft and which items can be stowed remotely for attachment prior to impact. If this option of pre-positioning is continued, a better method of securing the survival kit should be developed for future aircraft.

Rationale:

Research of past accidents on both land and in the water was conducted by Team 1, the data from that team has been used to propose changes to part 25 regulations and guidance to bring them up to date with the current state of the jet transport fleet. Related to ditching, one of the objectives is to change the focus of ditching certification requirements and guidance from a planned event that occurs at sea during an extended overwater operation to an unplanned event near shore that allows little or no time to prepare the airplane or the passengers. This proposal regarding required survival equipment packed or attached to slide/rafts is consistent with that objective.

TSO C70b specifies that "*new models of life rafts identified and manufactured on or after the effective date of this TSO must meet the requirements in SAE International Aerospace Standard (AS) AS1356, Life Rafts, dated July 2012, as modified by Appendix 1 of this TSO.*" AS1356 specifies the following safety equipment that must be provided with or attached to each raft:

- Canopy
- Manual Inflation Means (Pump)
- Water Removal Device (Bailer)
- Sponge
- Repair Means
- Immediate Action Instructions
- Mooring Line (mounted on raft)
- Lifeline - Grab Line
- Sea Anchor (Drogue) (mounted on raft)
- Heaving-Trailing Line and Rescue Quoit (mounted on raft)
- Hook Knife (mounted on raft)
- Lights - Internal and External (mounted on raft)
- Entry/Boarding Station (mounted on raft)

The above equipment supports short term survival. Other equipment, as suggested in Appendix A, for longer term survival would be added by an air carrier to their extended overwater survival kits that are packed inside rafts or attached to slide/rafts. As example, many air carriers currently provide signally devices like flares or sea dye markers, mirrors, and water purification tablets or kits. There should be no change to the items required in survival kits for extended overwater operations. While emphasis is moving to water events closer to shore, the possibility of a ditching on the open ocean still remains, therefore aircraft certified for extended overwater operations should still be provisioned with the full amount of equipment to enhance survivability until rescue. Raft stowage remote from an exit, i.e., ceiling compartment, overhead stowage bin, has adequate space for inclusion of full survival kit packed inside the raft or attached to raft. This requirement would not change

Again, while long term survival equipment is still necessary, team 4 acknowledges the limited space on emergency doors for the mounting of slide/rafts, thereby also limiting the amount of packing space inside the slide/raft. The proposed change is related to slide/rafts mounted on doors and the ability to limit the contents packed inside the slide/raft with the remaining items stowed remotely from the slide/raft. This would be a regulatory change from current US FAA regulations, 14 CFR 25.1415(c), that require that approved survival equipment must be attached to each life raft, which can be difficult due to the size restrictions of slide/rafts mounted on emergency exits. EASA CS 25.1415(c) currently allows the survival kit equipment to be installed adjacent to the life raft, in this instance, slide/raft. The FAA also allows this on a case by case basis via an ELOS or exemption.

Harmonizing with the EASA rule and providing AC guidance that provides the conditions and criteria associated with an adjacent installation of a survival kits related to slide/rafts mounted on evacuation doors will allow for installation flexibility without the need to process an FAA ELOS or exemption (i.e., it will standardize and streamline the certification processes).

Proposal:

> It is recommended that the FAA revise 14 CFR 25.1415(c) to allow survival equipment to be stowed adjacent to each liferaft. Guidance would reflect that remote stowage of the equipment for slide/rafts would be permitted as a means of compliance with the regulation.

Current FAA Regulation: 14 CFR 25.1415(c)
Approved survival equipment must be attached to each life raft

Proposed Change to the FAA Regulation:
Approved survival equipment must be attached to, or stored adjacent to, each liferaft.

Current EASA Regulation: CS 25.1415(c)
Approved survival equipment must be attached to, or stored adjacent to, each liferaft.

Proposed Recommendation to EASA: EASA guidance should be harmonized with the below proposed change to FAA Guidance.

Proposed Change to FAA Guidance (New Ditching AC (if one is created) and/or AC 25-17A):
For **rafts** stowed remotely from exit, the suggested survival equipment addressed in § 25.1415(c) shall, at a minimum, be packed in the raft or attached to the raft in the same compartment, and include the following equipment. Additional equipment referenced in TSO C70b and AS1356 would also need to be included, so this list may not be all inclusive.

Mounted on Raft:

- Immediate Action Instructions
- Mooring Line
- Sea Anchor (Drogue)
- Heaving-Trailing Line and Rescue Quoit
- Lifeline - Grab Line
- Hook Knife
- Light - Internal and External
- Entry/Boarding Station

In Survival Kits attached to the raft in the same compartment:

- Canopy
- Manual Inflation Means (Pump)
- Water Removal Device (Bailer)
- Sponge
- Repair Means
- Signaling devices (e.g. mirror, dye markers)
- First aid items

For slide/rafts stowed on an emergency exits, the approved survival equipment referenced in § 25.1415(c) shall, at a minimum, be packed in the slide/raft and include the following equipment:

Packed/Mounted on Slide/Raft:

- Immediate Action Instructions
- Mooring Line
- Sea Anchor (Drogue)
- Lifeline - Grab Line
- Hook Knife
- Light - Internal and External
- Entry/Boarding Station

In Survival Kit for use in slide/rafts, the following items may be stowed remotely for use in preparation for a ditching or collection after the ditched evacuation has started. Additional equipment referenced in TSO C70b and AS1356 would also need to be included in the remotely stowed survival kit for use in the slide/raft, so this list may not be all inclusive.

- Canopy
- Manual Inflation Means (Pump)
- Water Removal Device (Bailer)
- Sponge
- Repair means
- Signaling devices (e.g. mirror, dye markers)

- First aid items

.

4.4.1.8.1 FAA – EASA Harmonization

Recommend EASA harmonize CS §§25.1411 and 25.1415 for same rationale and consistency with CFRs.

4.4.1.9 Reorganization 14 CFR §§ 25.1411, 25.1415

Recommendation Summary:

Reorganize 25.1411 and 25.1415 and acknowledge the limitation of "portability" of some slide/rafts and the need for extra group.

Statement of the Issue:

The Transport Airplane Crashworthiness and Ditching Working Group was formed by the Aviation Rulemaking Advisory Committee (ARAC), through the Transport Airplane and Engine (TAE) Subcommittee. During early meetings it was suggested by the full working group that 14 CFR 25.1411 and 25.1415 could be better organized. This committee has reviewed the current rule and assessed the need for changes to both the regulations.

Specifically the regulations were re-organized to create a better flow of the design and equipment requirements. This committee also noted that the issue of portability needed to be better addressed as new types of rafts are installed, specifically slide/rafts that may be stowed in dedicated stowage compartments outside of the passenger cabin, or slide/rafts that by their design needs are extremely heavy to be removed and transported through the aircraft to another door. These types of "non-portable" slide/rafts would require that it be assumed that there would be a loss of 50% of those non-portable slide/rafts. Those two items are specifically addressed in this recommendation.

The recommendation includes the prior recommendations addressed in sections 4.4.1.6 (life preservers), 4.4.1.7 (life lines), and 4.4.1.8 (survival kits).

Proposed Recommendation(s)

It is recommended that the FAA reorder 25.1411 and 25.1415 for clarity and simplification. Included in the proposal is the deletion of life lines and the requirement for life preservers for all aircraft.

It is also recommended to revise §25.1415 related to non-portable rafts. Rafts shall have a combined overload capacity to accommodate all occupants of the airplane in the event of a loss of:

(i) one portable raft with the largest overload capacity, and
(ii) 50% of the non-portable rafts

Rationale for Recommendation(s)

On January 22, 1991, (56 FR 2190) the FAA had established another ARAC to provide advice and recommendations concerning the full range of the FAA's safety-related rulemaking activity. One of the issues researched at the time was the utilization of slide/rafts onboard aircraft. The ARAC explored multiple proposed changes related to slide/rafts – some of which we have utilized for this proposed recommendation. Some of the language from that previous rulemaking initiative is included in Appendix D for historical purposes.

Current FAA Regulations

§ 25.1411
General.

(a) Accessibility. Required safety equipment to be used by the crew in an emergency must be readily accessible.
(b) Stowage provisions. Stowage provisions for required emergency equipment must be furnished and must—
> *(1) Be arranged so that the equipment is directly accessible and its location is obvious; and*
> *(2) Protect the safety equipment from inadvertent damage.*

(c) Emergency exit descent device. The stowage provisions for the emergency exit descent devices required by Sec. 25.810(a) must be at each exit for which they are intended.]
(d) Liferafts.
> *(1) The stowage provisions for the liferafts described in Sec. 25.1415 must accommodate enough rafts for the maximum number of occupants for which certification for ditching is requested.*
> *(2) Liferafts must be stowed near exits through which the rafts can be launched during an unplanned ditching.*
> *(3) Rafts automatically or remotely released outside the airplane must be attached to the airplane by means of the static line prescribed in Sec. 25.1415.*
> *(4) The stowage provisions for each portable liferaft must allow rapid detachment and removal of the raft for use at other than the intended exits.*

(e) Long-range signaling device. The stowage provisions for the long-range signaling device required by Sec. 25.1415 must be near an exit available during an unplanned ditching.
(f) Life preserver stowage provisions. The stowage provisions for life preservers described in Sec. 25.1415 must accommodate one life preserver for each occupant for which certification for ditching is requested. Each life preserver must be within easy reach of each seated occupant.
(g) Life line stowage provisions. If certification for ditching under Sec. 25.801 is requested, there must be provisions to store life lines. These provisions must—
> *(1) Allow one life line to be attached to each side of the fuselage; and*
> *(2) Be arranged to allow the life lines to be used to enable the occupants to stay on the wing after ditching.*

Sec. 25.1415

Ditching equipment.

(a) The following equipment is required for airplanes to be certificated for ditching under Sec. 25.801:

(b) Each life raft and each life preserver must be approved. In addition—

(1) Unless excess rafts of enough capacity are provided, the buoyancy and seating capacity beyond the rated capacity of the rafts must accommodate all occupants of the airplane in the event of a loss of one raft of the largest rated capacity; and

(2) Each raft must have a trailing line, and must have a static line designed to hold the raft near the airplane but to release it if the airplane becomes totally submerged.

(c) Approved survival equipment must be attached to each life raft.

(d) There must be an approved survival type emergency locator transmitter for use in one life raft.

(e) For airplanes not certificated for ditching under Sec. 25.801 and not having approved life preservers, there must be an approved flotation means for each occupant. This means must be within easy reach of each seated occupant and must be readily removable from the airplane.

Proposed FAA Regulations

§ 25.1411

General.

(a) *Accessibility.* Required safety equipment to be used by the crew in an emergency must be readily accessible.

(b) *Stowage provisions.* Stowage provisions for required emergency equipment must be furnished and must—

(1) Be arranged so that the equipment is directly accessible and its location is obvious; and

(2) Protect the safety equipment from inadvertent damage.

(c) *Life preserver stowage provisions.* The stowage provisions for life preservers described in Sec. 25.1415 must accommodate one life preserver for each occupant.

(1) A life preserver must be within easy reach of each seated occupant.

(d) If certification with ditching provisions is requested under Sec. 25.801, the following stowage provisions must be provided:

(1) *Rafts.* The stowage provisions for the rafts described in Sec. 25.1415 must accommodate enough rafts for the maximum number of occupants for which certification for ditching is requested.

(i) Rafts must be stowed near ditching exits.

(ii) The stowage provisions for each portable raft must allow rapid detachment and removal of the raft for use at other than the intended exits.

(iii) The stowage provisions for non-portable rafts must allow for use at the intended exit during a ditching.

(2) *Long-range signaling device.* The stowage provisions for the long-range signaling device required by Sec. 25.1415 must be near a ditching exit.

Sec. 25.1415

Ditching equipment.

(a) An approved life preserver must be provided for each airplane occupant.

(b)If certification with ditching provisions is requested under Sec. 25.801, the following equipment must be provided:

(1) Approved rafts that have a combined rated capacity that accommodates all airplane occupants. In addition—

(2) the rafts shall have a combined overload capacity to accommodate all occupants of the airplane in the event of a loss of:

(i) one portable raft with the largest overload capacity, and

(ii) 50% of the non-portable rafts

(3) Each raft must have a mooring line designed to hold the raft near the airplane but to release it if the airplane becomes totally submerged.

(i) Rafts automatically or remotely released outside the airplane must be attached to the airplane by the mooring line.

(4) Survival equipment must be attached to, or stored adjacent to, each raft.

(5) An approved survival type emergency locator transmitter for use in one raft.

4.4.1.9.1 FAA – EASA Harmonization

It is suggested that EASA harmonize with this proposed FAA revision of §§ 25.1411 and 25.1415.

4.4.2 Considerations for Harmonization with NAA

This working group engaged regulatory agencies from Brazil, Canada, China, Europe, and Japan. While the different agencies provided varying levels of participation, all were engaged and it is hoped that all will try to harmonize their rules and guidance consistent with what this body recommends.

4.4.3 Cost / Benefit Assessment

Airbus

Association of Flight Attendants

AFA lacks access to detailed technical design/analysis information necessary to provide a cost/benefit assessment.

Boeing Commercial / Military

Boeing collected cost and benefit data for the proposed revisions of 14 CFR 25.1411 and 25.1415 and associated guidance. It is anticipated that most of these changes will result in an overall neutral impact or small benefit of a cost savings.

Most of the improvement is due to harmonization, codifying some of the generic means of compliance. There may be a very slight weight reduction for the aircraft due to deletion of life line and simplification of the emergency kits resulting in 2 lbs of weight savings per aircraft. However, the addition of life preservers for all aircraft will be a weight penalty for some aircraft.

<u>Qualitative Assessment of the Cost vs. benefit</u>

Boeing believes the proposed revised rules and associated guidance will result in a neutral to minor reduction in costs in certifying future products. There is no anticipated adverse impact and minimal effect or societal impact due to the very rare occurrences of ditching events

The anticipated weight reduction is not large enough to be a significant benefit.

Due to the proprietary nature of the data, Boeing provided the cost benefit data to the FAA directly.

Bombardier

Bombardier believes that proposed revised rule and associated guidance will be cost neutral for the certification of the new A/C in the future.

Consequently no cost benefit analysis was provided to FAA.

Cascade Aerospace

Cascade Aerospace will abstain from providing detail cost data. It is difficult to determine a detail impact due to the variable nature of our business.

Dassault Aviation

Dassault Aviation believes that proposed changes for equipage and emergency evacuation rules does not have a significant impact on research and development, engineering, certification, production, operation or test costs.

Dassault Aviation believes a cost benefit analysis is not needed.

Embraer

Embraer found that the revised rules proposed for equipage and emergency evacuation protocol does not have a measurable impact on design, certification, production or operation of future aircraft. Derisory benefits are expected on survivability. A cost benefit analysis is not justified.

German Aerospace Center (DLR)

DLR's main contribution to the working group is related to crashworthiness. DLR has no cost or benefit data to provide for these proposed changes.

Gulfstream Aerospace Corporation

Mitsubishi Aircraft Corporation

National Aeronautics and Space Administration

Naval Air Systems Command

National Institute of Aircraft Research

NIAR does not have prior experience required to provide a cost benefit analysis.

Textron Aviation

Textron believes that proposed revised rule and associated guidance for equipage and emergency evacuation will be cost neutral for the certification of new aircraft.

Consequently no cost benefit analysis was provided to FAA.

Total cost / benefit summary for airframe revised ditching rule/guidance:

Roll up the total cost/benefit

5 Comments/Issues with Findings

This section will present the key conclusions and issues identified with final proposals from the group. Each team will provide detail documentation of issues with the findings.

5.1 Crashworthiness

5.1.1 Comments / Issues

For Crashworthiness (Team 2) compliance is based on a representative fuselage section (barrel) loaded by a vertical impact condition. It remains to be determined whether such a section is sufficiently representative of the crashworthiness behavior of a complete aircraft. Similarly, impact of such a barrel with a rigid surface is proposed, but how this relates to a more realistic impact scenario on different soils also remains to be investigated. In addition, the effect of the absence of any horizontal speed remains to be determined.

That said, NIAR has conducted studies introducing vertical only and a combination of vertical and horizontal velocity components and has observed that the damage and injuries to occupants are due to the vertical change of velocity. Changing the pitch, or roll angle introduces more variability on the section vertical drop test.

5.1.2 Future Considerations

Locking or auto-locking of overhead bins when seatbelt signs are illuminated in order to prevent unintended opening with release of contents that strike passengers and crew or block escape pathways.

5.2 Ditching

5.2.1 Comments / Issues

None identified.

5.2.2 Future Considerations

None identified.

5.3 Equipage and Protocol

5.3.1 Comments / Issues

None identified.

5.3.2 Future Considerations

None identified.

5.4 Identification of Issues beyond the Tasking

Team 4 (Equipage) members discussed the topic of crewmember training during meetings related to drafting new or revised Part 25 regulations or standards. Part 25 equipment requirements are designed to enhance occupant survival in both a crash and ditching scenario. However, it was noted that equipment utilization and effectiveness can be limited by ineffective crewmember training. One topic discussed was the issue of slide-raft portability.

As noted earlier in this document, early rafts were required to be portable, and that requirement remained even when the combination emergency escape slide and raft, known as the "slide/raft," began to be mounted on exit doors inside the cabin. Slide/raft portability is required in the event that a door is unable to be used in an emergency ditching or water impact event. In this situation, the slide/raft can be removed from the unusable door and transported to a different available and appropriate exit that would allow the use of the slide/raft. That transfer assumption also assumes a calm sea state. Current regulations account for the loss of one of the largest portable rafts under the assumption that only one door will be inoperative. Given the discussions in this report that acknowledge the possibility of a fuselage breach, future discussions on the assumption that only one door will become inoperative during a water impact event is warranted.

During the discussions on slide/raft portability there were also some comments by Team 4 working group members that Flight Attendants are assumed to be receiving active training and sufficient hands-on practice of slide/raft portability. The Association of Flight Attendants (AFA) conducted an informal survey in April 2017 of an International Civil Aviation Organization (ICAO) Cabin Working Group to ask if any international operator or Civil Aviation Authority conducts or requires actual hands-on training related to slide raft portability. Of the 32 attending organizations none of the attending air carriers or civil aviation authorities had accomplished this hands-on task nor required it in their cabin crew training. Most operators noted they show a video of the procedure to move a slide/raft from one door to another. Some attendees even noted that the requirement is unrealistic and likely could not be accomplished in a real world event that could include aircraft structural damage, followed by flooding and sinking of the aircraft.

Although team 4 did not present a formal recommendation related to Part 25 regulatory changes around slide/raft portability, the FAA did note that one suggestion for improving the utilization of a portable slide/raft in a water impact scenario is to review the training requirements and make suggestions for better training, including hands-on training. This is especially warranted considering the part 25 design requirement is based on an assumption of a specific operational requirement that may not be realistic in an actual emergency event. Future work is needed by the FAA to review the training requirements related to slide/raft portability and the feasibility of slide/raft portability design.

Overhead Bin Design Requirements

AFA, DLR and NASA support the following:

The text as it is written suggests that bins only have to withstand loading required in 14 CFR § 25.561, which are static loads. The new proposed rule is going to require dynamic loading environments, which will impose loads on the bins potentially higher than the previously defined static loads. A dynamic loading environment has the potential to create problems in certification if a statically qualified bin fails during the testing in the new proposed rule, since requirement (b)(i) states that occupants must be protected during the impact event from items which include bins, and requirement (b)(iv) states that egress paths must be maintained. This means that a statically certified bin which passes 14 CFR § 25.561 could potentially fail the new rule. Furthermore, the guidance (*Section 5.1 Airframe Crashworthiness Attributes in Appendix B*) states that the bins should not open, which implies that the bins be able to withstand the dynamic environment, suggesting differences in expectations in bin performance. NASA feels that this inconsistency should be addressed.

At a minimum, suggested harmonization of these guidelines would be to include text to state the bin must be able to withstand loads from the dynamic tests. A more robust solution would be to proposed a new rule for dynamic bin testing or requirements such that the bin requirements are harmonized with both the seat (14 CFR § 25.562) and airframe (this FAA ARAC task) dynamic requirements.

6 Recommendations

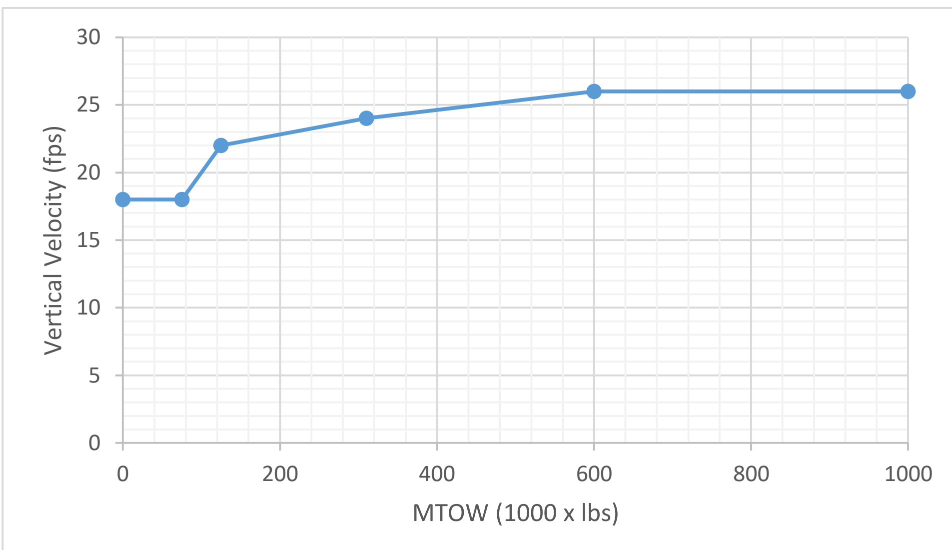
This section presents the final recommendations from the ARAC working group. Dissenting positions are also documented. This section also addresses the cost benefit analysis where participants provided cost and benefit data. Additional recommendations beyond the official scope of the tasking are also presented here. Future tasking recommendations are addressed as well.

6.1 Crashworthiness

6.1.1 Proposed Rule

25.XXX Airframe Crashworthiness Rule

(a) The fuselage structure, although it may be damaged in emergency landing conditions on land, must be designed as prescribed in this paragraph to provide for adequate occupant survivability during survivable crash events. In order to demonstrate adequate occupant survivability, compliance must be shown with the four criteria specified in subparagraph (b) under the following vertical impact conditions:



(b) Under the impact condition specified in subparagraph (a), compliance must be shown with the following four criteria addressing occupant survivability:

<u>(i) Retention of Items of Mass:</u> All occupants must be protected during the crash impact event from the release of seats, overhead bins, and other items of mass due to the impact loads and resultant structural deformations of the supporting airframe and floor structures.

(ii) <u>Maintenance of Acceptable Loads Experienced by the Occupants:</u> During the crash event the occupant injury criteria thresholds must not be exceeded for the load levels experienced by the occupants.

(iii) Maintenance of a Survivable Volume: All areas of the fuselage occupied by passengers for takeoff and landing must provide a survivable volume during the crash impact. Fuselage structural deformation will not result in infringement of the occupant's normal living space so that passenger survivability will not be significantly affected.

(iv) Maintenance of the Occupant Egress Paths: After the crash event, the fuselage structure must provide suitable egress paths to evacuate the occupants.

(c) As an alternative to subparagraphs (a) and (b), adequate occupant survivability can be demonstrated by showing an equivalent level of occupant survivability to those provided by previously certified transport category aircraft of similar size, design architecture, and material systems under survivable vertical crash events, provided that:

(i) The airplane does not have any design features or characteristics that have shown to be unsatisfactory with regard to occupant survivability;

(ii) The previously certified transport category aircraft does not exhibit an unsatisfactory service experience with regard to occupant survivability.

6.1.2 Dissenting Points

Airbus

Airbus dissenting position for the Appendix B guidance material

In chapter 5, for the subject maintenance of survivable volume, a criterion for overhead bins to not open has been added. Airbus do not agree that this should be a criterion for survivable volume. Overhead bins in general have been excluded from the assessment because of the reasons mentioned in paragraph 4.2.1.3. Moreover for the retention of items of mass subject, the static design condition versus 25.561 has been regarded as sufficient. As the new rule 25.xxx is an airframe requirement, Airbus do not wish to put additional design requirements on cabin interior components for which failure have been accepted to not add injuries or deaths in accidents in this report. That is why Airbus raises this dissenting opinion.

Airbus dissenting position for the Rule 25.xxx Airframe crashworthiness rule

The proposed new rule uses wording in paragraph b that is not clarified sufficiently in the appendix B guidance material. Paragraph (b)(i) states that "All occupants must be protected during the crash impact event…." . Paragraph (b)(iii) states that "All areas of the fuselage occupied by passengers for take off and landing must provide a survivable volume…". Literal reading of this rule, especially for the words "All", would lead to consider the complete fuselage in the compliance demonstration for all occupants, including front center and rear fuselage parts, not all of them being typical cylindrical fuselage sections.

When looking for guidance in the appendix B, incidental reference to this can be found. Chapter 5 refers to general capability of the airframe and that it is not intended to assess every seat location in the aircraft. Chapter 6.2.2 refers to representative fuselage section for test article selection that should encompass representative passenger areas of the plane for typical fuselage sections. Chapter 6.3.1 refers to a component level test representative of a typical passenger section. Chapter 6.3.2 refers to a fuselage test section chosen for analysis should encompass representative passenger areas of the plane. Nevertheless, interpretation of how to address the 25.xxx (b)(i) and (b)(iii) wording referring to all occupants and all areas of the fuselage could become controversial in an actual compliance activity. The Special Conditions on B787 and A350 have been quite clear in terms of allowing typical fuselage sections to be used for the compliance demonstration, while the appendix B guidance material is less clear what is expected to meet the rule. Airbus questions if the rule as it is written represents the current intent of what is expected to be demonstrated based on the Special Conditons by using the wording all occupants and all areas of the fuselage.

Concluding, as long as the 25.xxx rule refers to all occupants and all areas of the fuselage, and there is no clear and simple guidance on considering typical fuselage sections only for the compliance demonstration whether by design review, similarity, testing or analysis, Airbus is concerned with the complete crashworthiness package and raises therefore this dissenting opinion. It could be simply solved by changing the words “all” in to “the” and clarify in the guidance material that a typical fuselage section should be investigated for compliance demonstration.

Association of Flight Attendants – AFA

AFA is concerned about several significant aspects to the draft document; the three biggest of which are similarity, the rejection of dynamic loading/testing for overhead bins and PSUs, and the notion that several of the proposed recommendations were developed through general consensus. We have documented all three of these concerns in our dissenting statements. As we indicated in our dissent to Section 2.3 of the report, the FAA definition of “General Consensus” applies only if all members agree not to contest one or more proposed recommendations, even though some of the members may not agree with them, in the interest of supporting the document as a whole. ARM-001-015, February 2, 2015, p. 95 of 105. The ATCDWG report in its current form clearly does not meet this test, as it includes lengthy and significant dissent statements on a number of proposed recommendations from several different members, including AFA. Clearly, it is inaccurate to portray any proposed recommendations as having been achieved through general consensus if they are also weighed down by statements of dissent.

We do not concur that the current draft of the report reflects a consensus of recommendations the group would put forward (based on the dissents we and a few others have written regarding several key aspects of multiple recommendations, including similarity and the rejection of dynamic loading/testing), and so do not concur that the report as written should go forward. This best captures our perspective on "concurrence." If the ATCDWG has a different perspective on what it is seeking from a statement of concurrence, we have requested an explanation from the Chair on his meaning of the term with the group so we can better understand it.

It is AFA’s position that our disagreements with this report are so serious that we do not concur or agree that it is ready to be submitted from the ATCDWG to TAE. In particular, AFA believes that the existing process of obtaining Special Conditions for certification of the products in question is preferable to using an undefined term (similarity) in a new regulation to serve as a fulcrum for certification. For this reason alone, AFA does not concur with forwarding the report to TAE.

While there may still be a potential for reaching general consensus on each specific recommendation and the entire document, previous attempts to do so have been unsuccessful and AFA is pessimistic that further efforts will succeed. Therefore, AFA recommends that the report state that there is strong, unreconciled disagreement on specific issues, and drop any mentions of general consensus with respect to recommendations that are rejected or challenged by one or more dissent statements. In conclusion, AFA believes that the report, where there is disagreement, should highlight differences in specific recommendations. If this is done, the report would be a more accurate reflection of the working group findings.

Use of the “similarity” concept is proposed as a means of achieving compromise within the working group. Unfortunately, the Report proposes this concept but fails to define it in a way that would allow an applicant to specify when similarity applies and when it doesn't. Section 4.2.1.5, Use of Similarity, states that a design review that is unable to identify key features "that would require additional investigation with respect to energy absorption capability or as potential threats to occupants in a crash may be a starting point of a similarity assessment." This section goes on to state that "[u]ltimately the end result should conclude that the fuselage is sufficiently similar to the previous acceptable model that it can be assumed the design provides similarly acceptable crashworthiness protection to the passengers." But this is not a definition; it is instead a circular argument: you will know similarity when you see it. Ultimately, it lacks the quantitative (and even qualitative) rigor needed for a regulatory standard. Given this lack of clarity, AFA does not support the use of similarity.

In addition, AFA supports almost entirely the dissent statements of the German Aerospace Center (DLR) in Sections 4.2.5.2 (cost benefit), 6.1.2, and 6.1.4. The only exception to this support is that AFA disagrees with the DLR conclusion that use of design review (similarity) may be appropriately applied to conventional airframe designs with traditional metallic materials.

AFA supports the comments of DLR, EASA and NASA related to addressing/inclusion of overhead bin structures in the recommendations of the Transport Airplane Crashworthiness and Ditching Working Group.

The background of the tasking explains under Crashworthiness Factors that “Maintaining the integrity of the structures is a balance between keeping loads within human tolerance levels, retaining items of mass, preserving a survivable volume and maintaining access to exits.”

