U.S. Department of Transportation

Federal Aviation Administration

Advisory Circular

DRAFT

Subject: Methodology for Dynamic Seat Certification by Analysis for Use in Parts 23, 25, 27, and 29 Airplanes and Rotorcraft	**Date:** **Initiated By:** ACE-100	**AC No:** 20.XX **Change:**

1. PURPOSE.

This advisory circular (AC) sets forth acceptable means, but not the only means, for demonstrating compliance to the following by computer modeling analysis techniques validated by dynamic tests:

- Title 14 Code of Federal Regulations (14 CFR) parts 23, 25, 27, and 29, §§ 23.562, 25.562, 27.562, and 29.562.

- The Technical Standard Order (TSO) associated with the above regulations, TSO-C127/C127a.

This AC provides guidance on how to validate the computer model and under what conditions the model may be used in support of certification or TSO approval/authorization.

Material in this AC is neither mandatory nor regulatory in nature and does not constitute a regulation. In addition, this material is not to be construed as having any legal status and should be treated accordingly.

2. CANCELLATION.

This advisory circular does not cancel any previously issued AC.

3. BACKGROUND.

A series of proposals that focused on cabin safety and occupant protection design requirements were developed at the Small Airplane Airworthiness Review Conference, held in October 1984. The proposals culminated with Notice of Proposed Rulemaking (NPRM) 86-19, which included proposed rule § 23.562 "Emergency landing dynamic conditions."

The preamble to this rule states that at the time this rule was written, there was not a sufficient data base to permit the use of analysis in lieu of dynamic testing to show compliance with this requirement. However, the preamble also states that the language of § 23.562 is intended to provide flexibility when the state of analytical techniques evolve sufficiently to permit these techniques in lieu of dynamic tests. This document provides guidance for demonstrating compliance to § 23.562 by means of computer modeling techniques. Recognizing that this guidance is equally applicable to aircraft other than small airplanes, this document also applies to §§ 25.562, 27.562, and 29.562.

This document defines the acceptable applications, limitations, validation processes, and minimum documentation requirements involved when substantiation by computer modeling is used to support a seat certification program. It is a culmination of the efforts of the Advanced General Aviation Transportation Experiments Program (AGATE) Advanced Crashworthiness Workpackage Team. This team consisted of representatives from private industry, research institutions, academia, and the federal government. As part of the AGATE effort, the team developed a methodology for seat certification and design by analysis. This Advisory Circular is a direct result of that methodology.

In addition, TSO C127/C127a established a standard for the dynamic testing of seats as specified by §§ 23.562, 25.562, 27.562, and 29.562. Although installation approval under the airworthiness standards is required for any TSO item, applicants or holders of TSO C127/C127a may use the methodology presented in this AC.

4. APPLICABILITY.

This AC applies to several groups:

The first group that this AC applies to are those applicants who include the seat as part of the airplane/rotorcraft type design. In this case, the applicant is not using a TSO-C127/127a seat approved for installation in the aircraft. The applicant will test the seat to § xx.562 using the specific interior configuration of the target aircraft (including attachment hardware and fittings). The applicant can substantiate modifications to this seat design and installation using the guidance presented in this AC.

The second group this AC applies to is seat manufacturers who build seats to the requirements of TSO-C127/TSO-C127a, and hold either design approval or TSOA for those seats. In this instance, the TSO manufacturer would demonstrate compliance to the

TSO standard by test for THE ORIGINAL seat design. Subsequent changes to this seat may show compliance to the TSO by the use of the analytical techniques and limitations described in this AC.

The third group this AC applies to is an airplane/rotorcraft manufacturer or modifier that wishes to install a TSO seat. The original seat, installation limitations, and installation approval are used to certificate the original (or baseline) design and installation. Modifications to any of these elements are eligible for certification via the analytical techniques and limitations described in this AC.

Computer modeling analytical techniques may be used to do the following:

- Establish the critical seat installation/configuration in preparation for dynamic testing (discussed further in Section 8). This is not to suggest that static considerations or company expertise can no longer be used to determine the critical test configuration.

- Demonstrate compliance to §§ 23.562, 25.562, 27.562, or 29.562 for changes to a baseline seat design, where the baseline seat design has demonstrated compliance to these rules by dynamic tests. Changes may include geometric or material changes to primary and non-primary structure. Section 9 discusses this item further.

Independent of the bulleted items above, changes to joints and fittings will require certification by dynamic testing. Joints and fittings are typically highly loaded seat structural elements, characterized by indeterminate load paths and a difficulty to model mathematically.

Historically, in a dynamic test, failure will occur at either a joint or a fitting. A change in the load path or material properties of these elements can greatly affect the performance of the seat. Given their importance, and the difficulty associated with modeling them, a new series of dynamic tests will be required to substantiate changes to these elements.