The current requirements for certification of overhead stowage bins/PSUs installed in aircraft built with metallic materials are insufficient to protect occupants from the hazards of being struck or having their emergency evacuation path(s) obstructed or blocked. In aircraft built with nonmetallic materials, there also is a need for dynamic testing of overhead bins/PSUs to better prevent their detachment and injury to occupants and blockage of their emergency egress. Reference 15 summarizes drop impact tests conducted by the FAA from 1991 to 2000 on narrow body aircraft fuselage sections, and states in its executive summary that “overhead stowage bins experienced dynamic load factors in excess of 15-g vertical (twice the required static value). The static and dynamic vertical component influence coefficients differed by 30 percent." Therefore, dynamic testing of these structures should be specifically included in the Transport Airplane Crashworthiness and Ditching Working Group recommendations.

Finally, AFA disagrees with characterizing several of the working group decisions and recommendations as having been determined through "general consensus." Specifically, general consensus is claimed in the Executive Summary and Sections 4.2.1.3, 4.2.2, and 4.3.1. According to Reference 16, ARAC Manual Ch. 4 Consensus (p. 95):

> "General consensus: Although there may be disagreement, the group has heard, recognized, acknowledged, and reconciled the concerns or objections to the general acceptance of the group. Although not every member fully agrees in context and principle, all members support the overall position and agree not to object to the proposed recommendation report.
>
> "Dissent: A differing in opinions about the specific course of action. There may be times when one, some, or all members do not agree with the recommendation or cannot reach agreement on a recommendation."

Clearly, the recommendations cited above do not reflect general consensus of the working group members; they were instead obtained through a process of voting and the filing of written dissents.

Airbus and Boeing

Airbus and Boeing believe that the proposed rule developed by this team is the best that can be put forward at this time if an airframe level rule is absolutely necessary. Although we have cooperatively worked with the team to develop the proposed airframe crashworthiness rules we are still concerned that the potential additional costs for new design and amended type certificates / derivatives will not be commensurate with the level of safety improvement. Airbus and Boeing have provided costs for conventional derivatives and new aircraft as well as new and novel aircraft directly to the FAA.

We are concerned, because a new FAA rule will require a showing of compliance for every product. Costs for a potential new and novel design would be high for the proposed new airframe crash rule and potentially high in the case of a special condition. However, applicants can still negotiate the terms of the special condition whereas there is no room for negotiation if it was a rule. Additionally, there currently are no added costs associated with airframe crashworthiness for simple derivatives of conventional configuration. Derivative or ATC projects are more common than full new and novel Type Design projects. The proposed rule would require a showing of compliance by providing a design configuration comparison as a minimum. Although the TACDWG tasking states that conventionally configured airplanes fabricated with typical metallic materials and design details should be allowed to meet the proposed regulations without extensive investigation or documentation, Boeing and Airbus believe that the currently defined guidance will not be able to achieve this. The amount of justification and documentation as part of the design review will depend strongly on the interpretation of the regulator applied to a specific project, specifically on the depth of design review versus the 4 criteria and the identification of potential unsatisfactory characteristics for crashworthiness. There is a high probability that the effort will be extensive, and will have a tendency to increase over time. Also, any validating Authority might question the qualitative design review performed leading to additional activities in case of disagreement. It is noted that the Changed Product Rule per Part21 will provide little protection as it is believed that design evolutions of derivatives will quickly fall in the affected area classification for crashworthiness.

For these reason Airbus and Boeing believe it is premature to create a new airframe level rule. The special conditions should continue to be refined and applied when appropriate alleviating additional burdens for designs that are acceptable by inspection.

Bombardier

BA has participated with the TACDWG to help developing the new crashworthiness rules. However BA believes that anticipated costs of meeting the new crashworthiness rules are not commensurate with the level of safety improvement. Although the new rule could standardize/align authorities' approach for all OEMs, Bombardier concern is that the new FAA rule could be interpreted differently when applied across OEMs.

Showing compliance by similarity will have smaller impact when compared with compliance by Analysis / Simulation or testing validation. However the agreement with authorities to apply only similarity approach will have to be in early phase of the project when the design maturity is not in place. If similarity approach is expanded to some level of simulation and/or testing it would significantly increase the cost and affect the schedule.

Totally new designs will be affected by significant development cost increase.
Showing compliance by test only (for BA passenger and larger business aircraft) may require multiple expensive drop tests to address all 4 criteria. This would be <u>very</u> expensive.
Showing compliance by analysis/simulation would significantly increase the cost associated to:

i. Manpower required for extensive FEM/LSDYNA simulation (iterative process),
ii. Generating test data required for FEM validation

Dassault Aviation

Dassault Aviation dissenting position is based on following issues:

- The current fleet level of safety is satisfactory. We believe this is related to the design and engineering implementation of the current requirements on strength, fatigue, damage tolerance, and minor crash applied by OEMs all over the world and leading to an equivalent satisfactory level of safety.
- Both Airbus and Boeing experience has shown (as explained to the group during first meetings) that the application of the SC have not lead to any or to minor changes in the design, thus not significantly improving the level of safety, but increasing significantly the cost for showing compliance.
- Only very few research have been performed on small part 25 A/C during the past years, and very few accident data are available for these A/C. The applicability of the proposed rule to small part 25 A/C may then be questioned even for the similarity approach.

- The proposed rule does not cover the range of foreseeable "new and novel" architectures (blended wing bodies for example) (as stated in the document) and therefore does not match the objective of the Working Group.
- The discussions and dissenting opinions reported illustrate the low maturity level of the topic and of the proposed rule.
- The cost for showing compliance for every product (new and novel or not) does not seem commensurate to the industrial costs even for the proposed similarity option.

For these reasons, Dassault Aviation believes it is premature to create a new airframe level rule. The material developed in this report should rather be used as guidance for showing compliance to the special conditions, that should be applied when necessary.

DLR - German Aerospace Center:

DLR's dissenting points are based on a scientific/ technical view.

DLR is a research organization and has extensive experience in aircraft crashworthiness in terms of the design, testing and simulation of airframe structures, with a deeper focus on composite structures. The dissenting points provided hereinafter were carefully discussed within DLR and evaluated concerning the cost benefit balance.

DLR Item (1): 25.XXX (a); Determination of Vertical Impact Velocity Requirements

In general, DLR consents to the definition of vertical impact speeds in the proposed rule 25.XXX (a), in terms of a plot showing the Vertical Velocity versus the Gross Weight. Specifying the relation between both parameters with a function (plotted curve), instead of a table with gross weight categories, provides more flexibility in the design process as there are no discontinuities in the specified impact velocity when varying the gross weight. Instead of the gross weight, the available crush space or fuselage diameter of an airframe design might be a more reasonable parameter for consideration of the aircraft size effect. However, DLR agrees in specifying the gross weight for practical reasons.

Dissenting point:

DLR's dissenting point relates to the absolute velocity values determined for the gross weight categories. DLR's position is that higher velocity values up to 30 ft/s would better reflect the vertical impact velocity capability of traditional metallic aircraft, and hence should be used as basis for the proposed rule 25.XXX (a).

Rationale:

The determination of the vertical impact velocity capabilities (see Section 4.2.1.2 of this present report) is based on a comprehensive data set provided by the following sources:

(a) Aircraft accident study conducted by the ARAC working group

(b) FAA accident study conducted by Lance Labun

(c) FAA document DOT/FAA/CT-TN90/23 cited in the ARAC tasking for the working group.

(d) OEM's self-assessment of the vertical impact capability of their products

The accident studies (a) and (b), performed by the ARAC working group as well as by Lance Labun, provide valuable information and clarify that the majority of accidents occur during take-off, climb out or approach – mainly with extended landing gears. The fact of extended landing gears motivated the working group to determine the airframe impact velocity by taking the airplane impact velocity and subtracting the energy absorbing capacity of the landing gear as specified in 14 CFR 25.723 (b), simulating a descent velocity of 12 ft/s.

DLR's position is that under typical impact conditions the landing gears may collapse at a very early state of the crash sequence with limited energy absorption up to that collapse event. The determination of the airframe impact velocities based on the accident studies should provide more conservatism by taking into account only a small portion of the landing gear total energy absorption capacity.

The FAA document DOT/FAA/CT-TN90/23, source (c) in the above list, provides a trend line of vertical impact velocity capacity versus the aircraft size. This trend line was determined on a comprehensive data basis including various crash test results on aircraft structures performed in the past. In particular for the narrow body and wide body transport aircraft category, this trend line refers to fuselage section drop tests as well as to the Controlled Impact Demonstration (CID) test (data item F, G, H, and J in the CT-TN90/23 report). All of these tests were performed without landing gear respectively with retracted landing gear.

DLR's position is that landing gear energy absorption capacity according to 14 CFR 25.723 (b) cannot be subtracted from this trend line, at least for the narrow body and wide body aircraft category. In Figure 4 (Part 25 Aircraft Vertical Impact Velocity based on Subfloor Depth) of this present report, the "Airframe"-curve should correspond to the "Aircraft"-curve due to the absence of landing gear energy absorption for this trend line. This "Aircraft"-curve highlighted in blue color should be used as basis for the proposed rule 25.XXX (a).

DLR Item (2): 25.XXX (c); Similarity/ Design Review

In general, DLR consents to the demonstration of compliance by design review as specified in the proposed rule 25.XXX (c), as an alternative to the certification approach specified in 25.XXX (a) and (b). Demonstration of compliance by design review according to 25.XXX (c) is the preferred certification approach for traditional metallic airframe designs that meet this regulation without extensive investigation or documentation, as requested by the TACDWG tasking.

Dissenting point:

DLR agrees with the demonstration of compliance by design review, provided that

- the “previously certified aircraft” was certified according to the new rule 25.XXX (a) and (b),
- equivalent level of safety is demonstrated based on the impact conditions specified in 25.XXX (a), and
- demonstration by similarity/ design review is limited to traditional metallic aircraft.

DLR proposes to change the rule text of 25.XXX (c):

> (c) *As an alternative to subparagraphs (a) and (b), adequate occupant survivability can be demonstrated by showing an equivalent level of occupant survivability to those provided by previously 25.XXX (a) & (b) certified transport category aircraft of similar size, design architecture, and material systems under conditions specified in 25.XXX (a) ~~survivable vertical crash events~~, provided that:*
>
> > *(i) The airplane does not have any design features or characteristics that have shown to be unsatisfactory with regard to occupant survivability;*
> >
> > *(ii) The previously certified transport category aircraft does not exhibit an unsatisfactory service experience* with regard to occupant survivability.

Rationale:

One of the shortcomings in the present 14 CFR Part 25 is the lack of an airframe crashworthiness rule. Special conditions written by the FAA for unconventional fuselage structures (e.g. Special Conditions Nos. 25-362-SC, 25-537-SC) have been comparative in nature and hence the certification process is dependent on the traditional metallic skin-stringer-frame design taken by the applicant for comparison. The level of safety may vary dependent on the respective traditional design selected by the individual applicant.

DLR has concerns with the proposed rule 25.XXX (c), as it allows the applicant to continue with the comparative approach by the demonstration of similarity, and prevents the introduction of a consistent level of safety

- independent on the respective safety level of the “previously certified aircraft” individually selected by the applicant for showing compliance, and
- independent on the selected certification approach: whether the aircraft is certified by 25.XXX (a) and (b) or by 25.XXX (c).

DLR proposes the introduction of a consistent level of safety with the new rule 25.XXX. Only such aircraft can be taken for similarity/ design review that were previously certified according to the new rule 25.XXX (a) and (b). This previously certified aircraft then represents a safety level according to the new rule and the comparative approach by the demonstration of similarity would maintain that level of safety. As a consequence, the applicant must show compliance with the new rule 25.XXX (a) and (b) at least once, to use that certified design as reference for future certification approaches based on 25.XXX (c).

Another concern of DLR: The new rule 25.XXX (c) does not refer to the impact conditions specified in 25. XXX (a). Instead, similarity can be shown “under survivable vertical crash events”.

DLR proposes to explicitly specify the 25.XXX (a) impact conditions in the rule text of 25.XXX (c), as basis for demonstration of compliance by design review.

A final major concern of DLR: According to the proposed new rule 25.XXX (c) and the proposed guidance material, demonstration of compliance by design review is acceptable when the transport aircraft being certified is similar in size, design architecture, and material systems to previously certified transport category aircraft. As a consequence, the certification approach specified in 25.XXX (c) refers not only to traditional metallic skin-stringer-frame designs but for all designs certified in the past, provided that unsatisfactory crashworthiness characteristics or unsatisfactory service experience are not known. This includes non-traditional airframe designs, like composite airframe structures, equipped with a specific crash design. These are airframe designs that need structural features to achieve a crashworthy safety level that comply with the rule; features intended to absorb energy or to fail in a specific manner, like: crushable stanchions, metallic fittings, specific bolted joint designs, structural junctions of frame parts or shear ties, metallic frame work structures.

DLR has concerns with the proposed rule as it allows demonstration of compliance by design review for airframes with specific crash designs. Structural crashworthiness is a complex discipline and the global response of large structures subjected to crash loads can typically be driven by small design details. This is specifically true for airframe designs that need structural features to achieve a crashworthy safety level that comply with the rule. The transfer of such a specific crash concept from one design to another design that is similar in size, design architecture, and material systems solely by design review implies uncertainties that might not end up in similar structural crashworthiness.

In contrast to the non-traditional airframe designs, the traditional metallic skin-stringer-frame designs demonstrated by various crash tests and accident statistics sufficient robustness and hence less sensitivity to small design changes due to its predominantly ductile failure behavior.

DLR proposes to limit the demonstration of compliance by design review to traditional metallic skin-stringer-frame designs and to state this limitation in the guidance material. For other designs, e.g. previously certified composite designs, potential uncertainties should be taken seriously and the alternative demonstration of compliance by similarity/ design review should be limited to design modifications.

DLR Item (3): 25.XXX (b); Retention of Items of Mass

While not explicitly written in the proposed rule 25.XXX (b), the retention of items of mass is related to the emergency landing conditions specified in 14 CFR 25.561, as stated in detail in the proposed guidance material: “The interfaces of the airframe structures to seats, overhead bins and other items of mass need not be designed for static loads in excess of those defined in 14 CFR 25.561.”

Dissenting point:

DLR's position is that compliance for all four key crashworthiness parameters should be demonstrated based on the impact conditions specified in 25.XXX (a). The proposed new rule should be consistent.

Rationale:

The impact conditions specified in 25.XXX (a) refer to the impact capability of traditional airframe designs for survivable crash events, dependent on the aircraft size. Hence, the specified impact conditions represent the level of safety currently represented by the fleet of traditional metallic aircraft. Maintaining that level of safety requires the consideration of the determined vertical impact velocity requirements in 25.XXX (a) for all four key crashworthiness parameters.

Overhead bins are one of the critical challenges for retention of mass items. Up to 70% of impact related accidents involve overhead bin detachment, according to the Cherry study (CAA Paper 96011). There are Safety Recommendations from NTSB relating to overhead bin detachment (NTSB A-12-1 through -6). Another accident study states: "Although there are only a handful of cases where impact from the overhead bin may have directly caused a fatality, bin detachment is a significant issue, based on the frequency at which it occurs. Complications from displaced bins included head and upper torso injury, hindrance from egress and entrapment, and increased seat deformations" (SAE 2001-01-2658). The European Transport Safety Council recommended three impact protection measures for priority attention: Improvement of seat/floor strength, Three-point safety harness occupant restraint, Improvement to strength of overhead stowage (ISBN 90-801936-8-2).
DLR's position is that overhead bins coming loose represent a severe threat for survivability in crash events. Injuries caused by impact of detached overhead bins with the occupants can heavily influence the chance of escaping the aircraft after a crash event. Furthermore, detached overhead bins can block the occupant egress path. Although an increasing loading capacity of overhead bins is appreciated by airlines and passengers, DLR proposes to give priority to the safety aspect.

DLR Item (4): 25.XXX (b); Maintenance of the Occupant Egress Paths

While not explicitly written in the proposed rule 25.XXX (b), the demonstration of non-permanent deformation of the emergency exit structure, to prevent any jamming situation, is related to the emergency landing conditions specified in 14 CFR 25.561 respectively to minor crash landings (14 CFR 25.809 (g)), as stated in detail in the proposed guidance material: "A test can be conducted by including a door in the test article or alternatively by analysis or similarity that show that there is no permanent deformation in the door and/or door surround structure per 25.561 and 25.809(g)."

Dissenting point:

Similar to item (3), DLR's position is that compliance for all four key crashworthiness parameters should be demonstrated based on the impact conditions specified in 25.XXX (a). The proposed new rule should be consistent.

Rationale:

Similar to item (3), the impact conditions specified in 25.XXX (a) refer to the impact capability of traditional metallic airframe designs for survivable crash events, dependent on the aircraft size. Hence, the specified impact conditions represent the level of safety currently represented by the fleet of traditional aircraft. Maintaining that level of safety requires the consideration of the determined vertical impact velocity requirements in 25.XXX (a) for all four key crashworthiness parameters.

Jamming of emergency exit doors can be one of the most severe threats for occupant survivability after a crash event. The level of safety for this criterion should be the same as specified for all other key crashworthiness parameters.

DLR Item (5): 25.XXX (b); Maintenance of Acceptable Loads Experienced by the Occupants

The proposed rule 25.XXX (b) states that "the occupant injury criteria thresholds must not be exceeded", without specifying the thresholds in more detail.

Dissenting point:

DLR proposes to explicitly link the occupant injury criteria threshold to 14 CFR 25.562 (c)(2), and to change the rule text of 25.XXX (b):

> *(ii) Maintenance of Acceptable Loads Experienced by the Occupants: During the crash event the occupant injury criteria thresholds <u>defined in 25.562 (c)(2)</u> must not be exceeded for the load levels experienced by the occupants.*

Rationale:

DLR agrees with the TACDWG consensus to consider the lumbar load threshold of 1,500 pounds as sole criteria for the demonstration of acceptable occupant loads, as the focus of the proposed rule 25.XXX is on airframe crashworthiness. Consideration of further injury criteria as specified in 14 CFR 25.562 (c) would go beyond an airframe crashworthiness rule.

However, DLR proposes to provide consistency in the rule by explicitly linking the proposed rule 25.XXX (airframe) to the existing 14 CFR 25.562 (seat and restraint system). Occupant injury criteria other than the lumbar load may result in an inconsistent level of safety and should not be considered for the new rule 25.XXX and related guidance material.

EASA

EASA has provided the following dissenting positions with respect to the proposed airframe crashworthiness rule.

- The values proposed for vertical impact velocity (Vz) would need further evaluation, because:

- Accident data seem to point to higher survivable vertical impact velocities;
- The values do not seem fully consistent with OEM data previously provided;
- The assumption of landing gear extended and the subsequent reduction in energy (12 fps) is questionable;
- Limiting the Vz values for smaller Part 25 aircraft (less than 75.000 lbs) based on seat performance and lumbar loads is debatable (and would in fact allow reduction of the current existing structural capability for such aircraft);
- The Vz values are a function of aircraft weight, whereas other parameters (such as number of passengers or available structural crush depth) may be more appropriate.

Embraer

Dissenting Opinion on VDT

Embraer joins the general consensus achieved within the TACDWG regarding the need for a revised rule for ditching and a new rule for airframe-level crashworthiness. However, in the case of the crashworthiness criterion proposed for a new airframe design, i.e. the Vertical Drop Test of a barrel section of fuselage, the safety benefits are not entirely clear, whereas the investment costs for developing the design solutions and the means to show compliance are enormous. In Embraer's opinion, the VDT with the current conception and setting can generate a disproportionately large impact on the design of future airplanes, particularly the mid-size and smaller types.

It has repeatedly been said that the vertical response is a principal aspect in assessing the comparative performance of an airframe in a crash. Nevertheless, the accident reports published by the NTSB and alike organisms around the world consistently point to the 'blunt force trauma' as a prevalent cause of death, among those of mechanical nature. Still, according to medical findings, substantial part of the fatalities in an aviation mishap is due to burnings and smoke inhalation, often related to the disability to walk away from the wreckage, either due to 'loss of conscience' (in case of 'cervical dislocation' or 'percussion to the head') or 'limb fractures'. 'Blunt force trauma', 'cervical dislocation', 'percussion to the head' and 'limb fractures' are consequences of horizontal deceleration. 'Spinal compression' inflicted by 'lumbar loads', possibly an injury of lesser importance, is mainly caused by vertical deceleration. Therefore, an improved 'VDT performance' does not necessarily translate into a better occupant protection.

This signals that the data collected by the TACDWG are not yet sufficient to guarantee that the goal of the new rule (safeguard the current rates of survival and injury) will be achieved. The criterion uniquely based on VDT may help to maintain and improve the current level of safety of the fuselage for different sorts of aircraft - not necessarily for a fixed-wing commercial airplane.

The airframe level rule, which the future designs shall unconditionally comply with, must be the result of a deeper knowledge of the mechanisms that lead to occupants injury. Embraer is in favour of maintaining the interim procedure adopted by the FAA of issuing a Special Condition, which still appears to be more appropriate to address the crashworthiness aspects of a novel design than the proposed rule as it stands.

Comment on Overhead Bins

Section 25.561 of 14 CFR Part 25 has proved a useful criterion over decades. The set of load factors taken as a static envelop equivalent to the emergency landing can certainly be reviewed and improved. The inclusion of an instrumented overhead bin in the VDT and the adoption of whichever greater acceleration (25.561 or VDT) was refused by the majority of the voting members, including Embraer. The central reason to reaffirm our position on this matter is the good performance of the in-service fleet, as recorded in the investigation reports of survivable accidents. This aspect merits further study.

Gulfstream Aerospace

Gulfstream shares the concerns of other OEMs regarding the need for a new airframe level crashworthiness rule. Gulfstream believes that the existing rules provide a sufficient level of crashworthiness for today's conventional airframe designs. We are concerned that a new rule requiring a showing of compliance for all products will result in increased cost and schedule impacts, even for derivative and amended TC projects. Even simple derivative products could require what can be a significant effort to justify similarity to existing, proven products to the authorities. If similarity justification is not accepted, and compliance requirements are expanded to require analytical simulation and/or new testing, this will significantly increase costs and schedule impacts even for aircraft which are of convention metallic airframe construction without a commensurate increase in the level of safety. The original concern for a new rule originally seemed to be directed at "new and novel" airframe design and construction. Those type of projects were handled through the use of special conditions. Gulfstream believes that, at this time, that is still the best way to address crashworthiness concerns for "new and novel" designs for OEM's which have not used that type of design and construction previously. This will allow negotiation of the terms of the SC which would not be possible with a new rule.

National Aeronautics and Space Administration

Opinion #1 - *in Section 4.2.2 Proposed Rule*

NASA disagrees with final velocities in section 4.2.2. These velocities resulted from discussion from Abbotsford Face to Face and were changed to lower values than in previous drafts.

Special Conditions as identified in the Federal Register for the 25-528-SC (Learjet LJ-200), 25-321-SC (Airbus A350-800) and 25-362-SC (Boeing 787-8) stipulate showing compliance with vertical velocities of up to 30 ft/sec. Additionally, OEM-provided summary data to the ARAC task state that small transport aircraft have capability of up to approximately 22 ft/sec, narrow-body aircraft up to 24 ft/sec and wide-body up to 28 ft/sec. Additional discussion postulated that these limits, especially for the smaller aircraft, are mainly limited by the occupant injury levels (further discussion is provided in Opinion #3). Historical testing conducted by both the FAA and NASA have shown that occupant survivability is maintained on narrow-body and wide-body aircraft of up to 30 ft/sec.

Finally, in service accident and mishap data along with Team 1 ARAC data (Figures 1 and 2 which based on mishap and test data) show that for narrow-body aircraft, velocities of up to 22-24 ft/sec encompass up to 80% of accident percentiles, and for wide-body aircraft, velocities of up to 26-30 ft/sec encompass over 80% of accident percentiles.

Therefore, using OEM, mishap and test data, NASA would recommend splitting the aircraft into three categories with the following impact conditions to ensure that an equivalent level of crashworthiness is maintained:

Aircraft	*Impact Velocity (ft/sec)*
Small Narrow-body	22
Narrow-body	26
Wide-body	30

Textron Aviation.

Textron position on new crashworthiness rule:

We understand the FAA intention of trying to make sure all new designs have as much crash survivability as the fleet of conventional planes has had for the last 30 years, but we are very concerned with the cost and time to meet these new requirements with probably no increase in safety. A new and novel design is going to get special conditions with or without this new rule so we think it is probably better to cover the crashworthiness requirements in the special conditions at that time. There also seems to be resistance to saying a new design is good by similarity and the amount of the work required to show similarity could be significant. This means every derivative product is going to have increased cost and totally new designs will have significant development cost increase.

Current design/sizing makes sure fuselage parts are strong enough to carry design load without an upper limit on being too stiff/strong. These requirements to carry bending and pressures loads while maximizing payload drive a design that results in the current fleet which is considered to have acceptable crashworthiness. If a part is a little too stiff or strong the only penalty is weight and the company can choose to accept this weight penalty if they want when comparing it to cost and schedule. With the new rule, a part that is too stiff or strong could cause us to fail the max 1500 lbs lumbar load requirement and a re-design making parts weaker. This risk means you need to know you will pass the crashworthiness requirements before you start your assembly line or face potential costly rework. With static or fatigue test failures the fix can be to add a simple doubler to the planes on the assembly line which is a much less costly process than dis-assembling parts to put in new weaker parts. The current fleet is considered basically acceptable for crashworthiness but we don’t know if many of them could actually meet the requirements of the new rule.

We have participated with the TACDWG to help develop the new crashworthiness rules but we believe the costs of meeting the new crashworthiness rules are not commensurate with the level of safety improvement.

6.1.3 Proposed Guidance

See appendix B.1 for proposed guidance.

6.1.4 Dissenting Points

DLR - German Aerospace Center:

In addition to DLR's dissenting points to the proposed rule, documented in Section 6.1.2, DLR has further dissenting points as well as comments that relate to the proposed guidance material.

DLR Item (6): Robust Crashworthiness

The proposed guidance material in its final version addresses in an almost sufficient manner the need of considering variations in the impact condition and loading configuration to demonstrate robust crashworthiness.

Dissenting points & Rationale :

DLR proposes to state in a little more detail and in a clearer way the need and importance for demonstration of robust crashworthiness by variations of impact condition and loading configuration. Robustness is a key for crashworthiness, according to DLR's position. The consideration of other sections than the typical fuselage section as well as the consideration of variations in the loading condition is a key factor for obtaining true crashworthiness.

- Impact Velocity:
    - Dissenting point: The guidance material might clearly state that crashworthiness must be demonstrated for the full range "up to" the impact velocities specified in 25.XXX (a).
    - Rationale: Velocities lower than specified in the rule may be more severe dependent on the airframe design.
- Variations in Airplane Attitude:
    - No dissenting points: The guidance material states well the necessity "to perform some analysis or test evaluations to address off axis impact if the design includes design features intended to absorb energy and proper function of this feature is required to work properly for the design to satisfy 14 CFR 25.XXX".
      DLR would like to emphasize that off-axis loading is important for demonstration of compliance with the rule, in particular for specific crash designs. Potential off-axis loading for role and pitch angles might be in the range of +/- 5 degrees, for typical aircraft designs.
- Cargo and Passenger Arrangements:

  - No dissenting points: The guidance material states well the need for consideration of appropriate cargo and passenger arrangements "such as, full passenger and typical passenger loading, full cargo and no cargo and combinations there in".
    DLR would like to emphasize the importance to demonstrate compliance for a range of payload configurations that covers the majority of allowable configurations of passenger and cargo loading. Besides typical payload configurations, other allowable configurations can have significant influence on the crashworthiness performance.
    As an example, cargo loading can have an unfavorable stiffening effect or a favorable energy absorbing softening effect on the occupant loads, dependent on the airframe crash performance and the cabin loading configuration.
    As another example, a low density passenger loading may not be sufficient to generate inertia forces in a crash event necessary to trigger failure in specific structural elements. As a result, the stiff structural response may lead to occupant loads in excess to occupant injury criteria thresholds.
- Representative Fuselage Structure:
  - No dissenting points: The proposed guidance material states for both, means of compliance by test and by analysis: "In general, the fuselage test section should include all design features that can influence fuselage crashworthiness."
    However, the proposed guidance material may leave enough scope to exclude design features and to end up in a typical fuselage section for demonstration of compliance with the rule: "Specific design features can be excluded from the fuselage test section if they are not expected to influence the test results."
    DLR's position is that robust crashworthiness for an airframe design cannot sufficiently be demonstrated purely on the basis of a typical fuselage section. DLR would like to emphasize the importance to consider the majority of areas of the fuselage structure occupied during take-off and landing. Design features of non-typical fuselage sections, such as cargo doors, must be carefully evaluated before excluding from the fuselage test section.
    It is DLR's concern that new airframe structures may end up in a point design for the typical fuselage section that provide poor crashworthiness for the non-typical portions of the fuselage.
- Impact Terrain:
  - Dissenting point: The proposed guidance material states a concrete impact surface as satisfactory for demonstration of compliance. Different impact terrains need not to be evaluated.
    DLR is aware of the fact that consideration of different impact terrain for certification is a challenging aspect in terms of establishing a representative and repeatable consistent soft soil impact terrain for testing respectively analysis. There is not yet a standard established for soft soil impact terrain.
    However, based on research work performed at DLR and at other research organizations, DLR proposes to consider variations in impact terrain if design features intended to absorb energy are included in the airframe design. Besides concrete this should be at least one

representative soft soil impact surface. Repeatable consistent boundary conditions for soft soil might be realized by representative test devices similar to crash test barriers.

- Rationale: DLR's position is that airframe structures designed with features intended to absorb energy may not provide full crash resistance when the structure is subjected to different terrain.
  - Experimental studies performed at DLR have shown that crush absorbers integrated in subfloor structures perfectly worked on hard impact surface but penetrated the fuselage skin without triggering progressive failure for impact on soft soil.
  - Other research work ended up in the same conclusion: Aircraft or helicopter structures designed for crash resistance onto hard surfaces, do not perform well during multi-terrain impacts. (K.E. Jackson, E.L. Fasanella, K.H. Lyle, "Crash Certification by Analysis – Are We There Yet?", AHS 62nd Annual Forum, Phoenix, AZ, May 9-11, 2006)

- Forward Velocity Component:
  - No dissenting points: Consideration of the forward velocity for demonstration of compliance with the rule is beyond the cost benefit balance.