5. RELATED PUBLICATIONS.

a. Orders, Federal Regulations, and AC's.

FAA Order 8110.4B, Type Certification.

Code of Federal Regulations (CFR), Title 14 part 21 – Certification Procedures for Products and Parts.

Code of Federal Regulations, Title 14 part 23 – Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes, Subpart C – Structure.

Code of Federal Regulations, Title 14 part 25 – Airworthiness Standards: Transport Category Airplanes, Subpart C – Structure.

Code of Federal Regulations, Title 14 part 27 – Airworthiness Standards: Normal Category Rotorcraft, Subpart C – Strength Requirements.

Code of Federal Regulations, Title 14 part 29 – Airworthiness Standards: Transport Category Rotorcraft, Subpart C – Strength Requirements.

Code of Federal Regulations, Title 49 part 572, Chapter 5, Subpart B – Anthropomorphic Test Dummies (ATD).

Technical Standard Order TSO-C127, Rotorcraft and Transport Airplane Seating Systems, dated March 30, 1992.

Technical Standard Order TSO-C127a, Rotorcraft, Transport Airplane, and Normal and Utility Airplane Seating Systems, dated August 21, 1998.

Copies of the current publication of the AC listed below can be obtained from the U.S. Department of Transportation, Subsequent Distribution Office, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785:

AC 20.137, Dynamic Evaluation of Seat Restraint Systems & Occupant Restraint for Rotorcraft (Normal and Transport), dated March 30, 1992.

AC 23.562-1, Dynamic Testing of Part 23 Airplane Seat/Restraint Systems and Occupant Protection, dated June 22, 1989.

AC 25.562-1A, Dynamic Evaluation of Seat Restraint Systems & Occupant Protection on Transport Category Airplanes, dated January 19, 1996.

AC 27-1B, Certification of Normal Category Rotorcraft, dated September 30, 1999.

AC 29-2C, Certification of Transport Category Rotorcraft, dated September 30, 1999.

b. Industry Documents.

Methodology for Seat Design & Certification by Analysis, Advanced General Aviation Transportation Experiments (AGATE) WP3.4-034012-077, August 31, 2001.

Instrumentation for Impact Test - Part 1 – Electronic Instrumentation, SAE Surface Vehicle Recommended Practice, SAE J211-1, Society of Automotive Engineers International, March 1995.

c. Other References.

Finite Element Procedures in Engineering Analysis, K.J. Bathe, 1982.

Solutions Method, T. Belytschko, W.K. Liu, and B. Moran, 1999.

6. DEFINITIONS.

<u>Seating Configuration</u>. The airplane/rotorcraft interior floor plan, which defines the seating positions available to passengers during taxi, takeoff, landing, and in-flight conditions.

<u>Seating/Restraint System</u>. A system that includes the seat structure, cushions, upholstery, the safety belt, the shoulder harness, and the attachment devices.

<u>Computer Modeling</u>. The use of computer based finite element or multi-body transient analysis to simulate the emergency landing dynamic condition of the applicable airworthiness standard. These codes typically follow an explicit formulation. The following combination of computer codes and occupant models have been used in support of the design and certification of dynamic seats. This is not an exhaustive list. Codes not identified here, but shown to be equivalent to those referenced below, may be utilized as well:

a. MADYMO transient finite element/multi-body software and the MADYMO 50 percent part 572 Subpart B Hybrid II occupant model. [MADYMO is a registered trademark of TNO Road-Vehicles Research Institute.]

b. MSC/DYTRAN transient finite element software and the ATB Hybrid II occupant model. [MSC/DYTRAN is a registered trademark of the MacNeal – Schwendler Corporation. ATB is a public domain code developed and maintained by Wright Patterson Air Force Base.]

c. LS-DYNA3D transient finite element software and the MADYMO 50 percent part 572 Subpart B Hybrid II occupant model. [LS-DYNA3D is a registered trademark of the Livermore Software Technology Corporation.]

<u>Mass Scaling</u>. This concept relates closely to the stability of explicit codes. As indicated under stability of explicit codes, the integration time step is dependent upon the shortest natural period in the mesh. The integration time step must be less than the time required for a stress wave to cross the smallest element in the wave. Mass scaling is used to reduce the analysis time by artificially adding mass to the governing small elements. The addition of mass reduces the natural period of the element, which increases the time required for a stress wave to cross that element. Mass scaling should only be used on the smallest elements contained in the model, so as not to affect the overall mass of the system.

6.1 Stability of Explicit Codes

Most transient explicit finite element codes employ direct integration methods, and they take advantage of the numerical effectiveness of integration schemes such as the central difference method, Wilson-θ, or Newark-β methods. These integration schemes attempt to satisfy equilibrium only at discrete time intervals (Δt) rather than for the duration of the analysis.