    Nonetheless, DLR would like to emphasize the importance to consider forward accelerations (beyond 14 CFR 25.561) in the design of specific structural features intended for energy absorption. As an example, there may be risk of structural collapse instead of progressive energy absorption for crushable subfloor stanchions when the subfloor structure is subjected to significant forward accelerations that might occur under impact conditions on soft soil, like a ploughed field close to an airport. Furthermore, the simplification of a purely vertical impact velocity neglects secondary crash loads that may have an influence on relevant survivability factors. Seat/floor strength is one the most significant survivability factors identified by the Cherry study (CAA Paper 96011, and more recently Cherry report 1728/R/000593/KK). Bending and torsion loads caused by the global fuselage deformation under typical crash conditions may lead to cabin floor deformation or failure, and seat detachment as a consequence: "Due to the extensive disruption to the floor during the impact sequence, a number of accidents analyzed would not have any potential for lives being saved with the introduction of 16-g seats" (DOT/FAA/AR-00/13). Such effects may have significant influence on the occupant survivability but are not considered for the simplification of a purely vertical impact velocity.

DLR Item (7): Consistency in Means of Compliance by Test and by Analysis

The proposed guidance material specifies important issues separately for the means of compliance by test respectively by analysis.

Dissenting Point:

The proposed guidance material implies, in the way it is written, the risk of inconsistency between the means of compliance by test respectively by analysis as important issues are specified separately and not fully consistent; issues like

2) Test article selection/ Analysis model,
3) Impact conditions and loading configurations, or
4) Success criteria.

DLR proposes to harmonize the guidance material for means of compliance by test and by analysis in a way that all important issues are conform to a maximum, to ensure a consistent level of safety.

Rationale:

The level of safety respectively the demonstration of compliance with the rule should be the same, wherever possible, independent on whether compliance is demonstrated by test or by analysis. DLR acknowledges that this will not fully succeed, but the guidance material should support to maximum consistency between the means of compliance.

DLR's viewpoint is that the proposed guidance material would better support the applicant when its structure is harmonized and the differences between the means of compliance by test and by analysis are highlighted.

DLR Item (8): Limit of Reasonable Survivability

The guidance material introduces the limit of reasonable survivability for the means of compliance by analysis.

Dissenting Point:

The guidance material states: "The Limit of Reasonable Survivability defined for similar transport aircraft shall be accepted by the Administrator as a basis for compliance demonstration. In absence of more rational justification of Limit of Reasonable Survivability, based on in-service experience of conventional large transport airplane configurations with the range of vertical impact velocities defined in 25.XXX (a) can be considered."

According to DLR's position the guidance material should clearly state that compliance with all four key crashworthiness parameters must be demonstrated up to the impact velocities specified in 25.XXX (a).

Rationale:

The limit of reasonable survivability might be interpreted in a way that compliance with the rule must be demonstrated up to an impact velocity that was identified to be the limit of reasonable survivability for that category of aircraft. The impact velocity that relates to the limit of reasonable survivability might be less than the impact conditions specified in 25.XXX (a).

The proposed rule 25.XXX (a) specifies impact conditions that are conform to the impact capability of traditional airframe designs representing the level of safety of the current fleet of traditional aircraft. Allowing an applicant to deviate from the rule based on the limit of reasonable survivability would end up in an inconsistent level of safety.

DLR Item (9): Alternative Demonstration of Adequate Occupant Crash Survivability for Smaller Transport Category Aircraft

The proposed guidance material states: "As an alternative, for transport category airplanes that have a passenger seating configuration, excluding pilot seats, of 19 seats or less, and a maximum design takeoff weight less than 75,000 lb. (34.020 kg), adequate occupant crash survivability can be demonstrated by installing seats that comply with the requirements of 14 CFR 25.562 and the following additional dynamic test.

- A change in downward velocity (ΔV) of not less than 31 fps, with the airplane's longitudinal axis canted downward 30 degrees with respect to the horizontal plane and with the wings level. Peak floor deceleration must occur in not more than 0.06 seconds after impact and must reach a minimum of 15g."

Dissenting Position:

DLR proposes to remove this option from the guidance material.

Rationale:

Smaller transport aircraft typically have very limited crush depth below the cabin floor. For this category of aircraft, maintenance of acceptable loads experienced by the occupants is the most critical key crashworthiness parameter.

However, the proposed rule 25.XXX (a) specifies an impact velocity of 18 ft/s for the small transport aircraft category. This velocity corresponds to the vertical impact velocity capability of small transport aircraft for survivable impact events.

According to analysis results for typical small transport category aircraft, presented to the working group, an impact velocity of 18-20 ft/s corresponds to lumbar loads close to 1,500 pounds (NIAR presentation, Mesa meeting, March 2017).

The OEM's self-assessment of the vertical impact capability of their products specifies velocities higher or equal to 18 ft/s for all OEMs, including the small transport aircraft category.

The definition of the 18 ft/s impact velocity for small transport category aircraft in the proposed rule 25.XXX (a) explicitly considers the vertical impact velocity capability with respect to the occupant loads (lumbar loads). For that reason, DLR's position is that small transport category aircraft should not be exempted from the demonstration of compliance with the occupant injury criteria threshold.

DLR Item (10): Means of Compliance by Analysis Supported by Test

The guidance material describes the validation process for the analytical methods based on the building block approach, and the application of the validated analysis model for demonstration of compliance with the rule. Validation of the analytical methods is supported by tests (building block) whereas demonstration of compliance is purely given by the analytical model.

Dissenting position:

DLR proposes to request for the demonstration of compliance by analysis at least one large structure test (e.g. component test that may include an entire fuselage section). This test should serve as

2) certification test for demonstration of structural crashworthiness for the new airframe design, and
3) as basis for validation of the analytical model, which then can be used for demonstration of compliance considering variations in impact condition und loading configuration.

Rationale:

DLR's position is that analytical methods for crashworthiness are not yet entirely sufficient for certification. Validated analytical state-of-the-art methods can predict the crash performance of a structure within limited variations. Uncertainties in the simulation results significantly increase when the application of the validated model increasingly differs from its validation case.

The guidance material may be interpreted in a way that analytical models validated according to the building block approach in former certification processes can be used in the future for the certification of new airframe designs without performing additional tests at the high structural levels. According to DLR's position, this can lead to significant uncertainties in the demonstration of compliance by analysis. Therefore, DLR proposes that for the airframe design being certified compliance should be demonstrated at least by one large structure test as part of compliance by analysis.

EASA

EASA has provided the following dissenting positions with respect to the proposed airframe crashworthiness guidance.

- For retention of items of mass, the proposal to limit the interface loads to those defined by 25.561 loads is not accepted. Any interface load resulting from the vertical impact conditions defined by the new 25.XXX requirement should be considered, to prevent items of mass from coming loose. (Note: in addition to 25.561, such items also have to comply with flight and ground loads, which may exceed 25.561 loads). In addition, it must be shown that for seats 25.562 loads (especially vertical acceleration levels experienced at the seat/floor interface) are not exceeded.

- For maintenance of acceptable loads experienced by occupants, an alternative means of compliance is proposed for certain airplanes (additional dynamic seat test coming from Part 23 criteria). This is not agreed, because:
  - The proposed weight (75.000 lbs) and passenger (19) threshold would include airplanes of a size and configuration that have sufficient crushable volume to withstand considerable vertical impact velocities;
  - The amount of increased occupant survivability that would be provided by this additional dynamic seat test is undefined;
  - The proposal seems inconsistent with the proposed Vz of 18 fps for these airplanes, a value that is already defined (limited) by lumbar loads.

National Aeronautics and Space Administration

NASA disagrees with removing the text pertaining to the dynamic load factors on overhead bins.

A dynamic loading environment has the potential to create problems in certification if a statically qualified bin fails during the testing in the new proposed rule. NASA feels that dynamic bin guidelines (see Recommendation #1) should be addressed. Additionally, the guidance (*Section 5.1 Airframe Crashworthiness Attributes in Appendix B*) states that the bins should not open, which implies that the bins be able to withstand the dynamic environment, suggesting differences in expectations in bin performance.

At a minimum, suggested harmonization of these guidelines would be to include text to state the bin must be able to withstand loads from the dynamic tests.

Section 5.1 Airframe Crashworthiness Attributes in Appendix B

NASA disagrees with the inclusion of seat exemption in lieu of meeting “(ii) Maintenance of Acceptable loads experienced by the occupants” criteria in the proposed rule.

For small transport aircraft – defined by 19 seats or less and MTOW of 75,000 or less, an exemption is included to allow for a specific seat certified to 14 CRF 25.562 with an additional test of 31 ft/sec downward ΔV and 15 g peak deceleration at 0.06 s to be used for the meeting of criteria (ii) in the proposed rule. This exemption was discussed at March 2017 ARAC meeting and added to the subsequent draft version of the guidance material. Data from OEMs and other working group members suggest that a velocity of 18 ft/sec is at the lower end of vertical impact capability for small transport aircraft. Working group discussions pertaining to this data suggest that the limiting factor of this velocity is the occupant loading requirements defined in 14 CFR 25.562. Therefore, an impact velocity of 18 ft/sec for small transport aircraft should be able to meet the current requirements as is, and do not need this specific seat.

Therefore, it is NASA’s position to remove this seat exemption.

Use of Similarity

NASA understands the use of similarity in certifying new aircraft. The Federal Register states, as a part of the ARAC task, "…that these types of conventionally configured airplane fabricated with typical metallic materials and design details can be shown to meet the proposed regulation without extensive documentation." This portion of the ARAC task is the basis for paragraph (c) in the new proposed Rule. However, while metallic aircraft have in-service records and mishap and crash data is available, new types of composite aircraft do not.

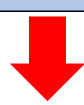
NASA believes that a similarity condition can be applied to "conventionally configured airplanes fabricated with typical metallic materials and design details", however it should not be applied to non-conventional airplanes – either through materials, design features, or both - unless adequate in-service crashworthy compliance has been shown. NASA is not disagreeing with the general rule in paragraph (c), however is only adding clarification on NASA's position.

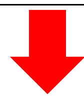
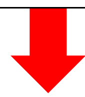
6.1.5 Changes Affecting Applicants

See section 4.2.4 for a summary of the proposed airframe crashworthiness rules that impact the costs or benefits for an applicant.

6.1.6 Qualitative Summary of Cost / Benefit

The actual labor hours and cost data is proprietary to each individual company and is not presented in this document. The detail costs are to be provided directly to the FAA by each member that is directly impacted by the proposals presented in this document. Each member did provide a qualitative assessment of the potential costs vs. benefit based on their individual perspective. This information is summarized here.

Voting Member	Crashworthiness Rule and Guidance Qualitative Assessment	Comments
Airbus		• Today, without new rule, for a conventional airframe configuration and the derivatives, a special condition is not required; so no industry effort would be expended • Future novel and unusual designs are not covered by the rule and will require Special condition • Current fleet records show that the compliance with existing set of crashworthiness and structural strength requirements results in acceptable level of safety • Recent certification projects demonstrated that the level of crash survivability is acceptable and level of safety is comparable

		to already certificated Large Transport aircraft • Significant effort was made both in terms of simulations and testing, resulting in no or minor changes to design for new aircraft. New airframe rule, will lead to significant efforts and cost for industry and would not be commensurate with expected safety benefit
Association of Flight Attendants	ABSTAIN	AFA lacks access to the detailed technical information that would be required to provide a cost/benefit assessment.
Boeing Commercial / Military		• The existing fleet is adequately safe. • New rules and Special Conditions are not necessary for conventional configurations. The material is not the controlling factor on performance. • A general rule creates unnecessary work for ALL current conceived designs. • Additional cost not commensurate with increase in safety.
Bombardier		• Showing compliance by similarity will have smaller impact when compared with compliance by Analysis / Simulation or testing validation. However the similarity approach could be limited by the design maturity at the time when the agreement with certification authorities (typically more than one) would need to be in place. *Example: If similarity approach is later on expanded to some level of simulation and/or testing it would significantly increase the cost and affect the schedule.* • Showing compliance by test only (for BA passenger and larger business aircraft) may require multiple expensive drop tests to address all 4 criteria. This would be <u>very</u> expensive. • Showing compliance by analysis/simulation would significantly increase the cost associated to: b. Manpower required for extensive FEM/LSDYNA simulation (iterative process), c. Generating test data required for FEM validation,
Cascade Aerospace	ABSTAIN	New aircraft certification: as an organization that produces changes to aeronautical products (not new type certifications),

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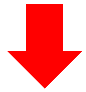
<td>

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Cascade abstains from commenting on this aspect.
Future modifications to aircraft certified to the new rule:

“Not Significant” changes: negligible cost/schedule effect for minor modifications.
“Significant”: cost/schedule would increase significantly for major modifications affecting crashworthiness/occupant safety criteria as modifiers would likely have to conduct extensive reinvestigation to show compliance and/or reach out to the OEMs to perform aircraft re-assessments. No significant improvement in survivability with significantly more cost.
“Substantial” mods: demonstrating full compliance will be extremely costly and likely not be feasible for smaller companies. Vast majority of the modifications done by the industry are <u>not</u> “Substantial”.

Modifications to existing fleets:

“Not Significant” changes: no cost/schedule effect.
“Significant” changes: small engineering cost/schedule increase in order to justify impracticality to comply with latest amendment (basic aircraft data may not exist) and document that compliance with latest rule does not contribute materially to level of safety. Significant cost/schedule increase if required use of latest rule, see below.
“Substantial” changes requiring compliance with latest amendment likely to make it unfeasible to comply. Extensive reinvestigation to show compliance and/or reach out to the OEMs to perform aircraft re-assessments, unless similarity arguments can be easily applied. No significant improvement in survivability with significantly more cost to test/analyze the structure.

Vast majority of the modifications done by the industry are <u>not</u> “Substantial”.
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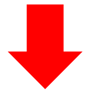
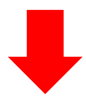
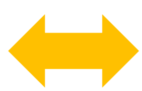
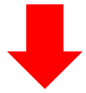
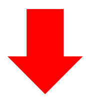
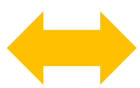
Dassault Aviation		• The existing fleet level of safety is considered acceptable, and Dassault Aviation believes it results from current requirements for strength, fatigue, and minor crash. • Currently, no effort would be required for a conventional aircraft. • Boeing and Airbus experience has shown application of the SC leaded to no or minor changes in the design. • A significant effort would be required to show compliance by similarity, test or analysis, especially for small part 25 aircraft that have been less supported by crashworthiness research in the past. Consecutive significant costs would not commensurate with the very limited increase in safety expected.
Embraer		• The VDT does not correlate directly with the harms found in the vast majority of real-world crashes (expressed as fatality and severe injury rates). In consequence, insignificant benefits are expected for crashworthiness - at not negligible additions to costs (recurring/ nonrecurring) and weight, particularly for single deck fuselages and smaller sizes. • Some configurations found in the existing fleet, therefore consistently regarded as acceptable, may have their design put in check and subject to stiff unrealistic penalties, unless they meet the similarity criteria - for those configurations, the impacts are not easy to predict.
German Aerospace Center (DLR)		Dependent on the airframe design: Limited additional effort or significantly reduced effort, with similar or reduced level of safety. • Conventional designs with traditional metallic materials: Limited additional effort for demonstration of compliance by design review according to 25.XXX (c), and a same level of safety as expected today. • Conventional designs with composite materials: Significantly less effort as expected today (certification based on special conditions), as such designs can be certified by design review according to the proposed rule 25.XXX (c). The level of safety may be reduced allowing the design review for such designs. Novel designs or material systems: Certification by the proposed rule 25.XXX (a) and (b) results in similar effort and a same

		level of safety as expected today (certification based on special conditions).
Gulfstream Aerospace Corporation		• Current conventional aircraft design and construction which meets existing requirements for strength, fatigue and damage tolerance, and crashworthiness as defined in the existing regulations has been shown to result in acceptable levels of safety. • Showing compliance to new rules by similarity to existing designs will likely entail significant new work to justify sufficient similarity to the certifying authority. • Showing compliance to new rules by other than similarity will require a significant expense and effort for new testing and/or analysis which must be also be supported by new or existing test evidence. For conventional aircraft design, new rules and guidance will result in additional cost and effort without any commensurate increase in safety.
Mitsubishi Aircraft Corporation		Additional cost (recurring and non-recurring) for justification is required, also showing compliance by test in new airplane yields program risks at later phase.
National Aeronautics and Space Administration	ABSTAIN	
Naval Air Systems Command	No input provided	
National Institute of Aviation Research		• For existing "conventional" aircraft fleet current safety record indicates an appropriate level of safety therefore introducing additional requirements will only increase development costs and will not improve significantly the current level of safety. • For "novel" aircraft designs the proposed rule will ensure that these new and novel designs will maintain or exceed the current level of safety. Maintaining the current level of safety for new and novel designs justifies the additional associated costs with the crashworthiness development and certification costs.
Textron Aviation		No significant improvement in survivability with significantly more cost to test and analyze the structure. For standard aircraft configuration (tube fuselage), we believe the resulting design to meet all the current

		requirements for strength and fatigue yields a fuselage with acceptable crashworthiness capability.

6.2 Ditching

6.2.1 Proposed Rules

§25.563 Structural ditching provisions.

If certification with ditching provisions is requested, the airframe structures that is necessary to maintain flotation shall withstand ditching loads, considered as ultimate, associated with a planned emergency landing on water. The airframe loads must account for reasonable variations in the flight parameters when the airplane enters the water.

§25.801 Ditching.

(a) Whether or not ditching certification is requested, it must be shown that following an unplanned ditching, the flotation time and trim of the airplane will allow the occupants to leave the airplane.

(b) If certification with ditching provisions is requested, the airplane must meet sections §§ 25.563, 25.1411(a) and 25.1415(d) and the following:

1) Each practicable design measure, compatible with the general characteristics of the airplane, must be taken to minimize the probability that in an emergency landing on water, the behavior of the airplane would cause immediate injury to the occupants or would make it impossible for them to escape.

2) The probable behavior of the airplane in an emergency landing on water must be investigated by model tests or validated analytical methods. Features likely to affect the hydrodynamic characteristics of the airplane must be considered.

3) It must be shown that following a planned emergency landing on water, the flotation time and trim of the airplane will allow the occupants to leave the airplane and enter rafts. The flotation and evacuation assessment shall account for probable damage resulting from the conditions prescribed in § 25.563.

6.2.2 Dissenting Points

Dassault Aviation

The allowance for “comparison to airplanes of similar configuration for which ditching characteristics are known” has been removed from the rule. Until now, this possibility has been widely used by OEMs and has proven to provide an acceptable level of safety.

Even if the opportunity is still available in the guidance, Dassault Aviation believes it would be more comprehensible to keep this similarity compliance option within the rule.

EASA

EASA has provided the following dissenting positions with respect to the proposed ditching rule.

- In the proposed 25.801(b)(3) there is no mentioning of “reasonable probable water conditions” unlike the current 25.801(d). It seems unrealistic to assume a calm sea (no waves) for the unplanned ditching scenario. Either a particular wave height (sea state) should be defined, or possibly some additional sill clearance, unless the flotation analysis can be shown to be sufficiently conservative.
- As discussed in the WG meetings, it seems that as long as some engine power is available (“reduced power” scenario) until the moment of initial water impact, high lift devices can be operated, although maybe in a limited sense. This would allow for sufficient control of the aircraft such that the resulting water loads can be reasonably addressed under the planned ditching scenario. However, for some aircraft high lift devices are not available in case of total engine failure (”no power” scenario). As fuel starvation or engine failure are the most likely scenarios for ditching events, this scenario (“no power”) needs to be addressed in more detail, beyond an AFM entry. For aircraft with a RAT or manual reversion modes, high lift devices may still be available even in an all-engine out situation. For those aircraft that not have this capability an additional investigation into maintaining the necessary structural integrity in an all-engine out scenario seems warranted.

6.2.3 Proposed Guidance

See appendix C.1 for proposed guidance.

6.2.4 Dissenting Points

EASA

EASA has provided the following dissenting positions with respect to the proposed ditching guidance.

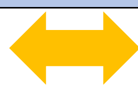
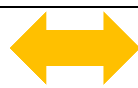
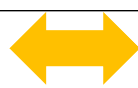
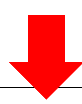
- Global aircraft integrity (i.e. not exceeding the BM/S/T design envelopes) for the planned ditching scenario should also be investigated, in addition to local (distributed) loads.
- Evaluation of ditching load factors (relative to 25.561) is proposed to be excluded for “conventional” aircraft configurations, but this is not acceptable. As per the EASA Generic CRI, accelerations during the ditching event should be shown to be less than as defined in 25.561(b), unless higher inertia load factors are substantiated.

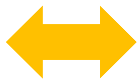
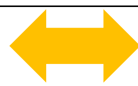
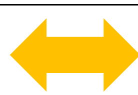
6.2.5 Changes Affecting Applicants

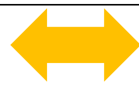
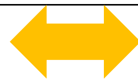
See section 4.3.5 for a summary of the changes to ditching rules that impact the costs or benefits for an applicant.

6.2.6 Qualitative Summary of Cost / Benefit

The actual labor hours and cost data is proprietary to each individual company and is not presented in this document. The detail costs are to be provided directly to the FAA by each member that is directly impacted by the proposals presented in this document. Each member did provide a qualitative assessment of the potential costs vs. benefit based on their individual perspective. This information is summarized here.

Voting Member	Ditching Rule and Guidance Qualitative Assessment	Comments
Airbus		• Revision of rules is clarifying open points of current regulation e.g. the introduction of a non-conditional §801(a) clarifies what is impolitely required in §807 for definition of ditching exits • No changes anticipated to aircraft weight. • Introduction of numerical methods for impact analyses extends the means to show compliance • These statements are valid for new development projects only. Prerequisite is that for current programmes and derivatives the existing methodology can be continued to be used by showing similarity with already certified design This point is crucial to limit the additional costs.
Association of Flight Attendants	ABSTAIN	AFA lacks access to the detailed technical information that would be required to provide a cost/benefit assessment.
Boeing Commercial / Military		• Revised rule and guidance codifies existing MOC simplifying paperwork. • No changes anticipated to aircraft weight.
Bombardier		• Revised rules and guidance would not result with significant additional cost associated to addressing the MOC. • No impact to weight increase is anticipated.
Cascade Aerospace		• The proposed changes clarify the current requirements and guidance, simplifying paperwork.

		• Additional cost/schedule increase compared to what is currently done: any changes to type designs will require evaluation of whether floatation and evacuation characteristics are affected, as floatation analysis is now part of basic aircraft certification. If design changes affect floatation, re-assessment would likely require collaboration with the OEM as there are typically unique tools and specific assumptions, may be highly dependent on OEM's willingness and availability to support, significantly impacting the schedule. Safety benefit believed to be commensurate with the cost.
Dassault Aviation		• Proposed changes in rules and guidance implement current state of the regulation and EASA CRI. However, the allowance for "comparison to airplanes of similar configuration for which ditching characteristics are known" has been removed from the rule. • No change is anticipated neither to industrial efforts (engineering, certification etc.), nor to current design, nor to the current level of safety.
Embraer		• No changes are envisaged to the design, the requirements are rendered more clear.
German Aerospace Center (DLR)	ABSTAIN	
Gulfstream Aerospace Corporation		• Revised rule and guidance generally codifies existing MOC. However, the verbiage regarding allowance of "comparison to airplanes of similar configuration for which ditching characteristics are known" has been removed from the rule. • If regulators decide that model testing and/or additional analysis is required beyond today's standards, will incur additional cost/schedule impacts.
Mitsubishi Aircraft Corporation		· Revised rules and guidance would not affect significant cost increase. · No impact to weight increase.

National Aeronautics and Space Administration	ABSTAIN	
Naval Air Systems Command	No input provided	
National Institute of Aviation Research		• Revised rule and guidance codifies existing MOC.
Textron Aviation		Textron does not currently certify for ditching so we don’t have the experience with the current effort required that some of the other OEMs have. It appears like most of the changes clarify the current requirements and do not add significant work to the process.

6.3 Equipage and Protocol

6.3.1 Proposed Rules

Description
The FAA harmonize 14 CFR 25.809(a) with EASA CS 25.809(a) to clarify that certain emergency exits may not be able to permit viewing of the evacuee ground contact area. The intent of the requirement is to enable a person to ascertain whether to open an exit, and whether it is safe to evacuate through the exit, based on an assessment of the outside conditions. The recommendations are related to viewing from certain overwing exits and flight crew emergency exits. Further, EASA should reorder their paragraphs in 25.809(a) to reflect the reorder recommended to the FAA for harmonization purposes.
Harmonize 14 CFR 25.810(a)(1)(ii) with EASA CS 25.810(a)(1)(ii) to reflect the reference to 10 seconds deployment time for assist means.
The requirements for stowage provisions and emergency descent means in § 25.1411(c) is obsolete and redundant since the same requirement is contained in 14 CFR 25.810, therefore the requirement in 25.1411 (c) should be deleted.
Harmonize US regulations sections 25.811(g), 25.812(b)(1) and (2) which specify the use of the word “exit” and the signs dimensions of exit locator signs, exit identifiers and exit marking to harmonize with EASA to allow the use of **symbolic symbols** as an alternative to red exit signs.

We recommend the FAA delete the reference to the requirement for **life line** stowage provisions as stipulated in §25.1411(g) for new design aircraft.
We recommend the FAA delete the requirement for life lines in §91.509(b)(5) as part of required survival equipment for overwater operations for new design aircraft.
For current in-service aircraft with life lines included, we recommend the FAA finalize the FAA activity to update advisory guidance material to relay information to passengers on the availability, stowage and use of life lines on aircraft equipped with life lines.
We recommend the FAA revise 14 CFR 25.1415(c) to allow **survival equipment** to be stowed adjacent to each liferaft. Guidance would reflect that remote **stowage** of the equipment for slide/rafts would be permitted as a means of compliance with the regulation.
Codify airbag standard, special conditions and guidance material related to inflatable seatbelt restraints and/or airbags; and expand the information to include all active restraints. It is also recommended that EASA adopt the harmonization into CS 25 regulations and guidance material.
Utilize the term “active restraints” into the regulations and guidance material including the proposed definition: *Active Restraint: A device that operates as the result of certain inputs (such as acceleration or velocity) to trigger a mechanism that is intended to protect an occupant (such as an airbag or pretensioner). By their very nature, devices of this type can have two protection environments, one prior to the device being triggered and one subsequent.*
It is proposed that 14 CFR 25.1411 be revised to require that an approved life preserver must be provided for each airplane occupant, regardless of whether the aircraft is certified for ditching or not. The FAA should also provide additional guidance to enhance the stowage provisions and accessibility of life preservers as required in 25.1415.
14 CFR parts 25.1411 and 25.1415 have been reordered for simplification. Included in the proposal is the deletion of requirement for life lines and reference to seat cushion floatation in favor of life preservers for each occupant.
It is recommended that FAA harmonize with EASA related to the stowage or attachment of survival equipment to life rafts. Clarification and modifications were also incorporated in relation to the contents of such kits.
Revise 25.1415 related to non-portable rafts: The rafts shall have a combined **overload capacity** to accommodate all occupants of the airplane in the event of a loss of: (i) one portable raft with the largest overload capacity, and (ii) 50% of the non-portable rafts

6.3.2 Dissenting Points

None provided.

6.3.3 Proposed Guidance

See section 4.4.

6.3.4 Dissenting Points

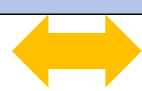
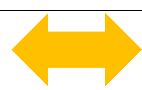
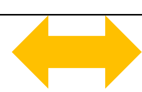
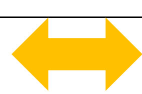
None provided.

6.3.5 Changes Affecting Applicants

The proposed changes are minor in nature mostly harmonization with NAA rules which should be a minor benefit to applicants. There will be a potential weight increase for some aircraft based on the proposal to require life preservers for ALL aircraft.

6.3.6 Summary of Cost / Benefit

The actual labor hours and cost data is proprietary to each individual company and is not presented in this document. The detail costs are to be provided directly to the FAA by each member that is directly impacted by the proposals presented in this document. Each member did provide a qualitative assessment of the potential costs vs. benefit based on their individual perspective. This information is summarized here.

Voting Member	Equipage Rule and Guidance Changes Qualitative Assessment	Comments
Airbus		• Proposed changes improve harmonization and rules organization • Life vest requirement already exists in Europe. • Application of 25.562 to flight crew seats should finally be harmonized with publication of a next EASA CS 25 amendment (NPA 2017-12).
Association of Flight Attendants	ABSTAIN	AFA lacks access to the detailed technical information that would be required to provide a cost/benefit assessment.
Boeing Commercial / Military		• Changes improve organization of rules. • Some incorporation of existing MOC material in guidance. • Some small weight increase for some aircraft, additional life preservers, optimized safety kits.
Bombardier		• Proposed changes will harmonize and improve rules organization • Although the Life vest requirement will impact the weight of a new program but since the rule will be applicable to all airliner, it is considered neutral.
Cascade Aerospace		• Proposed changes will harmonize and improve rules organization. • Cost neutral.

Dassault Aviation	↔	• Proposed changes harmonize current regulations. • No significant impact is anticipated neither on costs nor on safety.
Embraer	↔	• Minor changes are envisaged to the design and to the emergency procedures, the revision is generally beneficial and does not seem to generate an expensive impact.
German Aerospace Center (DLR)	ABSTAIN	
Gulfstream Aerospace Corporation	↔	• Generally minor changes/improvements to existing rules.
Mitsubishi Aircraft Corporation	↔	
National Aeronautics and Space Administration	ABSTAIN	
Naval Air Systems Command	No input provided	
National Institute of Aviation Research	ABSTAIN	
Textron Aviation	↔	Proposed changes clarify and organize requirements. We already use life vests in all our new planes.

6.4 Recommendations for Issues beyond the Scope of Tasking

6.4.1 Flotation Analysis for Large Fuselage Breach

The team spent some time investigating short comings in the current flotation analyses used by applicants today. In service events have proved that aircraft typically float much longer than the certified analyses would predict. It would be beneficial to the industry if it the flotation assessments were more representative. Ultimately flotation and evacuation are the most important aspects of survivability. Having a flotation analysis more representative of the in-service evidence should be investigated in the future. See section 4.3.3.2.

6.4.2 Other Factors Affecting Crash Survivability

As the tasking of the WG was focused on structural crashworthiness, other aspects related to occupant survivability such as fuel system integrity under crash conditions were not addressed. It is recommended that a more holistic evaluation of crashworthiness and occupant survivability at aircraft level is performed at a later stage.

References

1. "Light Fixed and Rotary Wing Aircraft Crash Resistance" MIL-STD-1290 Rev A. 26 September 1988.

2. Aircraft Accident Study performed by Team 1 – see appendix A.

3. DOT/FAA/TC-17/52, Study of Transport Aircraft Water Mishap Kinematics and Regional Jet Mishap Kinematics, October 2017

4. FAA document DOT/FAA/CT-TN90/23, Seat Dynamic Performance Standards for a Range of Sizes, August 1990

5. NTSB Safety Recommendation, Hudson River Ditching Event, NTSB/AAR-10/03, 4 May 2010

6. DOT/FAA/TC-14/8 (DRAFT), Review and Assessment of Transport Category Aeroplane Ditching Standards and Requirements, Issue 2, February 2014

7. DOT/FAA/AR-95/54, Transport Water Impact and Ditching Performance, March 1996

8. DOT/FAA/CT-92/04, Commuter/Air Taxi Ditchings and Water Related Impacts that Occurred from 1979 to 1989, July 1994

9. FAA Policy memorandum, PS-ANM100-1982-00124, INFORMATION: Interpretation of FAR 25.801 (d), Ditching Approvals of transport Airplanes, 10 December 1982

10. ISO/TS/18571. "Road Vehicles – Objective rating metric for non-ambiguous signals" 2014.

11. Gehre, C. et al. "Objective Rating of Signals Using Test and Simulation Responses."

12. Zhan, E. et al. "Enhanced Error Assessment of Response Time Histories (EEARTH) Metric and Calibration Process." SAE Technical Paper, 2011-01-0245. 2011.

13. Sprague, M.A. and Geers, T.L. "Spectral elements and Field Separation for an Acoustic Fluid Subject to Cavitation." J. of Compo Physics 184 (2003). 149-162.

14. 1728/R/000593/KK, issue 4, "A Study Into the Structural Factors Influencing The Survivability of Occupants in Airplane Accidents", Ray Cherry and Associates, April 2016

15. DOT/FAA/AR-09/51, Summary Report: Airplane Fuselage Section Tests With Overhead Stowage Bins, May 2010

16. DOT/FAA/ARM-001-015, The Office of Rulemaking Committee Manual, February 2015, www.faa.gov/regulations_policies/rulemaking/committees/arac/media/Comm_001_015.pdf

Bibliography

Special Condition: 25-321-SC, Airbus Model A380-800 Airplane, Crashworthiness

Special Condition: 25-362-SC, Boeing Model 787-8 Airplane; Crashworthiness

Special Condition: 25-528-SC, Learjet Inc., Model LJ-200-1A10 Airplane; Crashworthiness, Emergency Landing Conditions

Special Condition: 25-537-SC, Airbus A350-900 Airplane; Crashworthiness, Emergency Landing Conditions

Appendix A Data Collected by Team 1

This section should discuss the various reports and documents used for data collection. Specific reports providing most useful data may be singled out for further discussion if appropriate.

A.1 In Service Data

This team was established to collect data, reports, documents and in service data to aid the development of crashworthiness and ditching rules and guidance. A database was generated to facilitate the review and parsing of data.

The following Excel file contains the crash events investigated by team 1.

ARAC Activity 1 -
In-ServiceCrashHistc

Team 1 also collected data on water related events that may or may not have been true ditching events. The Excel file below contains the data collected by team 1.

ARAC Activity 1 -
In-ServiceDitching_H

The information collected from data, reports and documents was summarized by the team using Google Forms. The form was developed by the team and contains 105 questions respectively input fields in several categories:

- Review information
- Source document information
- Impact severity classification
- Details of event, analysis, simulation or test
- Aircraft information
- Analysis, simulation, and test specific data
- Injury and survivability details
- Impact conditions
- Event details
- Calculation results
- Final thoughts

For final documentation, the collected data was exported in a tabular format (Excel).

Some exemplary evaluation results are given in the following. In total, 141 reports were reviewed by the team, 81% aircraft accident reports and 19% other reports like test or analysis reports. Due to lack of data or information, not all reports were recommended for estimation of the strength capability of the current fleet. This is why some of the results presented in the following figures refer to 68 or 71 responses.

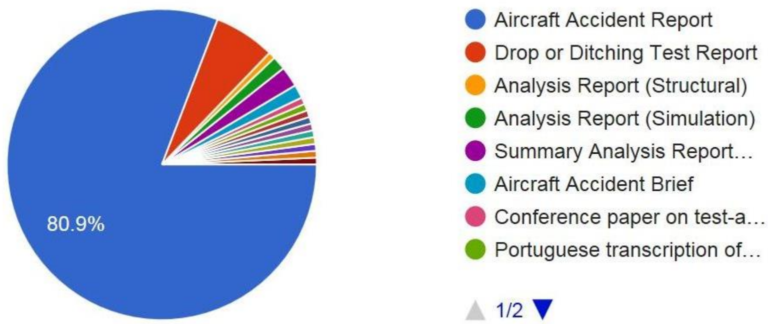


Figure 1: Type of report (141 responses)

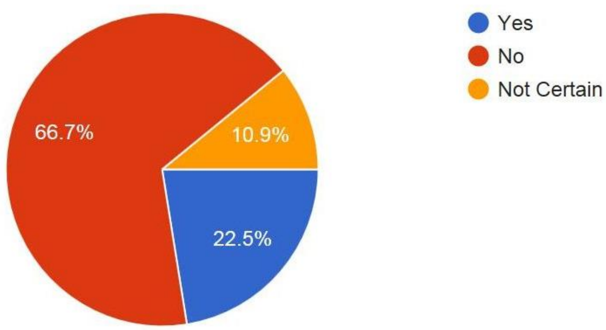
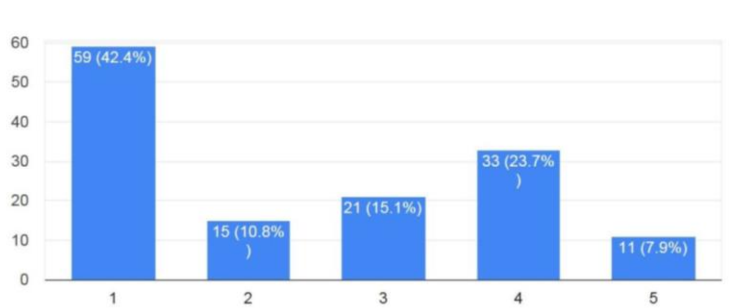


Figure 2: Report recommended for Team 4 review? (138 responses)



(1: strongly NOT recommended >> 5: strongly recommended)

Figure 3: Report recommended for estimation of strength capability? (139 responses)

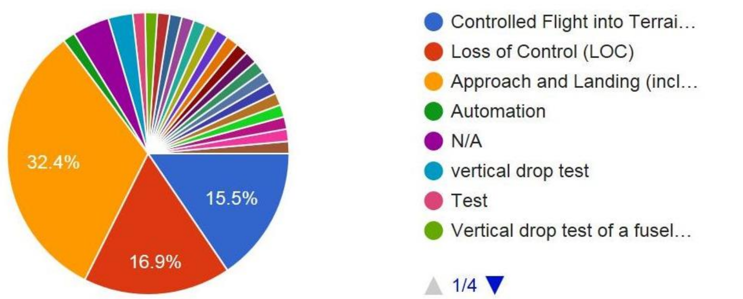


Figure 4: Class of accident (71 responses)

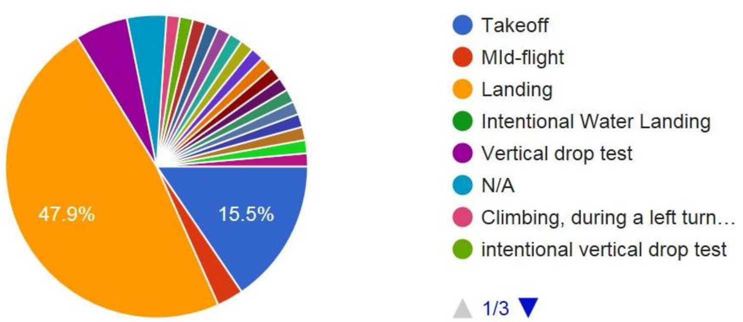


Figure 5: Phase of flight (71 responses)

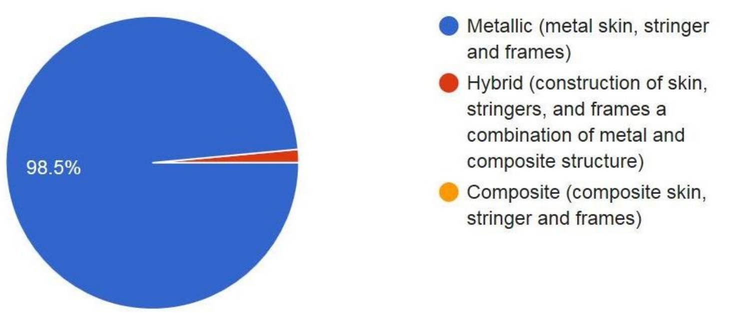


Figure 6: Aircraft construction (68 responses)

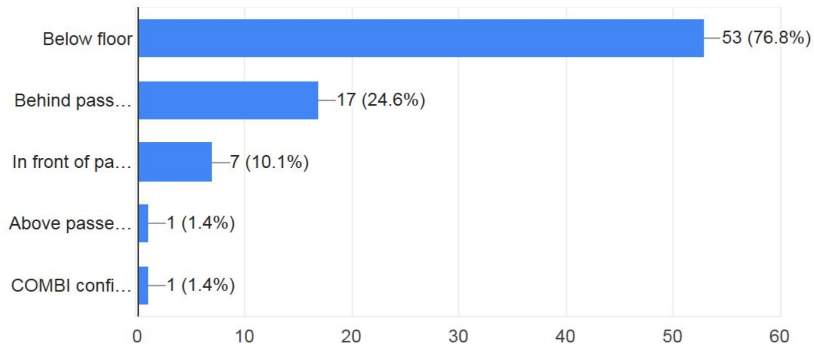


Figure 7: Location of cargo compartment (69 responses)

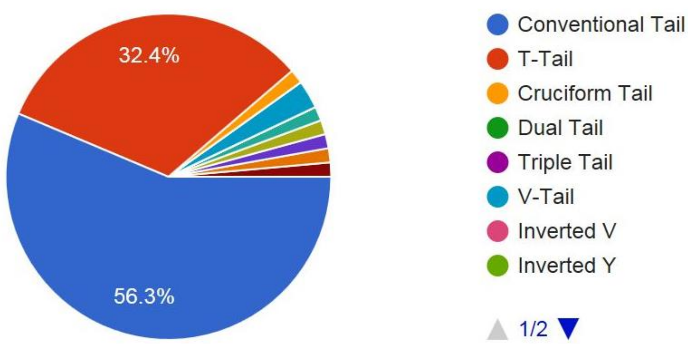


Figure 8: Tail design (71 responses)

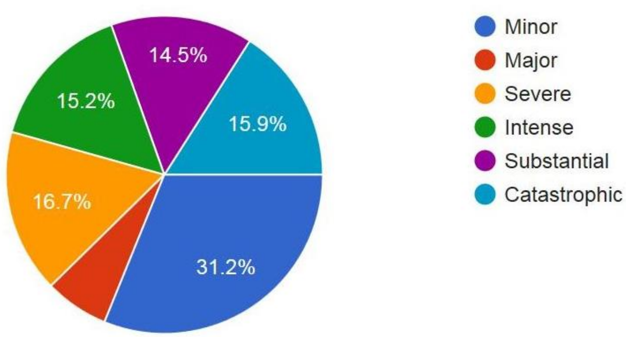
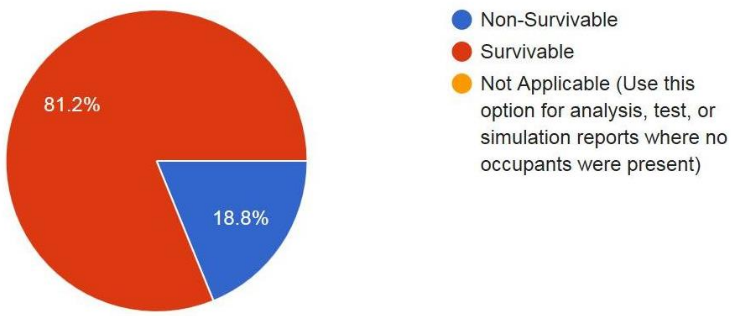


Figure 9: Impact Severity (138 responses)



DOT/FAA/TC-13/46:
Non-survivable: “A non-survivable accident is one in which all occupants sustain fatal injuries.”
Survivable: “An accident that is not non-survivable, but involves at least one fatal injury or the aircraft was destroyed”

Figure 10: Survivability (138 responses)

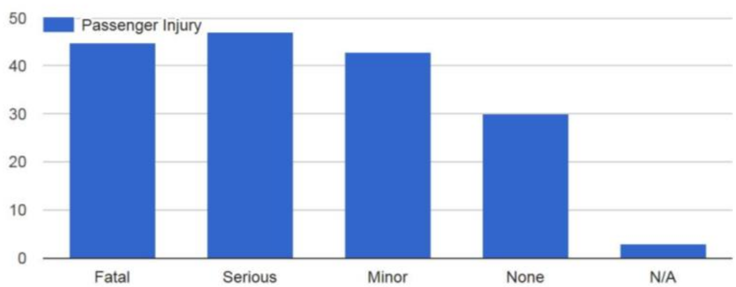


Figure 11: Type of injuries present in passengers

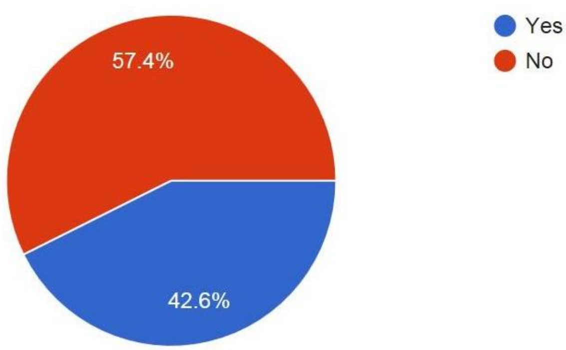
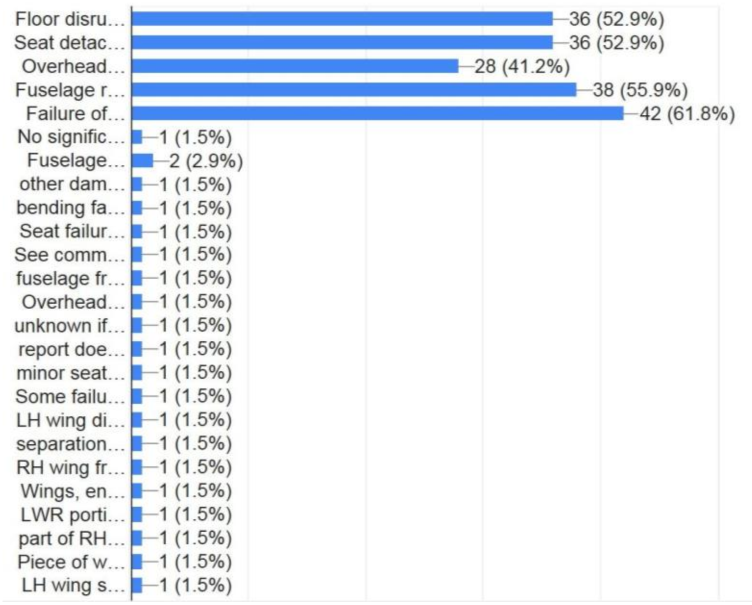


Figure 12: Does the report indicate that similar types of injuries were experienced in different locations of the aircraft? (68 responses)



Floor disruption, seat detachment, overhead bin detachment, fuselage rupture at production break, failure of extended landing gear, etc.

Figure 13: Types of structural failures (68 responses)

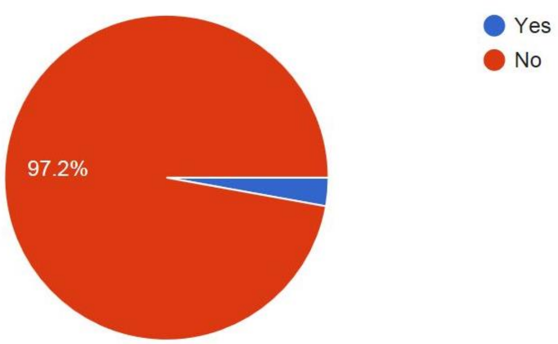


Figure 14: Fire during flight? (71 responses)

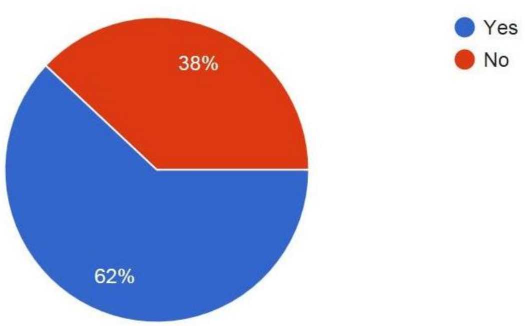


Figure 15: Fire on the ground? (71 responses)

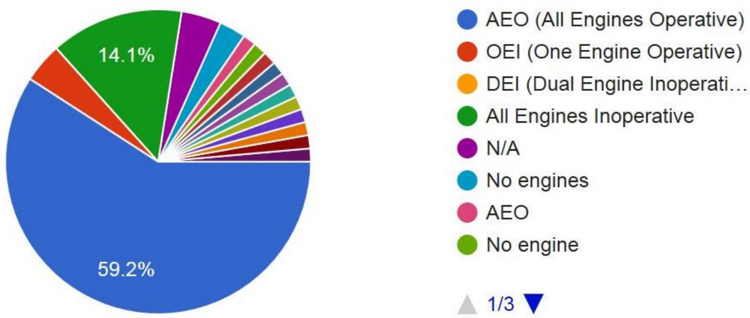


Figure 16: Status of engines (71 responses)

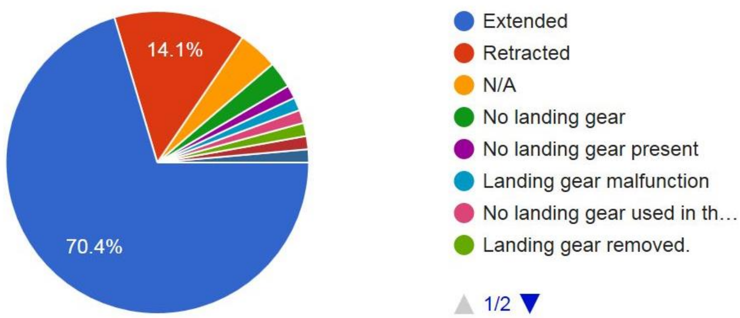


Figure 17: Landing gear status (71 responses)

A.2 Tests Related to Crashworthiness

Team 1 also collected data or reports for testing or simulations performed by research institutions and Government agencies. The Excel file below contains the test and simulation data collected by team 1

ARAC Activity 1 - CrashTest-Simulatio

Crash tests and analyses considered by team 1:

- B707 drop test: Vertical drop test of a transport fuselage section located forward of the wing (NASA TM-85679)
- B707 drop test: Vertical drop test of a transport fuselage center section including the wheel wells (NASA TM-85706)
- B707 drop test: Vertical drop test of a transport fuselage section located aft of the wing (NASA TM-89025)

- B737 drop tests/ analyses: Crash simulation of vertical drop tests of two Boeing 737 fuselage sections (DOT/FAA/AR-02/62)

- B707 drop test: Vertical drop test of a narrow-body fuselage section with overhead stowage bins and auxiliary fuel tank on board (DOT/FAA/CT-94/116)

- ATR-42 drop test: Vertical drop test of an ATR 42-300 airplane (DOT/FAA/AR-05/56)

- Shorts 3-30 drop test: Vertical drop test of a Shorts 3-30 airplane (DOT/FAA/AR-99/87)

- Metro III drop test: Vertical drop test of a Metro III aircraft (DOT/FAA/CT-93/1)

- Beechcraft 1900C drop test: Vertical drop test of a Beechcraft 1900C airliner (DOT/FAA/AR-96/119)

- A320 drop test/ analyses: Simulation of the A320 section drop test using the hybrid code KRASH (DLR-IB435-95/24)

- A321 full aircraft crash analyses: Simulation results of the A321 DRI-KRASH model including cabin load database (DLR-IB435-2003/20)

A.3 Key Reports - Crashworthiness

Identify key reports and studies used to develop proposed rule/guidance.

A.3.1 Soltis

Technical report: Seat dynamic performance standards for a range of aircraft sizes (DOT/FAA/CT-TN90/23)

Abstract: "This paper presents a summary of the rationale that was used to determine the crash impact characteristics for a range of aircraft sizes and places emphasis on developing seat dynamic performance standards that might be used for commuter category size aircraft. The existing crash dynamics data base which includes twin engine general aviation aircraft, rotorcraft, narrow body and wide body transport aircraft were used in this study. The crash impact characteristic of typical airframe structure will be related to the geometric size of the airframe."

A.3.2 Ray Cherry

Technical report: Analysis of structural factors influencing the survivability of occupants in aeroplane accidents (CAA Paper 96011)

Introduction: "In January 1995 R.G.W: Cherry & Associates Limited completed a research programme for the Commission of the European Communities to analyse the factors influencing the survivability of passengers in aircraft accidents. As part of this task an accident database of survivable accidents was developed containing information on over 500 accidents on in-service airliners. Subsequent to this, further work has been carried out on behalf of the UK CAA to analyse the structural factors significant to cabin safety. This report describes the methods employed in carrying out this analysis and the conclusions reached in relation to the potential safety benefit from improvements to structural survivability factors."

A.3.3 Ray Cherry 2

Technical report: A study into the structural factors influencing the survivability of occupants in airplane accidents (1728/R/000593/KK, Issue 4)

Introduction: "This study has been carried out at the request of the United Kingdom Civil Aviation Authority (UK CAA) and the United States Federal Aviation Administration (FAA). In 1996 the UK CAA published a study carried out by RGW Cherry & Associates Limited (RGWC) which analyzed the Structural Survivability Factors influencing the survivability of occupants in airplane accidents (Reference 1). This study is aimed at reanalyzing the Structural Survivability Factors, identified in the above study, to reflect more recent accident experience. This report constitutes the final deliverable of the UK CAA Contract No 2400."

Appendix B Crashworthiness Team Data

B.1 Airframe Crashworthiness Guidance

What follows is the guidance material developed as part of this ARAC task for airframe crashworthiness and accepted with general consensus.

Airframe Crashworthiness Guidance Material

1. Purpose

(a) This advisory circular (AC) provides guidance for compliance with the provisions of Title 14, Code of Federal Regulations (14 CFR) part 25, pertaining to the requirements for Airframe crashworthiness of transport category aircraft structure. This AC also includes guidance pertaining to clarification of the 4 primary attributes of airframe structural crashworthiness only and their associated performance goals. Evacuation and post-crash fire is not addressed by this guidance material.

(b) The following appendices appear at the end of this AC:

● Appendix 1 – References and Definitions

2. Applicability

(a) The guidance provided in this document is directed to airplane manufacturers, modifiers, foreign civil-aviation authorities, and Federal Aviation Administration (FAA) transport airplane type certification engineers and designees.

(b) This material is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. On the other hand, if the FAA becomes aware of circumstances that convince an applicant that following this AC would not result in compliance with the applicable regulations, the applicant will not be bound by the terms of this AC, and we may require additional substantiation or design changes as a basis for finding compliance.

(c) This material does not change, create additional, authorize changes in, or permit deviation from regulatory requirements.

3. Related Regulations

There are numerous rules related to protection of occupants. These rules can be found in parts of the emergency landing conditions, personnel and cargo accommodations, emergency provisions, safety equipment and within fire protection. This guidance material is intended to address the airframe structural aspects of crashworthiness. The regulations most directly related to airframe crashworthiness are:

25.561
25.562
25.787
25.789
25.809(g)

There are other regulations where compliance indirectly supports general crashworthiness or facilitates safe evacuation after a minor crash. This guidance material does not address these requirements.

25.721
25.783
25.785
25.791
25.803
25.807
25.810
25.811
25.812
25.813
25.815
25.853
25.854
25.855

25.856
25.857
25.858
25.859
25.865
25.867
25.869

4. Background

During the development of current airworthiness standards and regulatory guidance, the FAA assumed that airframe structure for transport airplanes would be constructed predominantly of metal, using skin-stringer-frame architecture. Therefore, certain requirements either do not address all of the issues associated with nonmetallic materials, or have criteria that are based on experience with traditionally-configured large metallic airplanes. With respect to crashworthiness, there is no airframe standard for crashworthiness.

The FAA promulgated standards for occupant protection at the seat installation level, with the presumption that the airframe provides an acceptable level of crashworthiness. Thus when an applicant proposes to use unconventional fuselage structure (materials, design architecture, or both), the FAA has written special conditions to ensure the level of crash protection is equivalent to that provided by a traditionally configured metallic airplane. These special conditions have been comparative in nature, and do not establish performance standards that are independent of traditional metallic skin stringer- frame architecture for airframe crashworthiness.

Airframe Crashworthiness: Many factors influence the crashworthiness of an airframe, including materials of construction, geometry, structural philosophy, multiple passenger decks, cargo below the passenger floor - crush space reduction, engine location - wing/fuselage/tail mount, unique structural architectures, aircraft size and weight, wing configuration - high, low, blended, use of auxiliary fuel tanks/systems and lower deck passenger seating. The key elements of crashworthy airframe design are managing energy absorption and maintaining structural integrity. For the most part, energy absorption is managed through plastic deformation and controlled failures of the lower fuselage structure. Maintaining the integrity of the structure is a balance between keeping loads within human tolerance levels, retaining items of mass, preserving a survivable volume and maintaining access to exits. Existing airworthiness requirements mainly focus on the safety of flight, and not crashworthiness, consequently when deviating from the traditional methods of construction an adequate level of safety cannot be assured.

Increased Use of Composites: In June 2009, the FAA Transport Airplane Directorate requested comments through the Federal Register (74 FR 26919) on whether there was a need for future rulemaking to address manufacturers' extensive use of composite materials in airplane construction. Several candidate technical areas were noted in the request, including fire safety, crashworthiness, lightning protection, fuel tank safety and damage tolerance. All responses that the FAA received indicated that crashworthiness in particular needs improved guidance and possible rulemaking.

5. Introduction

This AC provides guidance on showing compliance to the airframe crashworthiness rule 25.XXX by assessing general airframe structural behavior in a crash event and resulting effect on occupant survivability. This assessment reflects the general capability of the airframe and is not intended to assess every seat location in the aircraft. The airframe structures evaluated do not include seat structures which are adequately addressed in 14 CFR §§25.561, 25.562, and 25.785.

5.1 Airframe Crashworthiness Attributes

There are four primary attributes of airframe crashworthiness as specified in the airframe crashworthiness rule 25.XXX; Retention of Mass Items, Maintenance of Acceptable Loads experienced by the occupants, Maintenance of survivable volume, and maintenance of Occupant Egress paths. The compliance to the airframe crashworthiness rule 25.XXX for these four primary attributes can be demonstrated by analysis (supported by test evidence), test, design review and similarity or a combination of them. The intent of these four crashworthiness attributes are as follows:

Retention of Items of Mass: The intention of this attribute is to prevent large items of mass such as stowage bins or seats from coming loose and injuring passengers or creating a blocking hazard during evacuation. The interfaces of the airframe structures to seats, overhead bins and other items of mass need not be designed for static loads in excess of those defined in 14 CFR 25.561.

Maintenance of Acceptable Loads experienced by the Occupants: The primary purpose of this attribute is to make sure the occupant can exit the aircraft after the crash event. The focus is on bodily injury and the applicant must establish acceptable load levels where the passenger would have minimum injuries and still be able to exit the aircraft. The injury threshold limits for the lumbar loads may be used as specified in 14 CFR 25.562(c)(2). Alternatively, the applicant may utilize other occupant injury criteria as acceptable means of compliance, including the Dynamic Response Index for their design, in particular when showing similarity to previously certified aircraft. DRI is a well-established parameter and is regarded as an "acceptable means of compliance" to the thresholds specified in 25.562 as an alternative measure..

In addition, some of the smaller transport category aircraft may not have sufficient crush depth below the fuselage to provide adequate energy absorption capability to meet the occupant injury criteria specified in 14 CFR 25.562. As an alternative, for transport category airplanes that have a passenger seating configuration, excluding pilot seats, of 19 seats or less, and a maximum design takeoff weight less than 75,000 lb. (34.020 kg), adequate occupant crash survivability can be demonstrated by installing seats that comply with the requirements of 14 CFR 25.562 and the following additional dynamic test.

- A change in downward velocity (ΔV) of not less than 31 fps, with the airplane's longitudinal axis canted downward 30 degrees with respect to the horizontal plane and with the wings level. Peak floor deceleration must occur in not more than 0.06 seconds after impact and must reach a minimum of 15g.

Maintenance of a Survivable Volume: Maintenance of the occupant cabin is important in preventing injuries as well as aiding in egress. The evaluation must account for the large geometrical deflections as well as non-linear material behavior that may affect the results. Large structural displacement, distortion of the passenger cabin and resulting risk of passenger injury can also be evaluated by test.

The airframe structure should not infringe upon the occupant's living space. The occupant should represent a 95% male. Slumping forward or bending of the occupant at the waist during the impact event may be included in the analysis and/or test. Specifically, the applicant must show that:

1. The occupant does not get struck by overhead structure during the impact event.

2. The overhead or passenger compartment cabin floor does not collapse. Local failures of structure (e.g. local crippling, discrete fasteners) are acceptable if the general structural integrity is retained.

3. Overhead bins do not open.

Maintenance of the Occupant Egress Paths: This airframe crashworthiness attribute addresses the state of the floor and door surround structure supports the ability to open the doors. 14 CFR 25.562 requires that the floor warping be minimized and that the permanent distortion of the seat structure (ref AC 25.562) not adversely affect the ability of the passenger to exit the seat and seat row. Local failures of the floor system are acceptable if the passengers can still safely egress. As stated in Section 4, this is not a seat requirement or meant to change the requirements of 14 CFR 25.562. There may be some slightly different behavior of the seat due to structural deflection. Systemic failure at the interface would need to be addressed directly by the applicant. The emergency exit structure should not permanently deform causing a jamming situation.