The accuracy and stability of the solution is highly path dependent, and it relies heavily on the interpolated values of displacements, velocities, and accelerations within each time step interval. Bathe and Belytschko discuss the inherent numerical instabilities encountered with explicit dynamic analysis codes in detail, most notably in their respective publications. The solutions of these codes are, therefore, *conditionally* stable, a trade-off for the simplicity and cost effectiveness of the methods. The stability of the explicit methods is a function of the critical time step Δt_{cr} defined as

$$\Delta t_{cr} = \min(L_e/c),$$

where L_e is the effective length of the smallest element, and c is the stress wave speed (a function of material stiffness). In other words, the time step selected for the analysis must be smaller that the time for the stress wave to cross the smallest element in the finite element mesh. Otherwise, numerical instability may develop and cause the solution to diverge.

In theory, the most numerically efficient solution is obtained when an integrating time step equivalent to the stability limit is chosen. Commercial codes, such as MADYMO or LS-DYNA3D, attempt to offset the problems of numerical instability by regulating and constantly updating the time interval used throughout the analysis. Although the user may chose an initial time step to begin the analysis, the program will calculate the critical integration time step. The program will either terminate or default to the critical time step if the user input time step is larger than this minimum. A general guideline is to select a Δt smaller than the critical time step presented in the above equation. A margin of 20-30 percent will avoid the instability introduced by the inherent numerical disturbance associated with the integration process. The bit number accuracy of the computer configuration may affect this margin.

7. COMPUTER MODEL VALIDATION

Computer modeling and analysis techniques may be used to certificate incremental changes to a seat system design to the requirements of 14 CFR parts 23, 25, 27, and 29, §§ 23.562, 25.562, 27.562, and 29.562. The results of this computer analysis may be utilized for certification purposes under the conditions specified in Sections 8 and 9 of this document.

As with any form of analytical modeling, validation of the seat/restraint model is a key step in determining whether the model is acceptable for use in certification. The sections that follow will provide a guide to the accuracy desired between the analytical results and the dynamic test results.

However, in verifying the accuracy of a finite element model, there is no substitute for good engineering judgement. As such, it is not the intent of this AC to circumvent the level of communication and coordination required between an applicant and the ACO engineer when validating a finite element model. Rather, this AC will provide guidance on the numerous parameters that deserve consideration when comparing the results of transient finite element analysis to actual test data.

7.1 General Validation Acceptance Criteria

Results of the computer model may be used to demonstrate compliance to §§ 23.562, 25.562, 27.562, or 29.562 if the criteria specified in this section have been satisfied. These criteria allow for subjective interpretation as long as this interpretation is consistent with good engineering judgement. The level of correlation required of the applicant's model should not be imposed to tolerances beyond that observed in a dynamic test. The general validation acceptance criteria are as follows:

1. The model must be validated against dynamic tests.

2. The model should be utilized for conditions that are similar to the model validation conditions. Similarity should exist between the current seat analysis and the test and analysis used to validate the analysis model, including loading conditions, seat type, and worst-case conditions.

   For example, test results from a four-legged seat should not be used to validate a three-legged seat computer model. As another example, test results from a forward facing seat should not be used to validate an aft-facing seat computer model.

3. The general occupant trajectory, verified by time history plots, should correlate against test data.

In addition to the general validation criteria above, the model has to correlate to the application specific criteria defined in Section 7.1.1.

7.1.1 Application Specific Validation Criteria

Beyond the general validation criteria, the applicant should validate parameters that are relevant to the application of the model. The FAA Aircraft Certification Office (ACO) and the applicant should identify and agree upon the validation criteria that are specific to the application. The certification plan should list those criteria.

The computer model is considered validated if reasonable agreement (as discussed in Sections 7.1.1.1 to 7.1.1.6) between analysis and test data can be shown. Test data used to validate the model should be included as an appendix in the Validation and Analysis Report (VAR, see Section 11).

Sections 7.1.1.1 to 7.1.1.6 identify the minimum criteria used to evaluate the applicant's computer model. The ACO and the applicant should negotiate any additional validation criteria. These sections also define the acceptable correlation methods related to each specific validation criteria.

7.1.1.1 Occupant Trajectory

Occupant trajectory describes the overall translational and rotational motion of the occupant. The trajectory of the occupant may include headpath, pelvic and torso displacement, and arm/leg flail. The analytically derived occupant trajectory should be compared to high-speed video obtained from dynamic tests. The ability of the computer model to predict an occupant trajectory can be established by comparing planar space time-history plots to calibrated photometric data obtained from the baseline dynamic test. It is critical that the model be able to predict occupant motion in an accurate manner. Any discrepancy between the model and the test data that exceeds 5 percent should be resolved.