Maintenance of the occupant egress paths can be demonstrated by test, analysis or by similarity and design review. A test can be conducted by including a door in the test article or alternatively by analysis or similarity that show that there is no permanent deformation in the door and/or door surround structure per 25.561 and 25.809(g). Compliance demonstration may be accomplished by selecting the structure where the greatest loading or deformation is expected to conservatively envelop all emergency exits. Confirmation of materials remaining within the elastic limits is acceptable. Additional evaluations may be required if door surround structure permanently yields to demonstrate the opening of emergency exit.

5.2 Crash Impact Scenarios

Crashes can occur for a multitude of reasons and at various times in the flight regime. In service events indicate that the majority of crashes that can be considered survivable occur during take-off, climb out and approach. During a survivable accident the forces transmitted to the occupant through the seat and restraint system do not exceed the limits of human tolerance to abrupt accelerations and in which the structure in the occupant's immediate environment remains substantially intact to the extent that a livable volume is provided for the occupants throughout the crash sequence. Human tolerance is as established 14 CFR 25.562(c)(2). Crashes initiated at greater altitudes tend to include significant amounts of energy and are unlikely to be considered survivable.

All crash events include forward and vertical velocity. The intent of the airframe crashworthiness evaluation is to ensure that the new designs maintain the safety that the fleet has demonstrated over the last 30 years. It is not necessary to evaluate every conceivable impact scenario to determine that a new design will function similar to the existing fleet during a survivable crash event. It has been observed that the vertical response is the primary discriminator in comparing crashworthiness performance. The vertical impact event fully exercises the primary redundant load paths provided by frames, floor beams and the skin/stringer. The forward velocity component results in an axial loading of the airframe with the primary loads carried in the floor grid structure reacted by the fuselage side structure. The factors (principally deformation, mass, and friction) that govern impact response characteristics in the longitudinal direction are not significantly altered with material systems, aircraft size, and design architecture. Given the similarity of future anticipated aircraft to the current fleet with respect to these conditions, it has been determined that the requirements of fuselage crashworthiness will be limited to an assessment of the vertical impact direction. Future designs not consistent with the typical fuselage and wing designs prevalent today may necessitate unique special conditions.

Another variable that can be considered for crash scenarios is the airplane attitude at impact. Most part 25 aircraft can only accommodate a slight roll or pitch variation before the dynamics of the event change significantly. Striking a wingtip will cause an unpredictable cartwheel of the aircraft (e.g. Asiana 777 in San Francisco, United DC-10 in Sioux City). Striking nose or tail first creates a combination of vertical and longitudinal acceleration for which the designs are more sensitive to the vertical component. Yaw can be considered but does not contribute significantly to loading of the fuselage structure. Of greater concern with yaw is lateral velocity component on the passengers and how the seat reacts in that environment. The lateral loading on seats and is addressed in 14 CFR 25.562(b)(2) and will not be addressed here.

Varying terrain could also be considered. However, compliance with this requirement will be shown using analysis supported by test, test only, or similarity. The different terrains and surfaces while interesting do not need to be evaluated for every potential condition. It is satisfactory to establish a repeatable consistent boundary condition for analysis and test by using concrete as the impact surface.

It may be necessary to perform some analysis or test evaluations to address off axis impact if the design includes design features intended to absorb energy and proper function of this feature is required to work properly for the design to satisfy 14 CFR 25.XXX.

5.3 Cargo and Passenger Arrangements

The crashworthiness assessment should also evaluate the passenger and payload arrangements considered to be typical and maximum occupancy with associated maximum payload. Cargo can be considered to be baggage expected to be carried in the typical format for the aircraft being assessed. It is expected that small part 25 aircraft and narrow body aircraft will typically carry luggage in a loose format in the cargo compartment. Wide body aircraft are expected to carry baggage in cargo containers.

The airframe crashworthiness requirements are not applicable to freighter aircraft. Freighter aircraft typically operate with a minimum crew for which the risk exposure does not warrant this level of evaluation.

Combi aircraft are adequately addressed by assessment of the passenger configuration. The cargo-combi configuration does not require a dedicated assessment for crashworthiness. The critical component in this assessment is the vertical descent velocity. As discussed previously the horizontal component of velocity is reacted by the side walls of the fuselage via the floor grid structure. It is anticipated that general load transfer between the floor grid and fuselage will remain similar. Evaluations addressing the fore/aft accelerations has shown that the axial stiffness and multi-load path design is adequate to react the fore and aft loading components. It should also be noted that aircraft that function simultaneously as cargo and passenger aircraft are rarely found and not expected to be any more popular in the future.

Carry-on baggage shall be considered as part of the assessment and be consistent with the passenger loading density. It should be addressed by overhead bin loading and accounted for as mass under the seats consistent with the aircraft type design.

Bulk cargo is only limited by what can fit into the cargo hold. The design of the fuselage and passenger floor structure in the bulk cargo region does not differ appreciably from the typical cross section. Assessment of a typical passenger section is adequate to address the bulk cargo locations of the aircraft.

6.0 Acceptable Means of Compliance

Acceptable methods of compliance with the airframe crashworthiness rule 25.XXX includes analysis (supported by test), test, similarity by design review, and a combination of these. The applicable parts of airframe crashworthiness rule 25.XXX to show compliance with depend whether the transport aircraft being certified is a totally new design or if it is similar in size, design architecture, and material systems to previously certified transport category aircraft. The flow chart below may be used to determine which parts of airframe crashworthiness rule may be applicable to show compliance.

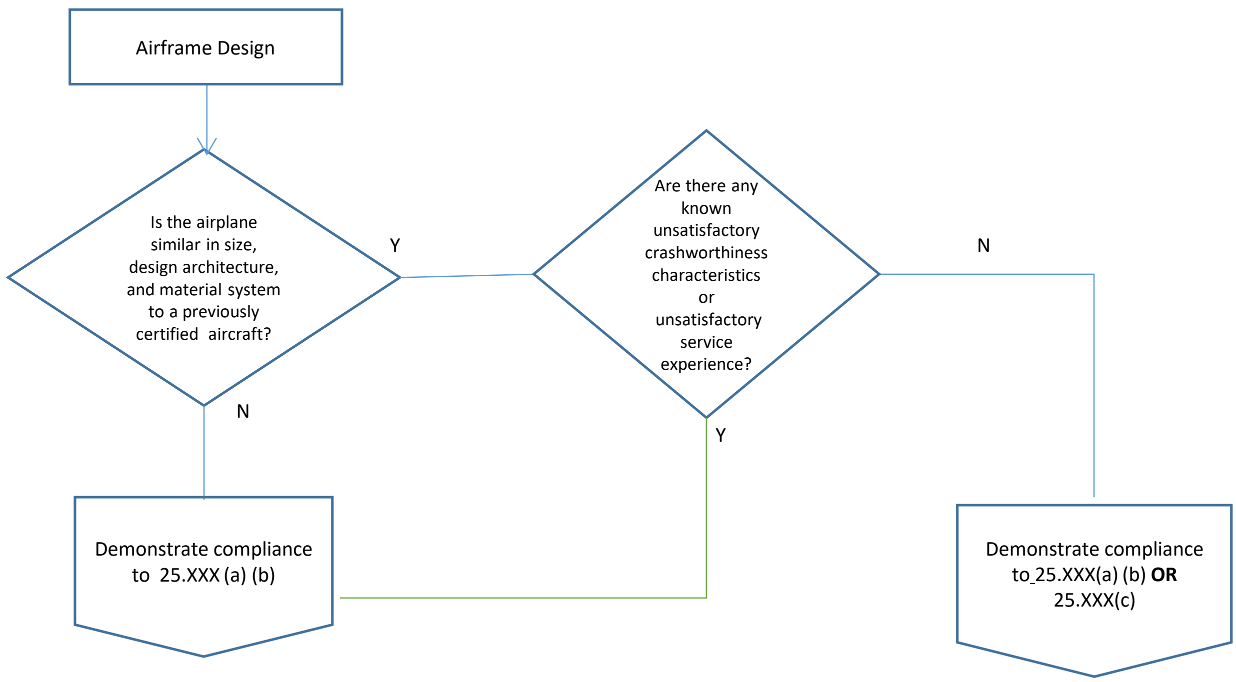


Figure 6. Airframe Crashworthiness Rule 25.XXX Compliance Flow Chart

Additional details of acceptable methods of compliance are presented in the following sections.

6.1 Means of Compliance by Design Review / Similarity

Compliance using a design review to show similarity in accordance with airframe crashworthiness rule 25.XXX (c) may be used provided:

(a) The previously certified transport category airplane does not have any design features or characteristics that have shown to be unsatisfactory with regard to occupant survivability.

(b) The previously certified transport category aircraft does not exhibit unsatisfactory service experience with regard to occupant survivability.

Similarity in this context means the structure uses structural design concepts such as details, geometry, structural arrangements, and load paths concepts; and materials that are similar or comparable to an existing design that is known to be acceptable for crashworthiness or has been certified to 14 CFR 25.XXX, crashworthiness special conditions or is of conventional design and is accepted by the regulators as being satisfactorily crashworthy.

Design review process involves review of the proposed type design data. This process includes verifying design details specific to compliance to the 25.XXX airframe crashworthiness requirements. Similarity is established by comparison with a previously certified aircraft for which sufficient crashworthiness information exists. The reference aircraft should be designed by the applicant and/or other OEMs for which sufficient information and crashworthiness know-how for similarity assessment is available to the applicant. The intent is to show that the proposed design will perform the same or better than the previously certificated design. If the amendment levels of the regulations are not the same for the two designs or there are changes applicable to guidance (ACs, etc.) the applicant must assess these differences to determine if similarity is appropriate. Using another manufacturers design to show similarity is very difficult and should not be considered practical unless the applicant has a licensing agreement with the other OEM to use their data and design.

6.1.1 Fuselage Crashworthy Design Attributes

Some of the fuselage design architecture and material system attributes that should be considered for the design review include:

(a) Fuselage Construction: Fuselage attachment to wing, empennage, landing gears, and power plant. Fuselage cross-section including shape and purpose of each compartment. Location of passengers during take-off and landing. General shape of the fuselage, closed cylinder extended along the flight direction with windows and doors. Design architecture, skins internally reinforced by stringers and frames, passenger floor grid and attachment design. Fuselage crush space and crushable structural elements. Assembly concepts, rivets, threaded pins, bonded joints.

(b) Material Systems and Manufacturing Techniques: Conventional metallic alloys (aluminum, steel, titanium), fiber reinforced plastics (composites), and hybrid materials.

(c) Unsatisfactory Characteristics for Crashworthiness: Characteristics in an existing design which have been shown to exhibit unsatisfactory performance in crash conditions, either through service experience or through test performance data, may lead to additional requirements in order to show compliance with the 25.XXX airframe crashworthiness requirements. Some examples of known unsatisfactory characteristics are: Absence of crushable structure in the lower fuselage, high-wing configurations which may intrude into the cabin in a crash event, and structural features which may increase the local loading in a crash event such as floor stanchions which do not deform with the shell.

6.1.2 Guidelines for Design Review / Similarity Assessment

Some of the guidelines for design review / similarity assessment of the four attributes defined in airframe crashworthiness rule 25.XXX (b) are as follows:

Retention of Mass Items: Large items of mass such as stowage bins or seats shall be retained to prevent them from coming loose and injuring passengers or creating a blocking hazard during evacuation. The interfaces of the airframe structures to seats, overhead bins and other items of mass need not be designed for static loads in excess of those defined in Sec. 25.561. Compliance by design review/similarity should show that the supporting airframe and floor structures at the interfaces of the airframe structure to seats, overhead bins, and other items of mass use structural details, geometry, structural arrangements, load paths, and materials that are similar to those used for previously certified aircraft of the same category.

Maintenance of Acceptable Loads Experienced by Occupants: Maintenance of acceptable occupant loads involves managing energy absorption. Elements to consider include floor support structure and underfloor fuselage airframe structure. Compliance by design review / similarity should show that the floor support structure and underfloor fuselage airframe structure use conventional structural details, geometry, structural arrangements, load paths, and materials that are similar to those used for previously certified aircraft of the same category. Occupant safety, concerning the threats directly related to the ground impact, is addressed at the seat installation level, under the presumption that the fuselage structure provides acceptable level of crash protection.

Maintenance of a Survivable Volume: The areas of the airframe occupied by all passengers for takeoff and landing must provide survivable volume remaining structurally intact during and after the crash impact events. The height of the occupied cockpit and cabin volume from floor to ceiling or overhead bin level must not be reduced such that the referred occupants come into contact with the structure. Compliance by design review / similarity should show that the floor support structure and fuselage airframe structure use conventional structural details, geometry, structural arrangements, load paths, and materials that are similar to those used for previously certified aircraft of the same category.

Maintenance of the Occupant Egress Paths: The airframe must maintain suitable egress paths to evacuate all occupants following a crash impact event. The applicant should show that the suitability of egress paths, as determined following a vertical impact event, is comparable to the suitability of egress paths for a comparable previously certified transport category aircraft. Compliance by design review / similarity should show that the floor support structure and fuselage airframe structure use conventional structural details, geometry, structural arrangements, load paths, and materials that are similar to those used for previously certified aircraft of the same category.

6.1.3 Design Modifications

The design review / similarity approach can also be utilized for amended type certification, supplemental type certificates (STC), and modifications and alterations. Any modifications that affect the airframe, floor support structure, interior, or seats should be assessed. See sections 6.1, 6.1.1 and 6.1.2 above.

6.2 Means of Compliance by Test

This section defines acceptable means to show compliance to certify crashworthiness solely by test. Acceptable test article definition, instrumentation and drop methods are given but other ways to show compliance can be developed and agreed to by the FAA. Compliance requires demonstrating satisfactory performance for the four airframe crashworthiness attributes specified by the airframe crashworthiness rule 25.XXX (b). If compliance is shown solely by test, it may take multiple test articles to cover variation in structure, interiors, seating, cargo and emergency exits since the critical configuration is not known.

6.2.1 Test Success Criteria

The crashworthiness test success criteria for demonstrating satisfactory performance for four attributes defined in 25.XXX (b) are as follows:

Retention of Items of Mass: No items of mass such as overhead bins or items in the bins can come loose. Occupants and Seat Structures supported throughout the crash event.

Maintenance of Acceptable Loads Experienced by the Occupants: Magnitude of the lumbar load on a Part 572 Hybrid II 50th Percentile ATD or Equivalent shall not exceed 1500 lb. as specified in 14 CFR 25.562(c)(2)

Maintenance of a Survivable Volume: Overall Survivable Space Dimensional Check (Peak during Dynamic Event and Post Test Deformations). The airframe should not infringe on the occupants normal living space. This assessment should account for a 95% male. Motion of the passenger and bending of the waist at the lap belt may be considered.

Maintenance of the Occupant Egress Paths: Seats cannot deform where passenger egress is significantly affected. Seats should remain attached and not block aisle. Floor structure remains reasonably intact. Exit doors must still function.

6.2.2 Test Article Selection

The test article selection must consider a representative fuselage section, appropriate boundary conditions, and cargo configuration and stiffness.

Fuselage Section Selection: The fuselage section chosen for test should encompass representative passenger areas of the plane for typical fuselage sections. If showing compliance by test only, significant changes in structure may require multiple test articles, or a test article large enough to encompass cross section variability due to exit and cargo doors or other design features. In general, the fuselage test section should include all design features that can influence fuselage crashworthiness. Specific design features can be excluded from the fuselage test section if they are not expected to influence the test results.

The wing structures outside the envelope of the fuselage need not be included unless the plane has a high-wing design. High-wing design sections can be tested with appropriate ballast weight to simulate maximum landing weight and 1 g wing lift.

Representative Boundary Conditions: Re-enforcement at the open ends of the test article should be analyzed to give appropriate stiffness of a complete fuselage. It should be long enough to include the most critical type of seats used with adjacent rows of similar seats so that floor load interaction is represented. Seats should be certified to 14 CFR 25.562 and data from that certification can be used to justify the critical seat configuration. Overhead structure should be installed with maximum allowed items of mass in each compartment. On the test article with an emergency exit, the exit must be in an area with representative seats, overhead mass and under floor luggage (if applicable) in order to give the most severe scenario for deformation.

Representative Cargo Configuration and Stiffness: If the compartment under the floor is used for baggage or cargo, the applicant must consider the cargo configurations and select the most critical cargo or baggage configuration. Typical baggage or representative surrogate ballast may be used in the test. Cargo door structure may be required as it would have a different crush stiffness than the basic fuselage.

6.2.3 Instrumentation

Anthropomorphic test dummies (Part 572 Hybrid II 50th Percentile ATD or equivalent) should be used to show compliance with occupant injury criteria limits. Lumbar load injury limits specified in 14 CFR 25.562 (c)(2) is the pass/fail criteria, and shall be measured for all ATDs in the test. High speed camera video should be used to demonstrate that a survivable volume is maintained. In tests where seats and ATDs are not included in the test article, additional seat-occupant analyses should be conducted using the airframe acceleration data obtained during the test to show compliance with the occupant injury limits.

Additional instrumentation may be included but is not required to measure the overall fuselage response from the test. Additional Instrumentation may include accelerometers at the base of the seats or on the seat tracks, along with accelerometers at frame/stiffener or other critical junctions at the floor and in the overhead bins at a minimum. Strain gages and/or high speed photogrammetric imaging/video may also be included to measure deformation of the subfloor crushing, overhead mass item motion, and survivable volume maintenance.

High speed video cameras that show the passenger area are required. Review of the video should be used to validate that a survivable volume was maintained throughout the impact, items of mass were contained, and the airframe deformations did not cause injury.

6.2.4 Test Conduct

The test article is to be dropped vertically at zero nominal pitch angle. If energy absorbing features are included in the design, variation of aircraft pitch angle must be considered to ensure proper functioning of such features under off-axis conditions or the applicant may consider a separate test to address the load attenuation feature. The drop surface should be rigid. The impact velocity must be consistent with the requirements in airframe crashworthiness requirement 25.XXX (a).

Post-test inspections shall be conducted to identify any structural failures during the test that may be a hazard to the occupants or indicate failure to satisfy one of the four attributes of 14 CFR 25.XXX(b). Post-test inspection of the egress paths are required to ensure they are clear and are not blocked due to excessive floor warping. Emergency exits shall be opened to determine if they comply with 14 CFR 25.810.

6.2.5 Design Modifications

Testing can also be used as a method of compliance for amended type certification, supplemental type certificates, and modifications and alterations.

If modifications in the amended or supplemental certificate affect the passenger compartment (airframe, floor support structure, interior or seats) such that it cannot be certified by similarity, it could be tested to show compliance to the crashworthiness requirements. To certify crashworthiness for an amended or supplemental type certificate or modification/alteration by test requires meeting the four crashworthiness attributes specified in 25.XXX (b) for vertical impact velocities specified in 25.XXX (a). Test article guidance from this section should be followed when applicable to the modification.

For example, new overhead bins would not require seat and ATD testing. Just testing to show the items of mass were contained in a drop. A new baggage door would not require seats, overhead bins or ATD in the test, just structure to show the door would open after an impact.

6.3 Means of Compliance by Analysis

This section provides acceptable means of compliance by analysis with crashworthiness requirements for the fuselage structure that must be designed to assure crash survivability during an emergency landing. It is applicable for Type Certification, Changes to Type design affecting Crashworthiness and Supplemental Type Certificates. The compliance may be demonstrated by analysis only or in combination with test and design review / similarity

In-service experience shows that conventional large transport airplane configurations have demonstrated inherent structural robustness with regard to crash survivability. For aircraft based on such conventional fuselage/cabin design, the applicant can show compliance by design review.

For aircraft fuselage/cabin designs that exhibit either significantly different design architecture or material systems from previously certified transport category aircraft, an analytical assessment of a representative fuselage section can be undertaken.

The analytical assessment shall demonstrate satisfactory performance for the four airframe crashworthiness attributes specified in airframe crashworthiness rule 25.XXX (b). These four crashworthiness attributes are:

1) Retention of Items of Mass

2) Maintenance of Acceptable Loads Experienced by the Occupants

3) Maintenance of a Survivable Volume

4) Maintenance of the Occupant Egress Paths

It is recognized that significant differences exist with respect to operating weights and fuselage/cabin design within the category of transport aircraft (i.e. including the amount of available crushable structure under the passenger floor). The acceptable crash performance must therefore be equivalent to the ones of a similar size, design architecture, and material systems of already certificated transport category aircraft.

The Limit of Reasonable Survivability defined for similar transport aircraft shall be accepted by the Administrator as a basis for compliance demonstration. In absence of more rational justification of Limit of Reasonable Survivability, based on in-service experience of conventional large transport airplane configurations with the range of vertical impact velocities defined in 25.XXX (a) can be considered.

6.3.1 Analysis Method Validation

When analytical methods are used for showing compliance, these methods are to be shown reliable and be supported by appropriate test evidences. A test portfolio should exist (new test or legacy aircraft tests, if applicable) to support and validate relevant parameters impacting crashworthiness of the product.

To validate the analytical methods a Building Block approach shown in Figure 7 is typically used. It typically includes the following steps to capture relevant design details of fuselage structure that contribute significantly to crashworthiness capability:

1. Coupon and element level material properties characterization and calibration.
2. Detail and sub-component level tests for model calibration.
3. Component level validation of the numerical model as necessary

The data from coupons, elements, details, sub-components is the basis for defining the appropriate attributes and material idealization for then analyzing the next higher level in the pyramid.

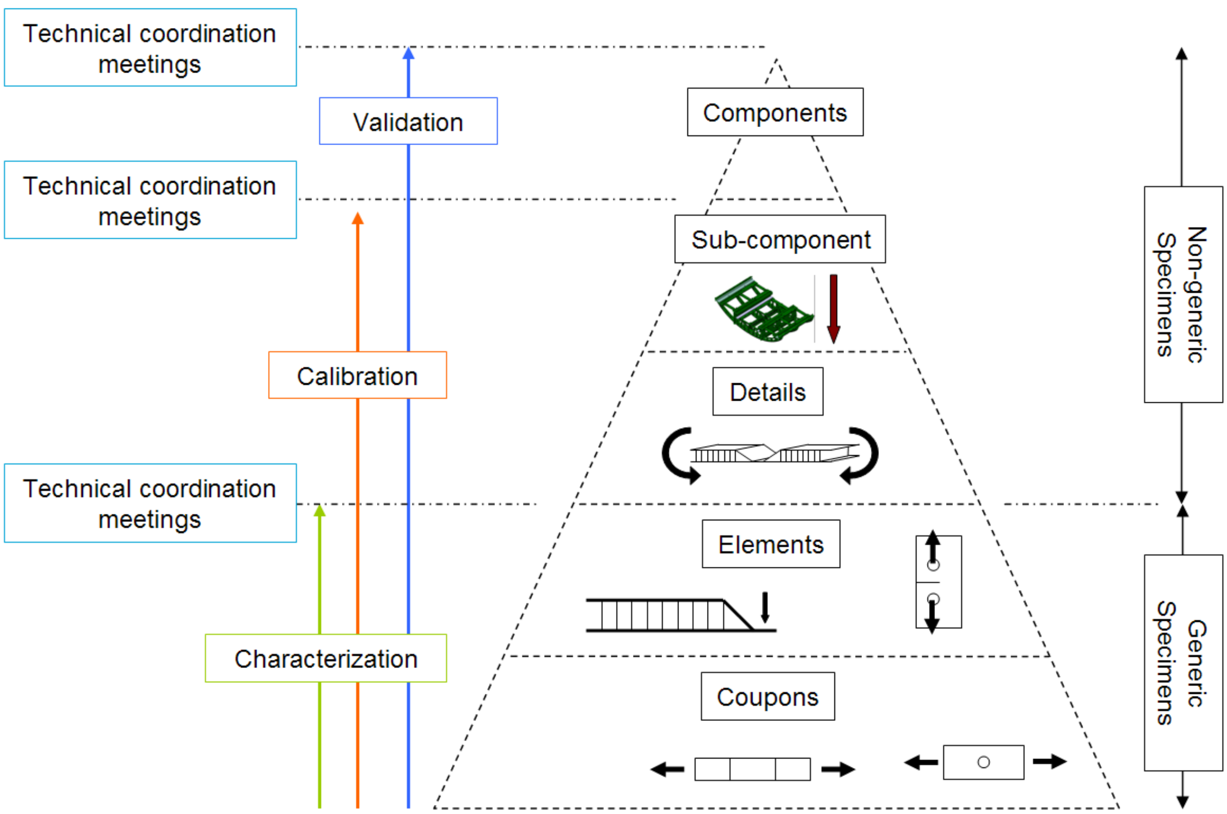


Figure 7. Building Block Approach to Test – Analysis Validation

Material coupon testing is typically used to calibrate material model up to failure, under static loading conditions, at room temperature and dry conditions. The outputs are stress versus strain curves for materials of the skin, stiffeners, clips, frames, etc. Dynamic loading may also be needed for some material systems that exhibit strain rate dependencies.

Joint testing is used to calibrate joint models up to failure, under both static and dynamic loading conditions as necessary. The outputs are load versus elongation curves for typical joint configurations. Fastener shear and material bending interaction can also be evaluated under dynamic loading as necessary.

Elements are tested in order to establish elementary failure modes and load versus deflection characteristics. These elements include clips, frames, etc. are typically tested under both static and dynamic loading conditions as necessary. Energy absorption capability is also investigated.

Design Details are tested in order to establish elementary failure modes. Such details may include splicing, various struts and other design features. These tests may be performed statically or dynamically as necessary.

Sub-components are tested in order to establish energy absorption capability, while checking the sequence of crash mechanisms and elementary failure modes. Sub-components may include frame assembly specimens with skin, stringers, frames, clips, floor beams, etc. These tests may be performed statically or dynamically as necessary.

Component level tests are run as the top of the building block to validate the analysis. The component must be representative of a typical passenger section and of sufficient size to properly capture interaction between seat rows.

For the designs with significantly different crashworthiness characteristics and/or strength and stiffness characteristics, configurations, materials, the validation will likely require a more robust building block of testing. For conventional metallic similarity by design review could be supported by analysis and lower level testing as necessary. This might be appropriate for a design change for a derivative aircraft. Example: for derivative aircraft, the use of supporting data from already certified program is acceptable. For higher levels of test pyramid, each of these articles is modeled and pre/post-test evaluated using Explicit Finite Element code.

It is acceptable to use room temperature dry, average “typical” material values in the analysis. Pre-test evaluation is recommended to establish the prediction for correlation and also to define the means for realistic boundary conditions and loading conditions needed for best representation of the airframe structure during test.

The validated analysis models should accurately predict the following crash dynamic response characteristics:

- Overall kinematic response of the structural components observed during testing
- Overall deformation of the structure. The analysis model should be able to predict areas of large deformation, including crushing, bending, and failures observed during testing.
- Loads on the ATDs. The model show reasonable correlation with the accelerations measured, along with loads on the ATDs.
- Strains and accelerations at critical interface locations (seat/floor, luggage bins/ceiling, etc.)

When using analysis as compliance data, elements of the analysis methods that should be considered include (but are not limited to):

- Boundary conditions, external and internal loads (including time history)
- Detail of structural simulation, including
    - Element types
    - Control parameters
    - Key idealizations and assumptions
    - Element deletion
    - Energy dissipation schemes
- Structural configuration
    - Joint design details
    - Structural systems
- Materials and material characteristics, including
    - Failure characteristics
    - Strain-rate dependent characteristics
    - Stiffness
    - Energy absorption characteristics
    - Environmental considerations
    - Orientation (grain direction/fiber orientation)
- Deflections and deformations
- Test experience
- Extent that extrapolation of test data is acceptable

Certain modelling parameters should be examined to determine their effect(s) on the results. Physical and non-physical parameters such as contact algorithms, mesh domain discretization, ATD positioning, mass scaling and other model characteristics should be investigated. Reasonable efforts to characterize the range in result values should be made, and conservative values should be used as the basis for the model results.

Analytical Accuracy

In order to quantitatively measure uncertainty in the experimental data, a number of validation or error metric methods should be considered. These methods consist of computable measures that can quantitatively compare experimental results over a series of parameters (Figure 8) to objectively assess experimental uncertainty over the traditional qualitative graphical comparison.

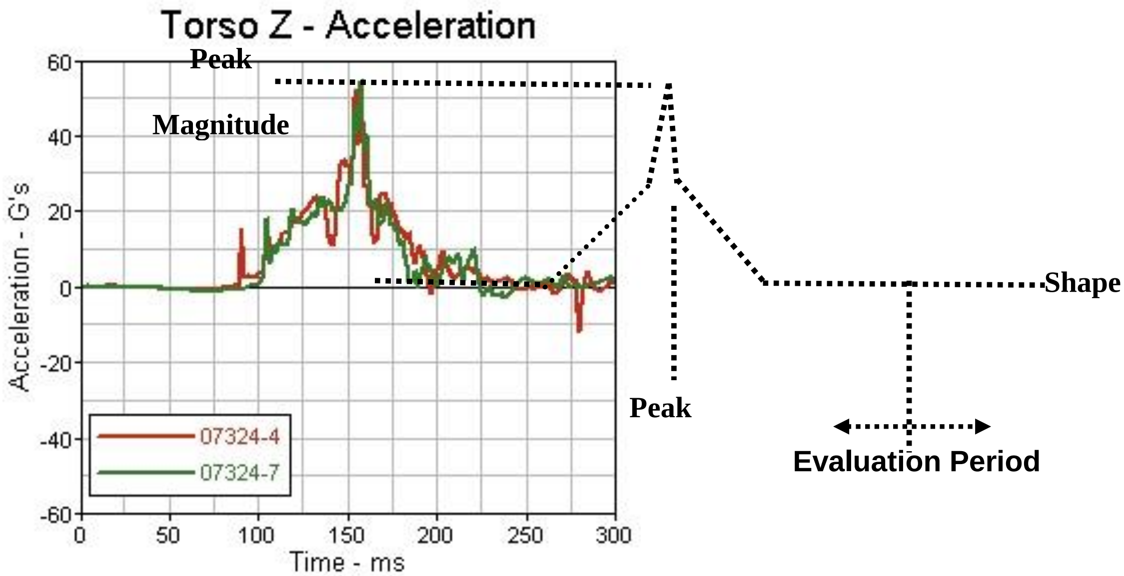


Figure 8. Validation Metric Measured Parameters

Sprague and Geers (S&G) Method: This method considers a magnitude error factor that is insensitive to phase discrepancies, and a phase error factor that is insensitive to magnitude discrepancies. (Figure 9). The total error factor or score is given by the following expressions.

$$Score = \sqrt{M^2 + P^2}$$

where,

M = magnitude error factor

P = phase error factor

$$M = \sqrt{\frac{I_{gg}}{I_{ff}}} - 1$$

$$P = \frac{1}{\pi} * ar\cos\left(\frac{I_{fg}}{\sqrt{I_{ff} * I_{gg}}}\right)$$

where,

$$I_{ff} = \frac{1}{t_2 - t_1} * \int_{t_1}^{t_2} f^2(t)dt$$

$$I_{gg} = \frac{1}{t_2 - t_1} * \int_{t_1}^{t_2} g^2(t)dt$$

$$I_{fg} = \frac{1}{t_2 - t_1} * \int_{t_1}^{t_2} f(t) * g(t)dt$$

where,

$t_1<t<t_2$ = time span or evaluation period

f(t) = benchmark history or reference data

g(t) = candidate solution or data to compare

Note that this method is biased towards the f(t) data set.

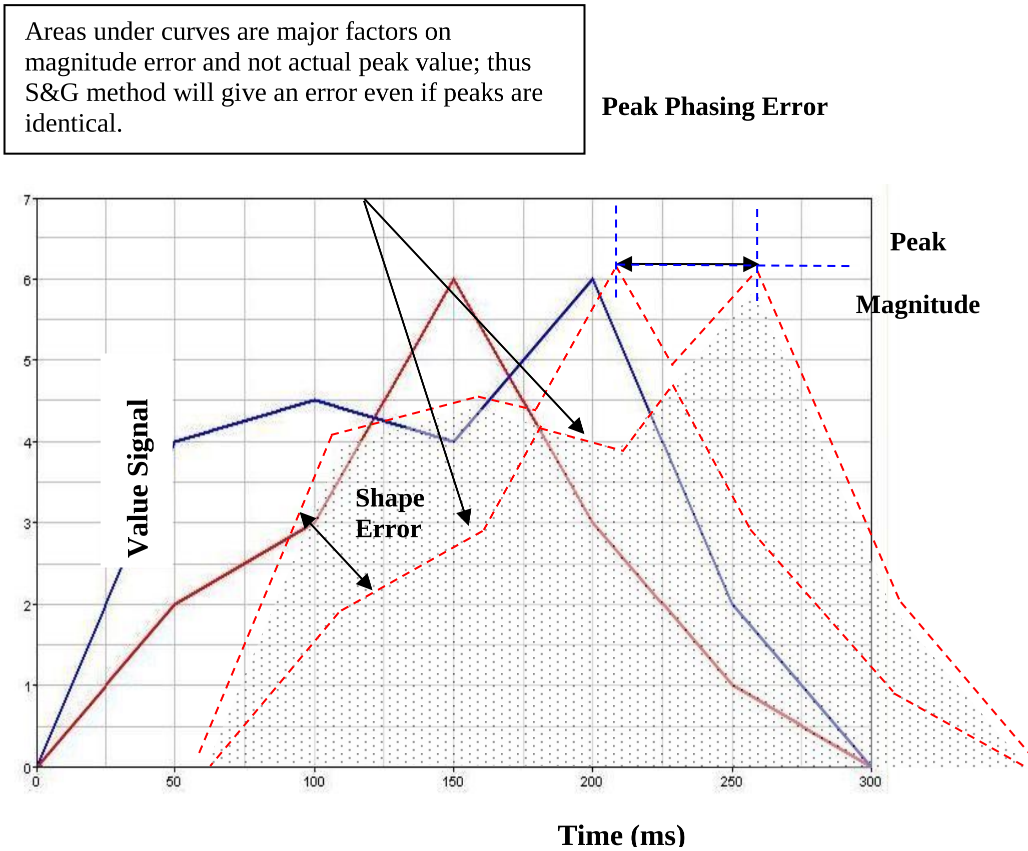


Figure 9. Sprague and Geers Metric Measured Parameters

Relative Error Method: The relative error method is a very common metric used to compare two values quantitatively in the form of a percentage difference. This method does not consider time variations or phasing, so it is only useful to compare the maximum magnitude of a response (Figure 10). The relative error is derived as follows:

Delta Error = $Maxg(t) - Maxf(t)$

Relative Error = Magnitude Error = $\dfrac{Maxg(t) - Maxf(t)}{Maxf(t)}$

where:

Maxf(t) = peak or maximum magnitude value (positive or negative) in reference data

Maxg(t) = peak or maximum magnitude value (positive or negative) in candidate solution or data to compare

Note that this method is biased towards the *f(t)* data set.

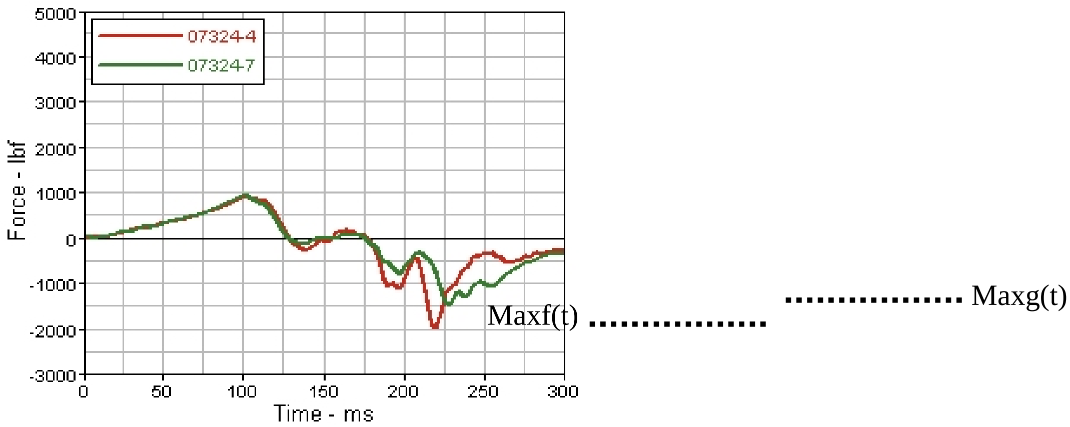


Figure 10. Relative Error Measured Parameters

ISO/TS/18571 Method: This method compares two signals and calculates the differences in their phase, magnitude and slope, and assigns each a score. The final level of correlation, R, combines each of the scores along with a corresponding weighting factor to provide a single number as a final determination. This number is then evaluated according to the criteria as shown in the following table (reprinted from Reference 1).

Rank	Grade	Rating, R	Description
1	Excellent	$R > 0.94$	Almost perfect characteristics of the reference signal is captured
2	Good	$0.80 < R < 0.94$	Reasonably good characteristics of the reference signal is captured but there are noticeable differences between both signals
3	Fair	$0.58 < R < 0.80$	Basic characteristics of the reference signal is captured by there are significant differences between the two signals
4	Poor	$R \leq 0.58$	Almost no correlations between the two signals

The test/analysis correlation lower limit should be mutually agreed upon between the applicant and regulator. Methods, such as Correlation and Analysis (CORA) [2], Enhanced Error Assessment of Response Time Histories (EEARTH) [3] or Sprague and Geers [4] all provide a rigorous level of correlation assessment between the magnitudes and phase shifts of the test and analysis data. Any of these methods can be used to determine correlation provided that it accounts for both magnitude and phase shift comparisons between test and analysis data. However, the specific metric and correlation factor(s) must be mutually agreed upon between the applicant and regulator.

6.3.2 Test Configuration Analysis Model

The analysis model of the validation test article configuration must accurately reflect the fuselage test sections structure and the appropriate boundary conditions. The fuselage test section chosen for analysis should encompass representative passenger areas of the plane. Typically, three rows of seating should be included. However, for smaller part 25 aircraft, including 2 rows of seating could be acceptable. It is desirable to have appropriate seat interaction from row to row. In general, the fuselage test section should include all design features that can influence fuselage crashworthiness. Specific design features can be excluded from the fuselage test section if they are shown to not influence the test results. If load attenuation features are included in the design, variation of aircraft pitch angle must be considered to ensure proper functioning of such features under off-axis conditions. Alternatively, the applicant may consider a sub-component or element test to directly evaluate the load attenuation feature loaded off axis.

The analysis should also consider a range of payload configurations. Such as, full passenger and typical passenger loading, full cargo and no cargo and combinations therein. It is not necessary to consider payload configurations that are not certifiable.

For the aircraft with high wing design or other design features that may affect crashworthiness (i.e., having the wing attached to the fuselage crown), the simulation model and supporting test specimen should include a representative structure of the wing or the detail in question where it interacts with the fuselage. The simulation and test article can use ballast to simulate the remainder of the structure beyond where it interfaces with the fuselage. The extended fuselage cylindrical section shall be modelled or properly accounted for in the boundary condition.

A validated analysis model should be used for showing compliance by analysis. Validation of the model shall include the criteria shown in Section 6.3.1. If the test configuration being analyzed or the impact conditions are very different, sensitivity studies should be conducted for mesh size, material properties, impact conditions, etc. to identify and quantify any factors of uncertainty.

6.3.3 Analysis Results Post-Processing and Acceptability Criteria

The fuselage and ATD analytical data should be post-processed per SAE J211 specification where applicable. Based on the post-processed analytical data, the structure performance should be assessed with respect to the following as necessary for the design space intended:

- Overall crushing kinematics
- General structural deformation of the passenger compartment
- Lumbar load levels experienced by occupants
- Passenger floor cross-beam and floor panel deformation and locations of failure initiation and extent (if any)
- Effect of fuselage shell deformation on passenger door and door surrounding structure.
-

Appendix 1: Definitions

Survivable Accident: An accident in which the forces transmitted to the occupant through the seat and restraint system do not exceed the limits of human tolerance to abrupt accelerations and in which the structure in the occupant's immediate environment remains substantially intact to the extent that a livable volume is provided for the occupants throughout the crash sequence.

Design Review: A process that involves the review of the proposed type design data. This includes verifying details specific to compliance with the referenced regulatory document.

Similarity: The structure uses structural design concepts such as details, geometry, structural arrangements, and load paths concepts; and materials that are similar or comparable to an existing design that is known to be acceptable for crashworthiness or has been certified to 14 CFR 25.XXX, crashworthiness special conditions or is of conventional design and is accepted by the regulators as being satisfactorily crashworthy. Comparison between a previously certified design by the applicant and/or other OEMs for which sufficient information is included in the similarity assessment. The intent is to show that the proposed design will perform the same or better than the previously certificated design. If the amendment levels of the regulations are not the same for the two designs or there are changes to the applicable guidance, the applicant must assess these differences to determine if similarity is appropriate.

Occupant: All passengers, flight attendants, and cockpit crew in the aircraft.

References

[1] ISO/TS/18571. “Road Vehicles – Objective rating metric for non-ambiguous signals” 2014.

[2] Gehre, C. et al. “Objective Rating of Signals Using Test and Simulation Responses.”

[3] Zhan, E. et al. “Enhanced Error Assessment of Response Time Histories (EEARTH) Metric and Calibration Process.” SAE Technical Paper, 2011-01-0245. 2011.

[4] Sprague, M.A. and Geers, T.L. “Spectral elements and Field Separation for an Acoustic Fluid Subject to Cavitation.” J. of Compo Physics 184 (2003). 149-162.

B.2 Crashworthiness Presentations

Presentations made by team members or by guests during face to face or all team telecons can be found in the companion document titled ARAC TACDWG Crash Presentations.

Appendix C Ditching Team Supporting Information

What follows is the guidance material developed as part of this ARAC task for ditching.

C.1 Ditching Guidance

1 Purpose

This Advisory Circular (AC) provides acceptable certification methods, but not necessarily the only acceptable methods, for demonstrating compliance with the ditching requirements of part 25, as amended through Amendment 25-1XX, of Title 14 of the Code of Federal Regulations (14 CFR) for transport category airplanes.

This section contains the proposed guidance as agreed to by general consensus in the TACDWG.

2 Applicability

a) Available guidance pertaining to part 25 is presented according to the amendment level of part 25 to which it applies. For modified airplanes certificated under part 25, the pertinent guidance may be obtained from this AC by reference to the applicable amendment level. (Compliance with later rules may be required in accordance with §§ 21.101(a) and 25.2, or with applicable operating rules as noted above.) Additional guidance may be included in this AC that pertains to either prior amendments or sections that have not been modified. The guidance presented herein applies to part 25 Amendment 25-1XX and later.

b) The guidance provided in this document is directed to airplane manufacturers, modifiers, foreign regulatory authorities, and FAA transport airplane type certification engineers, and their designees.

c) This material is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. On the other hand, if we become aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation or design changes as a basis for finding compliance.

d) This material does not change, create any additional, authorize changes in, or permit deviations from, regulatory requirements.

3 Cancellation

For airplanes that include 14 CFR 25.801 at Amendment 25-1XX, or later in the certification basis, the guidance contained herein supersedes guidance provided in AC 25-17A for 14 CFR 25.801.

4 Related regulations and Guidance

4.1 Related Regulations

This document includes guidance for showing compliance with the following regulations that are applicable to ditching certification:

Section 25.563, *Structural Ditching Provisions*

Section 25.801, *Ditching*

Section 25.807(i), *Emergency Exits*

Section 25.1411*, Safety Equipment*

Section 25.1415, *Ditching Equipment*

Section 25.1581, *Airplane Flight Manual*

The primary regulations for ditching are §§25.563, 25.801, 25.807(i), 25.1411, 25.1415 and 25.1581. There are numerous other regulations that contribute to the ability to provide occupant safety in emergency landing conditions, such as 14 CFR §§25.561, 25.562, and 25.809(g). However, since they are not specifically addressed in this document, they are not identified above as related regulation.

4.2 Related Guidance

Advisory Circular 25-17A, Transport Airplane Cabin Interiors Crashworthiness Handbook, Change 1, May 24, 2016.

4.3 Definitions

This document includes guidance for showing compliance with the following regulations that are applicable to ditching certification:

4.3.1 Buoyancy:

On airplanes, buoyancy features allow the airplane to float and include, but are not limited to, the portion of the following features that displace water: fuel tanks, pressure vessel, and any other items that can be shown to remain intact after the ditching event and displace water (e.g., structure and systems of the airplane, landing gear, the bell jar volume of the landing gear wheel wells).

4.3.2 Ditching Dam:

Internal devices (such as fixed sill raiser) or external devices (such as inflated barrier activated upon door opening) that raise the lower sill of a ditching exit. These devices may be used to provide the freeboard needed for an exit to qualify as a ditching exit.

4.3.3 Ditching Exit:

To qualify as a ditching exit, the exit sill must be initially above the waterline and it should remain above the waterline for the duration of the evacuation during a planned or unplanned ditching.

Note: If it can be shown to still be conservative, an exit(s) may qualify as a ditching exit if it doesn't remain above the waterline for the full duration of the evacuation. A showing of conservatism should include an assessment of how long the ditching exit remains above the waterline, the number of persons expected to be remaining in the airplane when the ditching exit(s) sill goes below the waterline and the number of other ditching exits remaining above the waterline.

4.3.4 Evacuation Time:

The time for all occupants to exit the airplane. The evacuation is assumed to start when the airplane comes to rest in the water. For a planned ditching the evacuation time ends when the last airplane occupant leaves the airplane and enters a raft. For an unplanned ditching, the evacuation time ends when the last airplane occupant leaves the airplane and enters a slide/raft, the water or steps on the wing.

4.3.5 Flotation Time:

The time from when the airplane comes to rest in the water to when the airplane condition is such that occupants can no longer safely evacuate.

Note: For certification, the flotation time is generally considered to be the time from when the airplane comes to rest in the water to when the first ditching exit sill goes below the waterline, or when the attitude of the airplane is such that it would require extraordinary effort to move through the cabin to reach available ditching exits. However, if it can be shown to still be conservative, the flotation time may be extended. A showing of conservatism should include an assessment of number of persons expected to be remaining in the airplane when the ditching exit sill(s) goes below the waterline, the number of ditching exits remaining above the waterline and the attitude of the airplane.

4.3.6 Inadvertent Water Entry:

Runway overshoot (at take-off or landing) or runway undershoot (at landing), where the airplane alights on water. This type of event is considered to be a minor crash, where the aircraft inadvertently ends up in water where it is supported or partially supported by land.

4.3.7 Planned Ditching:

An emergency landing on water where the flight and cabin crew have sufficient time to fully prepare the aircraft and the passengers, and execute the ditching in accordance with the AFM procedures.

4.3.8 Unplanned Ditching:

An emergency landing on water where the flight crew is not able to execute the ditching in accordance with the AFM procedures and no actions are taken before the ditching to improve the flotation characteristics of the airplane (e.g., close outflow valves).

5 Background

When certifying an airplane, it is necessary to demonstrate that the ditching requirements are met. Historically, it has been an accepted practice to show compliance with ditching requirements by addressing two ditching scenarios: “planned ditching” and “unplanned ditching”.

<u>In the planned ditching case</u>, it was typically assumed that there is sufficient time to prepare the airplane and occupants for a planned water landing in open seas. Allowances were generally made for jettisoning or burning off fuel, or closing of openings (e.g., outflow valves) and generally optimizing the aircraft to maximize the chances of occupant survival. The flotation analysis needed to account for structural damage that was likely to occur during the planned water landing. It was also assumed that the airplanes were equipped for extended overwater operations.

<u>In the unplanned ditching case</u>, it was generally assumed that sufficient time did not exist to prepare the airplane and occupants. The event was usually associated with a failed or aborted takeoff at an airport adjacent to a large body of water. Flight crew actions such as closing openings in the fuselage or reducing the airplane weight by burning fuel were generally assumed to not occur. As such, the airplane would initially sit lower in the water and may sink at a faster rate than in the planned event. Accordingly, airplane evacuation was much more time-critical. The flotation analysis did not account for structural damage resulting from the water landing (reference AC 25-17A). It was assumed that the airplane may or may not be equipped for extended overwater operations.

Although there are many possible scenarios that could result in a ditching event, history has shown that in-service events do not fully align with either of the planned or unplanned scenarios used for airplane certification. Past studies and investigations have also concluded that virtually all survivable water-related accidents occur at or near the shore. Therefore, ditching certification requirements and guidance have been expanded to better align the certification standards with an event that happens near shore with little time to prepare the airplane or the passengers. With the adoption of Amendment 25-1XX, the FAA has updated the ditching regulations to better align with the current state of the modern jet fleet.

This guidance material includes a discussion of acceptable compliance criteria for certification regulations identified in section 4.1 above. To make this AC easier to use, Section 7 includes the applicable rule text, followed by the compliance guidance.

6 Discussion

In principle the phases of ditching event are as follows:

a) The “Approach” phase addresses what happens before the initial contact with the water.

b) The “Impact” phase addresses what happens from the first water contact to immersion into the water.

c) The “Deceleration” phase addresses what happens while the airplane is gliding to a stop in the water.

d) The “Flotation” phase addresses the depth and attitude of the aircraft in the water over time.

e) The “Evacuation” phase addresses the time it takes to fully evacuate the aircraft.

Certification with ditching provisions is required for airplanes that will be operated on extended overwater routes. However, a ditching event can occur with any airplane, including those not certified with ditching provisions. Therefore, as specified in 14 CFR §§ 25.801(a), 25.807(i) and 25.1415(a), all airplanes must be designed with basic ditching provisions (e.g., ditching exits, life preservers) so that in an unplanned ditching, occupants have suitable escape routes and flotation means.

Note: The FAA defines what “*Extended Overwater Operation”* means in 14 CFR 1.1, *General Definitions* as *“with respect to aircraft other than helicopters, an operation over water at a horizontal distance of more than 50 nautical miles from the nearest shoreline”.* Other regulatory authorities may have different definitions for what constitutes extended overwater operations”

More recent events, those occurring since the 1970’s, indicate that ditching is more likely occur shortly after take-off or during approach and landing. For certification, these are categorized into the following categories:

a) Planned Ditching: An event where the flight crew knowingly makes a prepared and fully controlled emergency landing on water. The flight crew has sufficient time to fully prepare the aircraft and the passengers for ditching and executes the ditching in accordance with the ditching procedures provided in the AFM. It is recognized that some circumstances may degrade the ability of the crew to execute the ditching exactly per the AFM procedures. Therefore, an assessment should address variations in the airplane assumptions (e.g. attitude (pitch) and descent velocity) to account for potential degraded conditions. This type of event is assumed to occur with an airplane that is equipped for extended overwater operations. As a result, for certification, this event involves both a structural assessment and a flotation and evacuation assessment in accordance with §§ 25.563 and 25.801(b).

   For the modern jet transport fleet 14 CFR 25.561(b) has shown to be adequate for retaining items of mass in a ditching event based on service experience. Therefore, airplane configurations consistent with today’s fleet need not evaluate the ditching load factors. New and novel design configurations (e.g.

blended wing body) may require an assessment to ensure that ditching inertia loads remain similar to or less than those specified in 14 CFR 25.561(b).

b) Reduced Power/No Power: An emergency landing on water where the flight crew may not have sufficient time nor opportunity to fully prepare the aircraft and passengers for ditching. The flight crew able to perform the emergency landing in accordance with AFM procedures for a reduced/no power landing on water.

c) Unplanned Ditching: An emergency landing on water that is typically associated with a failed or aborted takeoff, or landing overrun at an airport adjacent to a large body of water where the aircraft is in water deep enough to float (i.e., the airplane is not supported by land). The flight crew is not able to execute the ditching in accordance with the AFM procedures and no actions are taken before the ditching to improve the flotation characteristics of the airplane (e.g., close outflow valves). This type of event can occur on any airplane, not just those certified with ditching provisions. For certification, this event involves a flotation and evacuation assessment only in accordance with § 25.801(a).

d) Inadvertent water entry: Runway overshoot (at take-off or landing) or runway undershoot (at landing), where the airplane alights on water. This type of event is considered to be a minor crash where the aircraft inadvertently ends up in water. It is possible that during the departure from land to water that the aircraft encountered varying terrain such as berms, rocks etc. It is not uncommon for aircraft to be severely damaged. However, these events rarely include scenario where the aircraft is floating after it comes to rest. It is more typical for the aircraft to be resting on the lake or sea bed or partially supported on land. This is not considered to be a ditching event and it is not addressed by the ditching regulations or this guidance. Rather, this type of event is addressed by other crashworthiness regulations such as §§ 25.561, 25.721, 25.963 and 25.xxx (the new Airframe crashworthiness rule).

The following table provides a summary of the key characteristics associated with each phase of the planned and unplanned ditching events used for ditching certification.

Summary of § § 25.563 and 25.801 Ditching Considerations		
	Planned	**Unplanned**
Applicability (Regulation)	A/Ps certified for Ditching (§ 25.563 & 25.801(b))	All A/Ps (§ 25.801(a))
Principle	Complete analysis, including approach and impact variations, and flotation and evacuation assessments.	Flotation and evacuation assessments
Approach	Ditching performed in accordance with AFM procedure	N/A
Impact	– Engine power available – Powered systems available – Weight not less than MLW – Calm sea state – Variation of parameters	N/A
Deceleration	– Ensure appropriate hydrodynamic behavior	N/A
Structure Assessment	– Local loads – Load factors – Distributed pressures – Ditching exits integrity – Structural leakage assessed	N/A

Flotation	– Airplane at MLW, which can be reduced by detached components – Structural leaks included – System openings closed in accordance with recommended AFM ditching procedures – Assume fresh water (conservative)	– No structural damage considered – Airplane at MTOW – Systems in most critical of takeoff or landing mode – Assume fresh water (conservative)
Evacuation	All occupants leave the airplane and enter rafts (life rafts or slide rafts)	All occupants leave the airplane and enter a slide raft, water or step onto the wing

7 Acceptable Means of Compliance

7.1 Section 25.563, Structural Ditching Provisions

7.1.1 Section 25.563

Rule:

If certification with ditching provisions is requested, the airframe structures that is necessary to maintain flotation shall withstand ditching loads, considered as ultimate, associated with a planned emergency landing on water. The airframe loads must account for reasonable variations in the flight parameters when the airplane enters the water.

Guidance:

Successful emergency water landings, "ditching's", depend on several crucial factors. The airplane should possess good hydrodynamic characteristics, the ditching procedures should be attainable, and the airframe should be intact enough for orderly evacuation. Also important are the natural variability of potential ditching events and the inherent difficulties of an emergency water landing, which together do not support a precise definition of a design ditching condition. These characteristics lead to the following structural and airplane features that should provide a level of structural performance for a reasonable chance of a successful ditching. Therefore structural substantiation of ditching capability per 14 CFR 25.563 necessitates consideration of the following aspects:

1. Hydrodynamic behavior in a planned ditching event should be predictable and well behaved.

2. The predicted hydrodynamic, aerodynamic and inertial loads experienced by the aircraft in the ditching should be based on methods shown to be reliable or conservative.

3. Reasonable variations of flight parameters should be considered to insure that execution of a successful ditching does not require exceptional pilot skill or strength and that the inherent uncertainties associated with a water impact do not jeopardize the ditching structural performance.

4. The airframe assessment of the ditching loads should demonstrate requisite strength and deformation to maintain the required floatation characteristics.

Accepted Methods for Evaluating Hydrodynamic Behavior

To show acceptable hydrodynamic behavior, testing and/or numerical simulation should be used. Testing need not be on the configuration under consideration if sufficient similarity can be shown, and the testing need not be performed or approved by the applicant if performed by a suitable organization, e.g. NACA. Numerical simulation of water impacts may be acceptable if validated and may be appropriate for unusual design features such as large cutouts, open bays, scoops and projections.

Fortunately, while the occurrence of emergency water landings is rare, there have been instances of water entry during approach, forced water landings due to fuel exhaustion and engine power loss from ingestion damage, etc. Hydrodynamic and structural performance in these incidents has generally been satisfactory for large transport airplanes. Consequently, applicable fleet history may also be used to supplement test and simulation data if acceptable to the Administrator.

a) Test methods:
   Model test should define the approach conditions and describe the hydrodynamic behavior until the aircraft comes to rest after a ditching. These tests or simulations may also show compliance to §25.801(b)(1) and (b)(2).

   For typical model tests, 1:10 or smaller scale models are “ditched” in a water tank. These models may be comparatively rigid or structurally similar (i.e. scale strength parts such as fuselage joints, flaps attachments and lower fuselage skins) to a full-scale aircraft with the intent to understand the dynamic behavior after impact in water examining a variety of parameters. The models may be equipped with pressure transducers and linear and angular accelerometers, to assess the pitch, roll and yaw of the model. The motion of the aircraft may be observed by high-speed imaging systems.

b) Numerical methods:
Numerical simulation techniques may be applied to determine the hydrodynamic behavior of the aircraft when in contact with water. This may be achieved by using commercially available software or specifically developed in-house tools that are validated. Some of these tools may be used for pressure (loads) generation at impact phase only, but typically the complete time period between initial contact to water and the aircraft coming to rest is simulated.

Accepted Methods for Developing Ditching Pressures and Loads

Ditching loads may be developed by analysis or test. Analysis methods should be validated by applicable testing. The guidance here concentrates on the approach conditions and the impact analyses. Nevertheless §25.563 gives relevant pre-definition:

- A planned ditching is the water entry of a controlled aircraft (i.e. with engine power available)

- Reasonable variations shall be accounted for as described in the variation of parameters section

Ditching loads, considered as ultimate, are to be applied to the airframe due to hydrodynamic effects resulting from a water landing, with accompanying aerodynamic and inertia loading. The hydrodynamic loads act directly on the lower skins of the fuselage or on lower wing structure.

The methods that follow have been accepted for developing loads for §25.563 and hydrodynamic behavior in §25.801(b)(1) and (b)(2):

a) Test methods:
Water pressures, in terms of magnitude and (fore-aft, lateral) distribution, that occur during the impact phase may be determined based on ditching model testing, with a model equipped with a sufficient amount of properly distributed pressure transducers. Typically, accelerometers are also installed to measure accelerations.

Ditching model test results need to be properly scaled to aircraft size. It would be conservative to envelope the measured (scaled) peak water pressures and apply these directly to design the bottom structure of the aircraft. If on the other hand the measured data are modified (for example, smoothing of peak pressures) this should be further substantiated.

With reference NASA TM X-2445-1972 (Ditching Investigation of a 1/30-Scale Dynamic Model of a Heavy Jet Transport Aircraft) a table of scaling coefficients as applied in published aircraft model tests:

Quantity	Scale factor
Length	λ
Force	λ^3
Moment of Inertia	λ^5
Mass	λ^3
Time	$\lambda^{1/2}$
Speed	$\lambda^{1/2}$
Linear accel.	1
Angular accel.	λ^{-1}
Pressure	λ

The underlying physics are based on similitude of Froude's law which allows using the scale (linear or non-linear) as a transfer function from measurement to real aircraft. The model scale, λ, is the ratio of the model dimension to the full scale airplane dimension.

Quantity (model) = Quantity(full scale airplane)*Scale Factor

Example: $Time_{model} = Time_{aircracft} * \sqrt{1/30}$

b) Analysis methods:

1) In order to quantify the structural capacity of aircraft structures under hydrodynamic loading, the prediction of global and local structural loads and resulting deformations is of fundamental importance. The analysis, however, is very challenging as ditching is a time-dependent, highly nonlinear multi-physics problem with different length and time scales resulting in complex loading conditions and coupled fluid-structure interaction. Hydrodynamic phenomena affect the fluid-structure interaction and their occurrence may therefore influence the global aircraft motion during the landing phase.

   To circumvent some of these complexities, an uncoupled analysis is often performed. In uncoupled computational approaches, the fluid solution is obtained independent of the structural solution, and both computations are run separately. The aircraft structure is typically represented by a Finite Element Model which represents the global aircraft structural stiffness and mass distribution, whereas the applied hydrodynamic models are generally based on the momentum theory and the concept of added mass developed by von Kármán and Wagner.

   Whatever analysis technique used, either coupled or uncoupled, validation of the analysis by model ditching test results is necessary, as well as an assessment how any of the hydrodynamic phenomena described above is addressed.

2) Suitable analytical methods may include a comparison with airplanes of similar configuration for which the ditching characteristics are known. This approach takes care of generating loads and the structural assessment. Reference for this technique can be found in NACA TN 2929 “Experimental investigation on the rear-fuselage shape on ditching behavior”.

3) Analysis using sea plane float pressures per 14 CFR 25.533. 14 CFR 25 contains a set of regulations for water loads for seaplane designs which can be used for conventional transport aircraft as well. These methods however may not be applicable to aircraft configurations with flat or essentially flat impact areas. Seaplane design methods may be used if these are shown to be appropriate for the specific transport aircraft configuration to be certified. This involves the determination of seaplane design parameter equivalency based on ditching model testing and establishing similarity of the product to the ditching model(s) used. Design parameter equivalency should be established by analysis based on test data and product similarity should be established by consideration of geometric (dimensions and shape) characteristics, number of engines and their placement, wing configuration and mass properties.

   Per 14 CFR 25.533(b) local pressures are to be developed for use in design of local stringers and skins and their attachments to supporting structure. These pressures are to simulate pressures occurring during high localized impacts on the hull but are not required to be extended over area that would induce critical loading in frames or overall structure. Note that for derivation of local pressures, 14 CFR 25.533(b)(1) for unflared bottoms is considered to be more appropriate to conventional transport aircraft. With 14 CFR 25.533(c) distributed pressures are given with a distribution along the fuselage length, for the design of the frames.

   In addition, 14 CFR 25.527 would allow calculation of water reaction load factors along the fuselage.

   When applying these 14 CFR Part 25 seaplane requirements to conventional transport aircraft, some of the seaplane design parameters cannot be applied directly and may need some adjustment. For example, on a seaplane the so-called step defines the fore-body and afterbody of the hull, but it is a design feature not present on conventional transport aircraft. Also, seaplanes have a flared or unflared bottom structure, with a physical chine line, whereas conventional transport aircraft are (semi)circular in shape.

As a result, applicants typically do not apply the local and distributed pressure distributions in the fore-aft and lateral (transverse) direction exactly as prescribed in the FAR 25 seaplane requirements, but derive more rationale pressure distribution based on ditching model testing data. Similarly, the definition of a chine line (defining the wetted area where water pressures are applied) and an equivalent angle of dead rise angle as applicable to a (semi)circular shaped fuselage needs to be derived from ditching model test data. When using the local or distributed pressure equations contained in 14 CFR 25.533 the aircraft speed and weight at impact should be as defined in CFR 25.125(b)(2)(i)) established for the airplane assessment weight and corresponding to the flap setting established under the preferred AFM ditching procedure.

Variation of Parameters

Considering the inherent complexity of the ditching event, the following parameters and characteristics should be used to define the structural loads with prescribed variations in certain impact parameters and approach configurations. In general, the ditching condition should consider the certified design ranges of airplane weight, center of gravity and allowable configurations.

Variation in certain parameters may be reduced if the airplane has reliable design features that control the variability.

Per 14 CFR 25.563, variations of flight parameters are to be considered:

- Pitch Attitude
- Forward Speed
- Sink rate
- Mass configuration (mass, center of gravity, moments of inertia)
- Flap setting
- Landing gear extended/retracted
- Engine Power Setting
- Rupture of Engines, Flaps or fairings

This list of parameters may not be complete depending on the aircraft design. For a limitation of the parameters or their amplitude see Detailed Guidance.

Model test or simulations may deliver time histories of all investigated parameters plus pressure distributions, which can be integrated to obtain global loads. In this case no further pressure calculation is necessary.

The objective is to find conditions which show:

a) Smooth (hydro)dynamic behavior (no nose-dive or re-bounce)

b) Accelerations comparable to §25.561(b)

As an example, this assessment may result in the following:

- Sink rate less than 5 feet/second
- Forward speed 100 knots @ MLW and flaps full
    - Assumes fuel is dumped or burned off
- Pitch attitude between 7° and 9° (degree)
- Landing Gear retracted
- Landing parallel to waves

These conditions may be directly used (not required) for an AFM procedure and should be reviewed by Pilots and Flight Mechanical specialists in order to confirm they are within the capability of the flight crew and airplane. The AFM procedure is then completed by defining the preferred ditching technique from level flight to the water surface.

Variation of Parameter Guidance:

The following apply for assessment of variation of parameters:

1) An airplane vertical descent rate not less than 5 feet per second relative to the mean water surface, unless a lower value is justified that fully accounts for likely variation over the value established under the preferred AFM ditching procedure; and:

2) A forward airplane speed along the flight path not less than V_{REF} (as defined in CFR 25.125(b)(2)(i)) established for the airplane assessment weight and corresponding to the flap setting established under the preferred AFM ditching procedure, unless a lower value is justified that fully accounts for likely variation over the value established under the preferred AFM ditching procedure

3) An increase in airplane attitude by at least 1° degree (nose up), as compared to the attitude established under the preferred AFM ditching procedure, and, separately a decreased in airplane attitude by at least 1° (nose down) as compared to the attitude established under the preferred planned AFM ditching procedure or unplanned ditching guidance/training

The following apply for planned and unplanned ditching evaluation for all aircraft:

1) For planned ditching, airplane weights may consider fuel jettisoning provisions or burn off but may not be less than the Maximum Design Landing Weight (MLW).

    a. Unplanned ditching flotation is to be based on MTOW.

2) Calm water states may be assumed.

3) Fresh water is assumed for flotation calculations.

4) Withstanding ditching loads implies an airframe assessment that needs to account for local loads (skin, stringers) and load factors for the fuselage and establish distributed pressures. Local damage may occur but the airframe structural integrity should be maintained. Any leakage must be accounted for in the flotation analysis. Additionally, breakaway or loss of large items (e.g. gear doors, belly fairing, flaps, and engines) and its effect on flotation and hydrodynamic behavior should be considered.

5) Only symmetrical conditions need to be considered and the resulting pressures can be considered as ultimate loads. A rational distribution may be used develop the pressure distribution along the side of the fuselage.

6) Seats, large items of mass and their attachments within the passenger compartment are designed for 14 CFR 25.561(b).

Fidelity of Loads

The fidelity of the Loads analysis depends on the process of structural substantiation, which follows the Loads generation.

The greatest fidelity achievable by analyses is where each calculation point on the airframe a pressure value is defined for each time step of the simulation. This can be used to develop a static design case to be loaded on a FEM or to be used by any other method for evaluating stresses. Also, a pressure time history can be built, which can be used in a structural substantiation.

For simplification, pressures can be averaged in time or space, or they may be integrated to local forces for frame or skin stress evaluation. This depends on stress methods used by the applicant.

Airframe Assessment

Fuselage structure shall be assessed to verify the frames can carry the distributed pressures loads (e.g. §25.533(c)), and consistent with floatation assumptions, the skins and stringers can withstand local pressures (e.g. §25.533(b)), and items of mass are retained (e.g., §25.561).

Applicable fleet and test data for water impacts may be used to show acceptable behavior.

7.2 Section 25.801, Ditching

7.2.1 Section 25.801(a)

Rule:

Whether or not ditching certification is requested, it must be shown that following an unplanned ditching, the flotation time and trim of the airplane will allow the occupants to leave the airplane.

Guidance: Although there are many possible scenarios that could result in an unplanned ditching, the following standard assumptions have been established for addressing compliance with the unplanned ditching requirement in § (a) of this section:

1) In order to simplify compliance determinations for an unplanned ditching scenario, no airplane damage is considered. As such, the dynamics of entry into the water are not considered, including analysis of dynamic pressures resulting from the aircraft coming to rest; it may be assumed that the airplane is resting in the water immediately after an unplanned ditching.

2) Because an unplanned ditching immediately after a failed or aborted takeoff could occur at high weights, for the purposes of developing a flotation analysis, the worst case combination of weight and CG must be considered (typically expected to be maximum takeoff weight with the CG at the aft limits).

3) All sources of water leakage into the aircraft must be considered.

4) Since not all aircraft are required to carry ditching equipment associated with extended overwater operations it is not necessary to account for the time to retrieve and launch rafts.

5) For the purposes of developing a flotation and evacuation analysis, an exit is conservatively considered unusable when water comes in over the top of the door sill.

6) Airplane flotation is typically assumed to end when the first ditching exit goes below the waterline or the attitude of the airplane is such that it would require extraordinary effort to move through the cabin (e.g., 20°). However, if it can be shown to be conservative, the flotation time may be extended. A showing of conservatism should include an assessment of number of persons

expected to be remaining in the airplane when the ditching exit sill(s) goes below the waterline, the number of ditching exits remaining above the waterline and the attitude of the airplane.

7) To receive its full passenger seat to exit ratio, each ditching exit must remain above the waterline for the entire evacuation, or it must be available for use long enough to allow the number of evacuees equal to its seat to ditching exit ratio to use the exit (e.g., a ditching exit with a 35 passenger seat to exit ratio must remain usable for the entire evacuation or long enough to allow at least 35 evacuees to exit the airplane through that exit in order to receive the full 35 passenger ratio). A lower passenger seat to exit ratio may be sought provided the exit remains above the waterline for the majority (greater than 50%) of the total airplane evacuation time. No passenger seat credit is allowed for a ditching exit that does not remain above the waterline for the majority of the total airplane evacuation time.

8) For non-overwing ditching exits, it is acceptable to assume that passengers will exit the aircraft by entering slide/raft (if provided), or by jumping into the water and swimming away from the exit. For the overwing exits, it is acceptable to assume that passengers will exit onto the wing and depending on the circumstances remain on-board the wing, or jump into the water. No credit should be taken for airplane weight reduction resulting from evacuees exiting the airplane through overwing exits.

9) For the purposes of preparing an evacuation timeline, the longest full-scale evacuation demonstration (FSED) exit preparation time for an exit of that type, for that airplane, or 15 seconds, whichever is greater, shall be assumed prior to the initial occupant evacuation from the aircraft.

10) For the purposes of preparing an evacuation timeline, evacuation rates obtained from the airplane FSED are acceptable for preparing a ditching evacuation analysis if the evacuees are exiting in the same or similar manner as the FSED and the assist means (if deployed) does not block the emergency exit opening. Alternatively, data developed by test and analysis for demonstrating compliance with §25.803 land evacuation requirements are also acceptable. However, the aisle flow rate may determine the evacuation rate at a pair of exits if the exit pair is being fed by passengers from only one direction and the combined exit pair flow rate is greater than the available aisle rate.

Note: The evacuation rate for slide/rafts deployed from representative sill heights should not exceed 60 persons per minute per lane for a duration of 70 seconds (reference FAA policy memorandum PS-ANM100-1982-00124).

11) For the purposes of preparing an evacuation timeline it is acceptable to assume that the flow of evacuees to the emergency exits is not diminished by the retrieval or the donning of life vests.

7.2.2 Section 25.801(b)

Rule:

If certification with ditching provisions is requested, the airplane must meet sections 25.563, 25.1411(d) and 25.1415(b) and the following:

1) Each practicable design measure, compatible with the general characteristics of the airplane, must be taken to minimize the probability that in an emergency landing on water, the behavior of the airplane would cause immediate injury to the occupants or would make it impossible for them to escape.

2) The probable behavior of the airplane in an emergency landing on water must be investigated by model tests or analytical methods. Features likely to affect the hydrodynamic characteristics of the airplane must be considered.

3) It must be shown that following a planned emergency landing on water, the flotation time and trim of the airplane will allow the occupants to leave the airplane and enter rafts. The flotation and evacuation assessment shall account for probable damage resulting from the conditions prescribed in § 25.563.

Guidance:

§ 25.801(b) requires an evaluation of the probable behavior of an aircraft at ditching and the hydrodynamic characteristics. This assessment can be performed in conjunction with the variation of parameters or the loads development if using numerical techniques and simulations. Section 7.1.1, “Accepted Methods for Evaluating Hydrodynamic Behavior” provides some guidance for 14 CFR §§ 25.801(b)(1) and (b)(2).

§ 25.801(b)(3):

Since ditching events can occur with varying degrees of airplane and passenger preparedness, the following assumptions are appropriate for assessing the flotation of the airplane and evacuation of the occupants following a planned ditching:

1) It should be assumed the airplane enters the water, in accordance with AFM ditching procedures, at the Maximum Design Landing Weight (MLW); with the most adverse airplane center of gravity. For the flotation analysis, the airplane weight may be reduced to account for items of mass in non-pressurized sections of the airplane that are shown to separate from the airplane as a result of the planned landing on the water.

2) All sources of water leakage into the aircraft must be considered, including leakage from probable damage resulting from the conditions prescribed in § 25.563.

4) For the purposes of developing a flotation and evacuation analysis, an exit is conservatively considered unusable when water comes in over the top of the door sill.

5) Airplane flotation is typically assumed to end when the first ditching exit goes below the waterline or the attitude of the airplane is such that it would require

extraordinary effort to move through the cabin (e.g., 20°). However, if it can be shown to be conservative, the flotation time may be extended. A showing of conservatism should include an assessment of number of persons expected to be remaining in the airplane when the ditching exit sill(s) goes below the waterline, the number of ditching exits remaining above the waterline and the attitude of the airplane.

6) To receive its full passenger seat to exit ratio, each ditching exit must remain above the waterline for the entire evacuation, or it must be available for use long enough to allow the number of evacuees equal to its seat to ditching exit ratio to use the exit (e.g., a ditching exit with a 35 passenger seat to exit ratio must remain usable for the entire evacuation or long enough to allow at least 35 evacuees to exit the airplane through that exit in order to receive the full 35 passenger ratio). A lower passenger seat to exit ratio may be sought provided the exit remains above the waterline for the majority (greater than 50%) of the total airplane evacuation time. No passenger seat credit is allowed for a ditching exit that does not remain above the waterline for the majority of the total airplane evacuation time.

7) For the purposes of preparing an evacuation timeline, the longest full-scale evacuation demonstration (FSED) exit preparation time for an exit of that type, for that airplane, or 15 seconds, whichever is greater, shall be assumed prior to the initial occupant evacuation from the aircraft.

8) For the purposes of preparing the evacuation timeline, it should be assumed that the aircraft has ditching equipment required for extended overwater operations. Therefore, it is necessary to account for the time to retrieve, launch rafts and board the life rafts.

9) For the purposes of preparing an evacuation timeline, evacuation rates obtained from the airplane FSED are acceptable for preparing a ditching evacuation analysis if the evacuees are exiting in the same or similar manner as the FSED and the assist means (if deployed) does not block the emergency exit opening. Alternatively, data developed by test and analysis for demonstrating compliance with §25.803 land evacuation requirements are also acceptable. However, the aisle flow rate may determine the evacuation rate at a pair of exits if the exit pair is being fed by passengers from only one direction and the combined exit pair flow rate is greater than the available aisle rate.

Note: The evacuation rate for slide/rafts deployed from representative sill heights should not exceed 60 persons per minute per lane for a duration of 70 seconds (reference FAA policy memorandum PS-ANM100-1982-00124).

10) For the purposes of preparing an evacuation timeline it is acceptable to assume that the flow of evacuees to the emergency exits is not diminished by the retrieval or the donning of life vests.

7.3 Section 25.807(i), Emergency Exits

Rule:

§ 25.807(i) Ditching emergency exits for passengers. Whether or not ditching certification is requested, ditching emergency exits must be provided in accordance with the following requirements, unless the emergency exits required by paragraph (g) of this section already meet them:

(1) For airplanes that have a passenger seating configuration of nine or fewer seats, excluding pilot seats, one exit above the waterline in each side of the airplane, meeting at least the dimensions of a Type IV exit.

(2) For airplanes that have a passenger seating configuration of 10 or more seats, excluding pilot seats, one exit above the waterline in a side of the airplane, meeting at least the dimensions of a Type III exit for each unit (or part of a unit) of 35 passenger seats, but no less than two such exits in the passenger cabin, with one on each side of the airplane. The passenger seat/exit ratio may be increased through the use of larger exits, or other means, provided it is shown that the evacuation capability during ditching has been improved accordingly.

(3) If it is impractical to locate side exits above the waterline, the side exits must be replaced by an equal number of readily accessible overhead hatches of not less than the dimensions of a Type III exit, except that for airplanes with a passenger configuration of 35 or fewer seats, excluding pilot seats, the two required Type III side exits need be replaced by only one overhead hatch.

Guidance:

To qualify as a ditching exit, the exit sill must be initially above the waterline and it should remain above the waterline for the duration of the evacuation during a planned or unplanned ditching. However, if it can be shown to still be conservative, an exit(s) may qualify as a ditching exit even if it doesn't remain above the waterline for the duration of the evacuation. A showing of conservatism should include an assessment of how long the ditching exit remains above the waterline, the number of persons expected to be remaining in the airplane when the ditching exit(s) sill goes below the waterline and the number of other ditching exits remaining above the waterline.

To receive its full passenger seat to exit ratio, each ditching exit must remain above the waterline for the entire evacuation, or it must be available for use long enough to allow the number of evacuees equal to its seat to ditching exit ratio to use the exit (e.g., a ditching exit with a 35 passenger seat to exit ratio must remain usable for the entire evacuation or long enough to allow at least 35 evacuees to exit the airplane through that exit in order to receive the full 35 passenger ratio). A lower passenger seat to exit ratio may be sought provided the exit remains above the waterline for the majority (greater than 50%) of the total airplane evacuation time. No passenger seat credit is allowed for a ditching exit that does not remain above the waterline for the majority of the total airplane evacuation time.

If Ditching Dams are installed to raise the sill of the exits prior to ditching the water dams and their installation should meet the following:

a. The water dams should be designed to withstand the water pressure as well as the loads that would be applied by evacuees stepping on them.

b. Installation of the water dams should be simple enough to allow any occupant and cabin crew to perform it without specific training or experience.

c. It should be shown that the water dams could be retrieved and installed before the sill of the exit goes below the waterline, and that all occupants can be evacuated within the calculated flotation time.

d. The force necessary to open the emergency exits against the water pressure should be shown to be within normal passenger capabilities.

e. When the water dams are installed and the emergency exit is open, an unobstructed opening available to passengers should meet the 25.807 (a) (3), Type III exit, requirement.

f. Each water dam should be stowed adjacent to the emergency exit where the device is going to be installed in case of ditching.

g. There must be a placard on, or adjacent to the emergency exit door specifying that, for ditching, the water dams shall be installed before opening the door. The placard should also show the location in which the water dam is stowed.

h. The AFM should include a ditching emergency procedure that foresees the installation of the water dams including a pre-flight check to confirm that the water dams are stowed in the designed locations. Installation instructions should be reported in passenger safety cards.

7.4 Section 25.1411 Emergency Equipment

Rule:

§ 25.1411: General.

(a) Accessibility. Required safety equipment to be used by the crew in an emergency must be readily accessible.

(b) Stowage provisions. Stowage provisions for required emergency equipment must be furnished and must—

(1) Be arranged so that the equipment is directly accessible and its location is obvious; and

(2) Protect the safety equipment from inadvertent damage.

(c) Life preserver stowage provisions. The stowage provisions for life preservers described in Sec. 25.1415 must accommodate one life preserver for each occupant.

(1) A life preserver must be within easy reach of each seated occupant.

(d) If certification with ditching provisions is requested under Sec. 25.801, the following stowage provisions must be provided:

(1) Rafts. The stowage provisions for the rafts described in Sec. 25.1415 must accommodate enough rafts for the maximum number of occupants for which certification for ditching is requested.

(i) Rafts must be stowed near ditching exits.

(ii) The stowage provisions for each portable raft must allow rapid detachment and removal of the raft for use at other than the intended exits.

(iii) The stowage provisions for non-portable rafts must allow for use at the intended exit during a ditching.

(2) Long-range signaling device. The stowage provisions for the long-range signaling device required by Sec. 25.1415 must be near a ditching exit.

7.5 Section 25.1415 Ditching Equipment

Rule:

§ 25.1415 Ditching equipment.

(a) Whether or not ditching certification is requested, an approved life preserver must be provided for each airplane occupant.

(b) If certification with ditching provisions is requested under Sec. 25.801, the following equipment must be provided:

(1) Approved rafts that have a combined rated capacity that accommodates all airplane occupants. In addition—

(2) the rafts shall have a combined overload capacity to accommodate all occupants of the airplane in the event of a loss of:

(i) one portable raft with the largest overload capacity, and

(ii) 50% of the non-portable rafts

(3) Each raft must have a mooring line designed to hold the raft near the airplane but to release it if the airplane becomes totally submerged.

(i) Rafts automatically or remotely released outside the airplane must be attached to the airplane by the mooring line.

(4) Survival equipment must be attached to, or stored adjacent to, each raft.

(5) An approved survival type emergency locator transmitter for use in one raft.

7.6 Section 25.1581, Airplane Flight Manual

Rule:

General

(a) Furnishing information. An Airplane Flight Manual must be furnished with each airplane, and it must contain the following:

(1) …

(2) Other information that is necessary for safe operation because of design, operating, or handling characteristics.

(3) ...

Guidance:

7.6.1 Aircraft Flight Manual (AFM) Procedures and Verification

The AFM includes procedures for the flight crew in certain emergency situations.

For ditching, the AFM needs to include, at a minimum, procedures for a planned emergency landing on the water (i.e., a planned ditching) and procedures for a reduced power or no power emergency landing on the water.

7.6.2 Cabin Crew Operating Manual

Information critical for a successful and safe evacuation of passengers and crew in the event of a ditching need to be established. While this information is not required for part 14 CFR part 25 certification, it is needed to allow operators to establish their ditching procedures.

Since it is not possible to cover all potential ditching situations, the ditching information provided, shall emphasize the importance of the cabin crew assessing the situation, maintaining situational awareness throughout the evacuation, and using their best judgment on how to evacuate the passengers as rapidly as possible. In addition the manual shall include the following information to enable operators to establish appropriate cabin crew ditching procedures and training programs:

- Coordination between flight crew and cabin crew
- Prepping the cabin and passengers for the landing on the water (as time allows)
- Operation of the ditching equipment and ditching exits
- Recommended cabin crew actions for initiating and performing the emergency evacuation
- Highlighting any critical differences between planned and unplanned ditching procedures
- Any other information critical to a successful evacuation

C.2 EASA Ditching White Paper

= **DRAFT** =

EASA Analysis of Water Impact Events
(17.01.17)

This paper is written to support the activities within the ARAC TACDWG on the subject of ditching. It may not reflect the final EASA views, and may not address all aspects, but is intended to provide further direction to the discussions.

1. Approach & Assumptions

A review of water impact events from 1970 until now has been conducted, using the data sources and references described in section 2. The events identified and investigated are listed in the Appendix to this paper.

This review has been limited to “large aeroplanes” / ”transport category airplanes”, i.e those aircraft certified against JAR-25/CS-25, CAR 4b/Part 25 or similar codes used in Canada, Brasil, Russia, etc.

Included are events that involve:

- Passenger, freighter or combi aeroplanes.

Excluded are events that involve:

- Military aircraft, or military derivatives of civil aeroplanes (such as C-47);
- Piston engine driven a/c (such as DC-3);
- Hijacks/suicides (such as Ethiopian Airlines Flight 961 (B767-200ER) in November 1996 and Japan Airlines Flight 350 (DC-8-61) in February 1982).

(Note: contrary to the above, some of the sources and references mentioned in section 2. exclude non-Western built aircraft, include piston engine driven aircraft, exclude cargo aircraft, exclude aircraft with less than 20 passengers, etc., and may therefore not be completely compatible with the data presented in the Appendix to this paper.)

2. Data Sources & References

The following data sources and references have been used in this paper:

- DOT/FAA/TC-14/8
- Website “Aviation Safety Network”
- Accident investigation reports
- Wikipedia page “Water Landing”

3. Data Analysis

Forty-one (41) water impact events have been identified (see Appendix), with identification of date, location, aircraft type/model, root cause, damage to aircraft and number of occupants / fatalities / injuries.
Note: not for all events all of this information was readily available and has therefore not (yet) been included.

These water impact events can be divided in the following main categories (cases):
(I) Planned ditching, or emergency landing on water: the flight crew knowingly makes an emergency landing on water, either:

> (A) Prepared: the flight crew had sufficient time to fully prepare the aircraft for ditching and execute the ditching in accordance with the AFM procedures; or:
> (B) Semi-prepared: the flight crew did not have sufficient time to fully prepare the aircraft for ditching and/or was not able to execute the ditching in accordance with the AFM procedures.

(II) Unplanned ditching, or inadvertent water impact: runway overshoot (at take-off or landing) or runway undershoot (at landing), where the airplane alights on water.

Note: for future discussion, further distinction could perhaps be made between "low energy" events where the aircraft went off the runway after landing, and "high energy" events where the aircraft impacted the water directly.
(III) The airplane is prepared for ditching, but the ditching is not executed.

Number of events identified within each category:

Case	Number of occurrences
(I) Planned ditching / emergency landing on water	Fourteen (14)
(A) Prepared	One (1)
(B) Semi-prepared	Thirteen (13)
(II) Unplanned ditching / inadvertent water impact	Twenty-five (25)
(III) Prepared for ditching but not executed	Two (2)
Total:	Forty-one (41)

Based on these data, the following can be stated:

(1) Since 1970, inadvertent water impact events (case II) have happened about twice as often as emergency landings on water (case I).
Note: the DOT/FAA/TC-14/8 report states that the accident rates for both events appear to be roughly the same over the period 1999-2009.

(2) For emergency landings on water (case I), in the vast majority of cases (13 out of 14) the flight crew did not have sufficient time to fully prepare the aircraft for ditching and/or was not able to execute the ditching in accordance with the AFM procedures. Fuel starvation (resulting in loss of engines thrust) and engine failure(s)/flame-out(s) were identified as being the main root causes.
For the one event identified as case IA the weather conditions were very poor and probably beyond what can be envisaged as being "optimum" ditching conditions.

When considering the existing planned / unplanned ditching certification requirements and related advisory material in relation to these events, the following main observations can be made:

(1) Although a fully prepared emergency landing on water (case IA) is a very rare event, it can not be completely disregarded. Therefore, to maximize the survivability of such an event all ditching phases/aspects should be addressed, i.e.:
- (a) preparation before water impact
- (b) water impact
- (c) sliding on water and coming to rest
- (d) flotation & evacuation

(e) ditching equipage
(f) AFM instructions

(2) Current ditching requirements do not address an emergency landing on water where the flight crew does not have sufficient time to fully prepare the aircraft for ditching and/or is not able to execute the ditching in accordance with the AFM procedures (case IB). Therefore, the ditching requirements need to be updated to include such a case, for which all ditching phases/aspects (a) – (f) as mentioned above should be addressed as well.
Note: this is in line with NTSB recommendation A-10-72. The EASA Generic CRI on Ditching attempts to address these "non-optimum" conditions by requiring variation of certain ditching parameters beyond the "optimum" ones defined for a fully prepared ditching.

(3) Inadvertent water impacts (case II) are mostly addressed via advisory material (FAA AC 25-17A). For example, there is no direct requirement to perform a flotation analysis for such an event. It seems therefore necessary to more clearly identify in the requirements what is expected from Applicants in the various water impact cases to be considered.

(4) The accidents described in the Appendix to this paper indicate that in case II considerable damage to the aircraft (e.g. break-up of fuselage) may occur. This contradicts FAA AC 25-17A that states no structural damage may be assumed. Further discussion on this point would be needed.

In section 4. these main observations (plus a few additional minor ones) are turned into recommendations for future rulemaking and/or development of (additional) advisory material.

4. Recommendations

Based on the data and analysis presented in this paper, the following objectives and recommendations / comments related to water impact events can be identified, to be addressed in the applicable requirements and/or related advisory material.

Objective	Current text	Recommendations & Comments
(1) Define which requirements apply to aircraft for which ditching certification is required, and which requirements apply to aircraft for which ditching certification is not required	CS 25.801 (a) If certification with ditching provisions is requested, the aeroplane must meet the requirements of this paragraph and CS 25.807(i), 25.1411 and 25.1415(a).	(1) Whether ditching certification is required or not, is determined by operational requirements (Note: these may be different between EU, US, Canada, etc.) (2) Is reference to CS 25.1411 and CS 25.1415(a) for ditching equipage correct/sufficient?
(2) Overall, take (practical) design measures to minimise probability of fatalities / maximize occupant protection in case of emergency landing on water	CS 25.561 (a) The aeroplane, although it may be damaged in emergency landing conditions on land or water, must be designed as prescribed in this paragraph to protect each occupant under those conditions. CS 25.801 (b) Each practicable design measure, compatible with the general characteristics of the aeroplane, must be taken to minimise the probability that in an emergency landing on water, the behaviour of the aeroplane would cause immediate injury to the occupants or would make it impossible for them to escape.	(1) Link with CS 25.561 also mentioned in EASA Generic CRI subparagraph (e)(ii), and FAA AC 25-17A. Needs to be more strongly highlighted?

Objective	Current text	Recommendations & Comments

(3) Clarify that planned ditching certification would have to include all phases/aspects:
(a) preparation before water impact
(b) water impact
(c) sliding on water and coming to rest
(d) flotation & evacuation
(e) ditching equipage
(f) AFM instructions
	For (a):
	EASA Generic CRI
	The proposed optimum conditions for the approach and resulting impact must be verified to be practical by flight test panels of the applicant and the Agency.
	
	For (b): see CS 25.563 and CS 25.801(e) below
	
	For (c): see CS 25.801(c) below
	
	For (d): see CS 25.801(d) and CS 25.807(i) below
	
	For (e): see CS 25.1411 and 25.1415 below
	
	For (f): see CS 25.1581 below
		(1) Need to clarify that these phases/aspects need to be investigated for "optimum" and "non-optimum" (e.g. engine-out) conditions.

(4) Clarify that for unplanned ditching "only" the following is required:
(d) flotation & evacuation
(e) ditching equipage
(f) AFM instructions
	For (d): see CS 25.801(d) and CS 25.807(i) below
	
	For (e): see CS 25.1411 and 25.1415 below
	
	For (f): see CS 25.1581 below
		(1) Need to update requirements to clarify consideration of these 3 aspects (d)(e)(f)
		(2) Need to discuss possible break-up of aircraft during these events (contrary to FAA AC 25-17A that allows assumption of no structural damage)

(5) Determine whether (hydrodynamic) behaviour of the aeroplane in case of an emergency landing on water is acceptable	*CS 25.801*	(1) Need to provide more guidance on "comparison with aeroplanes of similar configuration" – is comparison with 1950's NACA reports really sufficient?

Objective	Current text	Recommendations & Comments
	(c) The probable behaviour of the aeroplane in a water landing must be investigated by model tests or by comparison with aeroplanes of similar configuration for which the ditching characteristics are known. Scoops, wing-flaps, projections, and any other factor likely to affect the hydrodynamic characteristics of the aeroplane, must be considered.	
(6) Provide sufficient flotation time for occupants to evacuate the aircraft	*CS 25.801* (d) It must be shown that, under reasonably probable water conditions, the flotation time and trim of the aeroplane will allow the occupants to leave the aeroplane and enter the life rafts required by CS 25.1415. If compliance with this provision is shown by buoyancy and trim computations, appropriate allowances must be made for probable structural damage and leakage. If the aeroplane has fuel tanks (with fuel jettisoning provisions) that can reasonably be expected to withstand a ditching without leakage, the jettisonable volume of fuel may be considered as buoyancy volume.	(1) Need to determine reasonably probable water conditions (salt or sweet/fresh water, calm see or certain sea state,…?) (2) For unplanned ditching, MTOW should be used (as per FAA AC 25-17A) – with aft c.g.? (3) Need for further guidance on: - acceptable flotation time - evacuation issues => review EASA CRI's and FAA IP's on Unplanned Ditching (4) Last sentence (about fuel jettisoning provisions) is unclear and appears to be incorrect (volume of displaced water provides buoyancy rather than jettisonable volume of fuel) – is about to be removed from CS-29
(7) Determine structural damage due to water contact, and its effect on (hydrodynamic) behavior and flotation time (leakage)	*CS 25.563* Structural strength considerations of ditching provisions must be in accordance with CS 25.801 (e). *CS 25.801*	(1) Why only consider external doors and windows, and not the entire aircraft (as required by EASA Generic CRI)? (2) Need to incorporate subparagraph (b) of EASA Generic CRI in CS-25 to define impact condition (3) Need for further guidance on how to assess structural damage, e.g. on wing/body fairings

Objective	Current text	Recommendations & Comments
	(e) Unless the effects of the collapse of external doors and windows are accounted for in the investigation of the probable behaviour of the aeroplane in a water landing (as prescribed in sub-paragraphs (c) and (d) of this paragraph), the external doors and windows must be designed to withstand the probable maximum local pressures. *FAA AC 25-17A* ….adjustments have been made to airplane weight and c.g. to account for loss of such items as engines, nacelles, and trailing edge flaps on impact with the water. *EASA Generic CRI paragraph (b)(i)(ii)(iii)* Impact conditions: MLW / Vz = 5 fps / Vref	(4) Need for further guidance on acceptable means of compliance for determination of water impact loads and pressures, such as: - FAR 25 water loads; - data from ditching model tests; - NLFEA (SPH/ALE) analysis.
(8) Provide sufficient emergency exits above waterline of sufficient size (dimensions) to timely evacuate the aircraft	*CS 25.807* (i) *Ditching emergency exits for passengers*. Whether or not ditching certification is requested, ditching emergency exits must be provided in accordance with the following conditions, unless the emergency exits required by subparagraph (g) of this paragraph already meet them: (followed by subparagraphs (1), (2) and (3))	(1) Incorporate Generic CRI/IP on Ditching Dams? (2) Need for further guidance on water level vs. sill height (available exits)
(9) Provide required ditching equipage	*CS 25.1411*, *CS 25.1415*	(1) Need to further clarify required ditching equipage in CS 25.1411 and CS 25.1415, also considering operational requirements
(10) Provide ditching and emergency evacuation instructions to flight and cabin crew	*AMC 25.1581* Emergency procedures - Crash landing or ditching - Emergency evacuation	(1) Need to clarify that (separate) instructions must be given for: - "optimum" ditching conditions - "non-optimum" ditching conditions (e.g. engine-out conditions)

Objective	Current text	Recommendations & Comments
		- unplanned ditching

Appendix -Water Impact Events

Cat.	Date	Airplane Type	Location	Root Cause	Aircraft Damage & Fatalities/Injuries	Comment(s)
(I)(B)	July 2011	Antonov 24	Near Strezhevoy, Russia	Fire in left engine	Aircraft hit underwater obstacles Occupants: 37 Fatalities: 7	
(I)(A)	November 2009	IAI 1124A	West of Norfolk Island, Australia	After four missed approaches due to bad weather conditions the a/c was ditched	The main plug-type aircraft door was pushed in by the force of the water Occupants: 6 Fatalities: 0 Injuries: 1	Engines set at idle, no fuel starvation
(I)(B)	January 2009	A320	Hudson River, Weehawken, New Jersey, U.S.A.	Dual engine failure due to bird ingestions	Damage to rear bottom of fuselage Occupants: 155 Fatalities: 0 Injuries: 100	
(I)(B)	August 2005	ATR72	North East Of Palermo Airport, Italy	Fuel starvation	Aircraft broke in 3 sections upon impact Occupants: 39 Fatalities: 16	
(I)(B)	April 2003	Falcon 20	Near St. Louis airport	Ran out of fuel	Aircraft damaged beyond repair Occupants: 2 Fatalities: 0	
(I)(B)	January 2002	B737-300	Bengawan Solo River, Java, Indonesia	Dual engine flameout during heavy precipitation and hail	Severe damage to aircraft belly Occupants: 60 Fatalities: 1	
(I)(B)	February 2001	SD360	Granton Harbour, Scotland, U.K.	Dual engine flameout due to icing	Aircaft destroyed Occupants: 2 Fatalities: 2 Injuries: 0	

Cat.	Date	Airplane Type	Location	Root Cause	Aircraft Damage & Fatalities/Injuries	Comment(s)
(I)(B)	November 2000	DHC6-100	Vancouver Harbour, British Columbia, Canada	No.. 2 engine failure after take-off	Aircaft impacted the water in a nose-down, right wing-low attitude Occupants: 17 Fatalities: 0 Injuries: 0	
(I)(B)	January 2000	SD360	Marsa El Brega, Libya	Dual engine flameout due to icing	Aircraft hit water in 10 deg nose up attitude; tail broke off Occupants: 41 Fatalities: 22	
(I)(B)	September 1990	B727-247	SE off Newfoundland, Canada	Low fuel light	Aircraft was never found	
(I)(B)	October 1987	Dassualt Falcon 20D	Near Kevlafik, Iceland	Fuel starvation due to strong head winds. Engines stopped 5 minutes before impact	Tear-off of nose cone, no structural damage to fuselage Occupants: 6 Fatalities: 0	
(I)(B)	March 1979	Nord 262	Santa Monica Bay, Marina Del Rey, California, U.S.A.	Auto-feather of RH propeller, crew erroneously shut down LH engine	Aircaft hit water smoothly, bounced twice, impacted the water in a nose down attitude, and sank almost immediately Occupants: 7 Fatalities: 3 Injuries: ??	
(I)(B)	May 1970	DC9-33F	St. Croix, Virgin Islands (U.S.)	After several unsuccessful landing attempts, the aircraft's fuel was exhausted	Aircraft remained relatively intact after the water landing Occupants: 63 Fatalities: 23 Injuries: 37	
(I)(B)	February 1970	DHC6-100	Long Island Sound, Connecticut, U.S.A.	Fuel exhaustion	Occupants: 5 Fatalities: 5 Injuries: 0	

Cat.	Date	Airplane Type	Location	Root Cause	Aircraft Damage & Fatalities/Injuries	Comment(s)

Cat.	Date	Airplane Type	Location	Root Cause	Aircraft Damage	Comments(s)
(II)	April 2013	B737-800	Ngurah Rai International Airport, Indonesia	Undershot runway	Fuselage broke in two	
(II)	June 2011	Antonov 26	Libreville, Gabon	Both propellers stopped due to hydraulic failure (?), hit water short of runway	The airplane came to rest submerged with the top of the tail sticking out of the water	
(II)	June 2004	HS748	Libreville airport, Gabon	Engine no. 2 shut down due to loss of oil pressure, tried to land, overshot runway	Aircraft damaged beyond repair	
(II)	November 2002	F27 Mk 600	Off Manilla airport, Philipinnes	LH engine trouble, hit water when trying to land	Aircraft broke up and sank	
(II)	April 2002	DC-10-30F	Entebbe, Uganda	Slid off the runway after landing	Cockpit section separated from fuselage	
(II)	February 2000	B707-351C	Mwanza Airport	Overshot runway during landing		
(II)	November 1993	B747-400	Kai Tak, Hong Kong	Overran runway on landing during typhoon		

Cat.	Date	Airplane Type	Location	Root Cause	Aircraft Damage	Comments(s)
(II)	September 1993	B747	Papeete, Tahiti	Hydroplaned during landing and overshot runway		
(II)	March 1992	F28 Mk 4000	La Guardia, New York, U.S.A.	Ice accumulation on wings, crashed after takeoff	Aeroplane came to rest partially inverted at the edge of Flushing Bay, and parts of the fuselage and cockpit were submerged in water	
(II)	September 1989	B737-400	La Guardia, New York U.S.A.	Overran runway during take-off	A/c broke in three pieces	
(II)	August 1988	Trident 2E	Hong Kong			
(II)	1985	DC-10	Munoz Marin Airport, Puerto Rico	Overran runway at take-off		
(II)	February 1984	DC10-30	John F. Kennedy International Airport, New York, U.S.A.			
(II)	January 1982	DC10-30CF	Logan International Airport, Massachusetts, U.S.A.			
(II)	January 1982	B737-222	Potomac River, Washington D.C., U.S.A.	After take-off during snowstorm without proper de-icing		
(II)	August 1990	Tupolev 154B	Nouadhibou Airport, Mauritania	Short of runaway during landing		
(II)	July 1979	HS748	Sumburgh, Shetland Islands, U.K.			

Cat.	Date	Airplane Type	Location	Root Cause	Aircraft Damage	Comments(s)
(II)	February 1979	F27 Mk500	Manakau Harbour, Auckland, New Zealand			
(II)	September 1978	DHC6-200	Vancouver, Canada			
(II)	May 1978	B727-235	Near Pensacola, Florida, U.S.A.	Short of runaway during foggy approach		
(II)	December 1977	Caravelle 10B1R	Near Funchal, Madeira, Portugal			
(II)	January 1976	Sabreliner	Near Recife, PE	Fuel shortage	Aeroplane damaged beyond repair	
(II)	July 1972	Tu-134	Near Moscow airport	Both engines flamed out on final approach		
(II)	July 1972	BAC1-11	Corfu, Greece			
(II)	July 1970	DC8-63F	Naha Ab, Okinawa, U.S.A.			

Cat.	Date	Airplane Type	Location	Root Cause	Aircraft Damage	Comments(s)
(III)	August 2001	A330-243	Lajes, Azores, Portugal	Complete power loss due to a fuel leak	Damage to landing gears	
(III)	May 1983	L1011	Miami, Florida, U.S.A.	Multiple engine failures due to oil leaks	Damage to engines	

Appendix D Data and Presentations from Team 4

D.1 Supporting Information for Proposal for 50% of the non-portable rafts related to overload

Supporting background information related to the reorganization of 14 CFR 25.1411 and 25.1415.

The regulation would be changed to allow for non-portable rafts, provided certain conditions are satisfied.

Background

The airworthiness standards for transport category airplanes are contained in 14 CFR, part 25, which was adopted in February, 1965. At that time, the only type of group flotation equipment available for extended over-water airplanes was life rafts. They weighed up to 150 pounds and were stored in closets or overhead stowage compartments. When needed, the life rafts were to be removed from stowage, transported to an appropriate exit, moored to the fuselage, deployed, inflated, boarded, and then detached from the airplane.

The applicable regulations required that “Life rafts must be stowed near exits through which the rafts can be launched during an unplanned ditching” (§ 25.1411(d)(2)), and that “The stowage provisions for each portable life raft must allow rapid detachment and removal of the raft for use at other than the intended exits” (§ 25.1411(d)(4)). In addition, § 25.1415(b)(1) stated, “Unless excess rafts of enough capacity are provided, the buoyancy and seating capacity beyond the rated capacity of the rafts must accommodate all occupants of the airplane in the event of a loss of one raft of the largest rated capacity”.

In the late 1960’s a new type of equipment was first designed and demonstrated - the combination emergency escape slide and life raft, known as the “slide/raft.” This type of equipment mounts on the exit door inside the cabin and functions as an escape slide for evacuations on land and as a life raft during evacuations on water. The objective of this design was to reduce substantially the weight and space required for separate rafts and slides. Another significant benefit was having the slide/raft available at the exit for immediate deployment as a raft.

Since the regulations did not explicitly address slide/rafts, discussions were held among the FAA, the airplane manufacturers, and the slide manufacturers concerning proposed slide/raft requirements. On August 25, 1970, FAA issued guidance in the form of a white paper entitled “Commentary on Combination Slide/Raft Devices”. Subsequently, in Rev. A of the Commentary, dated March 1971, under the heading “FAR Considerations (Slide/Rafts),” –“Portability”, FAA offered the following guidance:

It is necessary to determine equivalency regarding the use of slide/raft devices at other than the design exits. As provided in FAR 25.1411(d) current life rafts are stowed near exits at which they are intended to be used; also, they can be deployed at any number of *exits by virtue of their portable design. Since an unusable exit as [a] result of water ditching could prevent use of a non-portable raft device, we are presently recommending that each raft must be portable and easily transferred under adverse conditions by not more than two persons for use at other than the primary exit location, or if not portable, provide together with additional rafts, if needed, flotation for 100% aircraft capacity with non-portable rafts on one side of the aircraft not used.*

Although the regulations concerning life rafts have never been updated to include the term "slide/raft," the slide/raft combination has been required to comply with all the requirements for both evacuation slides and life rafts. The result has been that all slide/rafts have been door mounted and portable. The evolution of airplanes, however, is leading toward new configurations that will likely have evacuation systems that challenge "portability" as being the only appropriate method to meet group flotation requirements.

For example, one planned configuration is a full-length, double-deck airplane, with upper deck doorsill heights that will require a significant increase in slide/raft lengths, as compared to current main deck applications. Such slide/rafts will likely weigh in excess of 300 pounds. Another airplane configuration being investigated is a wider single deck configuration with more aisles and/or more passenger seats per row. Both configurations may require new, wider exits with higher passenger egress ratings to provide the necessary evacuation capability. Already, the concept of five-foot wide exits for main deck applications has been explored. Slide/rafts designed for such large openings could easily weigh as much as the longer slide/rafts designed for upper deck placements, and they will likely be too large to maneuver through aisles and cross aisles in the airplane cabin. In either case, it may not be practical or safe to transport one of these slide/rafts from one exit to another.

A second evolution in design is the concept of locating slide/rafts in dedicated compartments outside of the passenger cabin. In one placement, the slide/raft would be stowed in a compartment located directly below the exit, inaccessible from the cabin. This location produces several benefits: First, equipment/structure that could become detached in a survivable crash scenario, or pose a passenger contact hazard in a minor crash landing, is eliminated from the cabin. Second, wear and tear on the slide/raft system (especially the girt attachment fabric) related to service/entry door opening and closing on every flight is eliminated. Third, the removal of the slide/raft weight from the door reduces loading and wear on the door mechanisms, thereby improving maintainability, functionality, and reliability of the door. Fourth, better stability for slide/raft inflation and use by occupants is likely, particularly in windy conditions. This improved stability is especially important to the design of very long or very wide slide/rafts. Finally, if compartments are designed to be above the ditching water level, the slide/raft may be deployed and used externally even if fuselage deformation inhibits door opening.

Together, these challenges and benefits suggest that it may not be desirable for some future slide/rafts to be portable. Practical experience with the current portable slide/rafts, whose size and weight already challenge human ergonomic capacity, indicates that non-portable rafts may provide a safer, more reliable means of group flotation. Therefore, the requirement for slide/raft portability needs to be augmented to allow the use of non-portable slide/rafts so long as sufficient flotation capacity is provided for all occupants of the airplane.

This approach is addressed in the “Commentary on Combination Slide/Raft Devices” cited above and is discussed in the comments to Amendment 25-46 to 14 CFR Part 25 (adopted October 20, 1978). There, the FAA had proposed to add a new § 25.1415(b)(4) which would require that one-half of the non-portable rafts be considered unusable for ditching. Commenters had stated that the requirement was unrealistic; the FAA stated that a non-portable raft, or a raft which by design cannot be used at other than its primary exit, may not be usable if that exit malfunctions or if ditching conditions are such that the exit cannot be used. FAA did not incorporate the proposed §25.1415(b)(4) because after further review, FAA believed that it did not have “enough information to prescribe a rule of general applicability for the design of ditching provisions which incorporate non-portable rafts”.

Since that time, however, and in addition to the practical experiences noted, ditching data have been examined in relation to the aforementioned FAA guidance on slide/raft portability. The most relevant study, “Passenger Emergency Exit Usage in Actual Emergencies of Jet Airliners 1960 – 1989,” was conducted by Fokker Aircraft BV and presented at the European Cabin Safety Conference in 1990. This study identified sixteen ditchings during that period. Fokker reported that, in five of those ditchings, where the fuselage remained intact, only 35% of the exits, on average, were not used during the evacuation. When compared with the rule proposed earlier by the FAA, this finding confirms that, as a criterion, the loss of half of the non-portable rafts is a generally conservative rationale for non-portablity.

In consideration of the foregoing (i.e. the potential for heavier slide/raft designs and for remote or out-of-cabin slide/raft storage locations, as well as the Fokker study), the use of non-portable slide/rafts is an acceptable design approach, provided that all occupants can be accommodated in the raft mode when 50% of the exits are not usable.

Discussion of the Proposal

<u>Specifically allow non-portable rafts.</u>

Section 25.1415(b)(1) has been restructured to make it clear that the raft capacity must equal or exceed airplane occupancy for two separate conditions: (1) all occupants must be accommodated at the combined rated capacity of all rafts, with all rafts assumed available, and, (2) all occupants must be accommodated at the overload capacity of the remaining rafts, assuming the loss of the portable raft with the largest overload capacity and the loss of half of the non-portable rafts. The first condition defines the total rated capacity (irrespective of raft portability). The second condition defines the total overload capacity resulting from a specific mix of portable and non-portable rafts. Note that “rated capacity” has been changed to “overload capacity” because that is the defining condition for loss of the largest slide/raft.

If all rafts are portable, then only subsection A of proposed § 25.1415(b)(1)(ii) need be considered. This scenario is identical to the existing requirement in § 25.1415(b)(1). However, if some rafts are not portable, then both subsections A and B of § 25.1415 (b)(1)(ii) must be considered and § 25.1415(d)(2) must be addressed.

Non-portable rafts are assumed to be located at exit pairs, one on each side of the airplane. The loss of 50% of the non-portable flotation capacity is intended to mean the loss of the largest raft of each exit pair, in accordance with the FAA policy described in the commentary noted above. Further, total raft overload capacity calculations must be based on the loss of the largest single portable raft, and of 50% of the non-portable rafts, ensuring that the raft flotation capacities are always sufficient to accommodate all occupants. The overload capacity of a raft at a non-paired exit may be included in the total overload flotation capacity only if the raft is portable; the rated capacity of this raft is included in the total rated capacity of all rafts regardless of exit pairing.

For example, considering an airplane with 4 pairs of floor level, ditching emergency exits:

	Door 1	Door 2	Door 3	Door 4
Rated capacity for each raft at that exit pair:	60	30	20	60
Overload capacity for each raft at that exit pair:	75	37	25	75

Total rated capacity = 2(60+30+20+60) = 340

Total overload capacity is determined as follows:

<u>Case 1</u>: All rafts are portable.

Lose one raft with the highest overload capacity (60 with an overload of 75).

Total overload capacity: 75 + 2(37+25+75) = 349

For this case, the total occupancy is limited by the rated capacity of 340.

Case 2: None of the rafts are portable.

Lose one raft from each exit pair (60 + 30 +20 + 60).

Total overload capacity: 75 + 37 + 25 + 75 = 212

For this case, the total occupancy is limited by the total overload capacity of 212.

Case 3: Only door 3 rafts are not portable.

Lose one 20-person raft per the 50% rule (i.e. you must consider loss of 50% of non-portable rafts) and one 60-person raft. Then, the total overload capacity is: 75 + 2(37) + 25 +2(75) = 324

For this case, the total occupancy is limited by the total overload capacity of 324.

Case 4: Door 3 and 4 rafts are not portable.

Lose one 20-person raft and one 60-person raft per the 50% rule and one portable raft with the highest overload capacity (60-person raft; 75 overload). At the overload capacity, the remaining rafts can provide flotation for 75 + 2(37) +25 + 75 = 249

For this case, the total occupancy is limited by the total overload capacity of 249.

Case 5: Door 2 and 3 rafts are not portable.

Lose one 30-person raft and one 20-person raft per the 50% rule and one portable raft with the highest overload capacity (60-person raft). Then, the calculation is: 75 + 37 + 25 + 2(75) = 287

For this case, the total occupancy is limited by the total overload capacity of 287.

Case 6: Door 1 and 4 rafts are not portable.

Lose two 60-person rafts per the 50% rule and one portable raft with the highest overload capacity (30-person raft). Then, the calculation is: 75 + 37 + 2(25) + 75 = 237

For this case, the total occupancy is limited by the total overload capacity of 237.

Case 7: The airplane is given an additional exit. Doors 1 through 4 rafts are portable, Door 5 raft is portable, but unpaired (example: a tailcone exit), and has a raft with a normal capacity of 20 and an overload capacity of 25.

Lose one raft with the highest overload capacity (60 with an overload of 75).

Total overload capacity: 75 +2(37+25+75) + 25 = 374

For this case, the total occupancy is limited by the rated capacity of 360.

<u>Case 8</u>: Door 5 raft is not portable, and is unpaired. The rest of the rafts are portable.

Lose one raft with the highest overload capacity (60 with an overload of 75).

Total overload capacity: 75 + 2(37+25+75) = 349

For this case, the total occupancy is limited by the overload capacity of 349.

FLOTATION CAPABILITY											
RAFT CAPACITY	DOORS									OCCUPANCY	
	1 LH	1 RH	2 LH	2 RH	3 LH	3 RH	4 LH	4 RH	5	TOTAL	ALLOWABLE
RATED	60	60	30	30	20	20	60	60	20	360	
OVERLOAD	75	75	37	37	25	25	75	75	25	N/A	
CASE 1	X[b]	75	37	37	25	25	75	75	N/A		340[a]
CASE 2	X[c]	75[c]	X[c]	37[c]	X[c]	25[c]	X[c]	75[c]	N/A		212
CASE 3	X	75	37	37	X[c]	25[c]	75	75	N/A		324
CASE 4	X	75	37	37	X[c]	25[c]	X[c]	75[c]	N/A		249
CASE 5	X	75	X[c]	37[c]	X[c]	25[c]	75	75	N/A		287
CASE 6	X[c]	75[c]	X	37	25	25	X[c]	75[c]	N/A		237
CASE 7	75	75	37	37	25	25	X	75	25		360[a]
CASE 8	75	75	37	37	25	25	X	75	X[d]		349

Notes:

a. Airplane occupancy cannot exceed the rated capacity.

b. X = loss of that raft; for convenience of charting, only LH door rafts are shown to be lost.

c. Loss of one raft due to non-portability of the pair.

d. Loss of the only raft at a non-paired exit.

PROPOSED TEXT FROM 2001 PROPOSED NPRM

By amending § 25.1411 by revising paragraphs (d), (d)(1), (d)(2), (d)(4) and (g), § 25.1415 by revising paragraphs (b), (b)(1), (c) and (d), and § 25.1561 (a) and (d) to read as follows:

§ 25.1411 General

(a) * * *

(b) * * *

(c) * * *

(d) Rafts. (1) The stowage provisions for the rafts described in § 25.1415 must accommodate enough rafts for the maximum number of occupants for which certification for ditching is requested.

(2) Portable rafts must be stowed near exits at which the rafts can be launched during an unplanned ditching and must be designed to permit use at other than the intended exits. Non-portable rafts must be stowed in a manner that will allow use at the associated exit during an unplanned ditching.

(3) * * *

(4) The stowage provisions for each portable raft must allow rapid detachment and removal of the raft.

(e) * * *

(f) * * *

§ 25.1415 Ditching Equipment

(a) * * *

(b) Each raft and each life preserver must be approved. In addition--

(1) Rafts of sufficient buoyancy and seating capacity must be provided such that:

(i) the rated capacity of the rafts accommodates all airplane occupants.

(ii) the overload capacity of the remaining rafts accommodates all airplane occupants in the event of the loss of:

A. the portable raft with the largest overload capacity, and

B. 50% of the non-portable rafts

D.2 Contents of Extended Overwater Operations Survival Kits

The following information was from FAA Advisory Circular (AC) 120.47, *Survival Equipment for Use in Overwater Operations*, dated 6/12/87. The purpose of the AC was to provide information related to survival items that should be carried during extended overwater operations. It should be noted that this list is being provided as an example of a past document that references some of the items that should be carried on extended overwater operations. Some of the items listed may not be available today and it can be assumed that equipment substitutions may have been made.

The AC notes that rafts (and slide/rafts where appropriate) should be equipped with the following:

(1) Lines, including an inflation/mooring line with a snaphook, rescue or life line, and a hearing or trailing line.
(2) Sea anchors.
(3) Raft repair equipment such as repair clamps, rubber plugs, and leak stoppers.
(4) Inflation devices, including hand pumps and cylinders (i.e., carbon dioxide bottles), for emergency flotation.
(5) Safety/inflation relief valves.
(6) Canopy and appropriate equipment to erect the canopy.
(7) Position lights.
(8) Hook-type knife, sheathed and secured by a retaining line.
(9) Placards that give the location of raft equipment and are consistend with placard requirements.
(10) Propelling devices such as oars, or in smaller rafts, glove paddles.
(11) Water catchment devices, including bailing buckets, reincatchment equipment, cups and sponges.
(12) Signaling devices including:
  (i) At least one approved pyrotechnic signaling device.
  (ii) One signaling mirror.
  (iii) One spotlight or flashlight (including a spare bulb) having at least two “D” cell batteries or equivalent.
  (iv) One police whistle.
  (v) One dye marker.
  (vi) Radio beacon with water-activated battery.
  (vii) Radar reflector.
(13) One magnetic compass.
(14) A 2-day supply of emergency food rations supplying at least 1,000 calories a day per person.

(15) One saltwater desalting kit for each two persons the raft is rated to carry or two pints of water for each person the raft is rated to carry.

(16) One fishing line.

(17) One book on survival, appropriate for any area.

(18) A survival kit, appropriately equipped. Some of the items which could be included in the survival kit are:

- (i) Triangular cloths
- (ii) Bandages
- (iii) Eye ointments
- (iv) Water disinfection tablets
- (v) Sun protection balsam
- (vi) Heat retention foils
- (vii) Burning glass
- (viii) Seasickness tablets
- (ix) Ammonia inhalants
- (x) Packets with plaster

Acronyms

AC	Advisory Circular
AIA	Aerospace Industries Association
ARAC	Aviation Rulemaking Advisory Committee
CFR	Code of Federal Regulations
CS	Certification Specifications
DLR	Deutsches Zentrum fuer Luft- und Raumfahrt (German Aerospace Center)
DSG	Design Service Goal
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
NAA	National Aviation Authorities
NASA	National Aviation and Space Administration
NAVAIR	
NIAR	National Institute of Aviation Research
OEM	Original Equipment Manufacturer
PS	Policy Statement
TAE	Transport Aircraft and Engine Committee
TACDWG	Transport Airplane Crashworthiness and Ditching Working Group

Revision Record

Release/Revision	**NEW, 31 October 2017**
Description of Change	Incorporated additional material where incomplete. Included editorial changes to equipage material. Incorporated preliminary input from: Bombardier, DLR, EASA, NASA and Textron
Release/Revision	Rev. A, 9 November 2017
Description of Change	This revision includes: Information related to all team meetings. Updated information related to cost benefit including qualitative assessment tables. Editorial pickups for crashworthiness background Set up Section 5 for comments/issues Discussion on controlled ditching Editorial updates to introduction Fixing pitch variation to 1 deg based on OEM study. Added team 1 databases as excel files Inputs from Airbus, Boeing, Bombardier, DLR, EASA Embraer, NASA, NIAR and Textron
Release/Revision	Rev. B, 18 November 2017
Description of Change	This revision includes: Updated text in Executive summary, Section 1, Hazard Assessment for ditching, Qualitative cost assessment input from team. Editorial updates to exec summary and section 1. Inputs from AFA, Airbus, Boeing, Bombardier, Cascade Aerospace, DLR, Embraer, NIAR and Textron
Release/Revision	Rev. Final, 8th December 2017
Description of Change	This revision captures all input up through Dec 7th and is intended to be the final copy for final group review and approval. This version includes: Incorporation of editorial comments/revisions accepted by the group. Corrections for typographical errors. Input from NASA to consider future investigation of overhead bins and dynamic loads in crash. Input from NASA, Gulfstream, Textron, Dassault, Mitsubishi and NIAR. Editorial corrections from Bombardier and Dassault.
Release/Revision	Rev. Final, 15th December 2017
Description of Change	This revision captured final editorial and typographical corrections. Addition of dissenting position regarding need, or appropriate, timing for airframe crashworthiness rules at this time from multiple OEM

	representatives. Concurrence from team members that document is complete represents discussions and decisions made by the team and can be transmitted to FAA.
Release/Revision	Rev. A, 10 May 2018
Description of Change	A summary of the major dissenting points with rationale to address the dissenting points was added to the executive summary as a specific request from the TAE members. This addition is to help clarify why the report should continue forward and go to ARAC as opposed to devoting additional time with the team in an attempt to develop an alternate proposal for an airframe crashworthiness rule. The additional material in the executive summary is intended to capture the major dissenting points documented in section 6. The formal positions of the signatories is represented in detail by the material found in section 6.1.2.
Release/Revision	Rev. B, 20 September 2018
Description of Change	Removed concurrence approvals page 2 and 3 at request of ARAC.