7.1.1.2 Structural Response

Quantifying the structural response of the computer model includes evaluating the internal loads and structural deflections of the seat. Validation of the computer model should include a comparison of the structural performance criteria presented in Sections 7.1.1.2.1 and 7.1.1.2.2 to the predictions of the model.

7.1.1.2.1 Internal Loads

Floor reaction loads are a required means to show correlation. There should be reasonable agreement between time history plots of the resultant floor reaction loads obtained in the analysis and measured test data. The peak floor reaction loads between the analysis and test data should correlate to within 10 percent. In addition, the time history plots of the floor reaction load phase and magnitude should correlate within 10 percent between the analysis and the test results. Correlation of the floor reaction load phase and magnitude is critical in demonstrating a proper load path from the occupant to the restraint system to the floor.

In some cases, it may be necessary to calibrate and measure internal loads in other structural members of the seat. The applicant and the ACO should coordinate to determine if these loads will be used to help validate the model and the expected accuracy.

7.1.1.2.2 Structural Deformation

Reasonable agreement should be obtained between the mode and magnitude of structural deformation obtained by analysis and test data for members that are critical to the overall performance or structural integrity of the seat or seating system. A comparison between the planar space plots obtained from the analysis to photometric data obtained from dynamic test can help to validate the model. Correlation should be within 20 percent for those structures that exhibit low structural deformation (less that 3 inches). Structures that utilize discrete energy absorbers that allow for large seat displacements should correlate to within 10 percent.

7.1.1.3 Restraint System

Validation of the restraint system may be obtained by correlating the analysis belt load time-history to test data. The phase, maximum value, and load time-history profile should correlate to within 10 percent of dynamic test data. This ensures that the computer model will predict the inertial force energy transfer from the occupant to the seat and vice-versa. Additional parameters, such as belt payout or permanent elongation, may be correlated if similar measurements were recorded during dynamic test.

Since occupant trajectory and restraint system loads are closely related functions, the computer model must adequately predict both items. It is unacceptable to show compliance to occupant trajectory in lieu of restraint system performance or to validate restraint system performance at the expense of occupant trajectory.

7.1.1.4 Head Injury Criteria (HIC)

14 CFR parts 23, 25, 27, and 29, §§ 23.562(c)(5), 25.562(c)(5), 27.562(c)(5) and 29.562(c)(5), define the certification requirements for Head Injury Criteria. An applicant may use the results of computer modeling to show compliance with these rules under the following circumstances:

a. The predicted occupant head strike envelope will satisfy the above stated rules by showing that no contact with adjacent seats, structure, or other items in the cabin will occur.

b. To evaluate a modified seat installation where the potential head impact surfaces are *identical*, only the geometric strike envelope has changed. Installation changes that result in a higher head strike velocity will require testing to demonstrate compliance to HIC requirements.

For subparagraph (b) above, the regulation specifies calculating HIC during the duration of the major head impact, with a maximum allowable HIC limit of 1,000 units. The selected time interval should correspond to the duration of the major head impact on aircraft interior features.

The phase and profile of the acceleration time-history plot, as well as the average "G" loading for resultant head accelerations obtained in the analysis, should correlate to the results of the dynamic test. The average "G" loading is measured at the head center of gravity.

Given two dynamic tests with the same desired deceleration profile, the maximum HIC values will likely vary. Therefore, a precise match between the test derived HIC and the analytical HIC is not realistic. However, the maximum analytical HIC value should correlate to within 5 percent of the maximum test derived HIC value.

It is extremely unlikely that the analytical head deceleration time history function will match the test generated head deceleration time history function. While the HIC integral, therefore, must be evaluated at time periods that correlate to dynamic test, the actual times that produce the maximum HIC values will likely vary.

7.1.1.5 Spine Load

14 CFR parts 23, 25, 27 and 29, §§ 23.562(c)(7), 25.562(c)(2), 27.562(c)(7), and 29.562(c)(7), define the certification requirements for lumbar spinal loading. The maximum allowable limit is 1,500 pounds. The phase and load time-history profile for spine load obtained in the analysis should correlate to the dynamic test data. The time history of the lumbar loading and the peak load value, as determined by the analysis, should compare to within 10 percent of the dynamic test results.

7.1.1.6 Femur Compressive Load (part 25 airplanes only)

14 CFR part 25, § 25.562(c)(6) defines the certification requirements for axial compressive loading of the femur. The maximum allowable limit is 2,250 pounds. The phase and load time-history profile for the compressive femur load obtained in the analysis should correlate to the dynamic test data. The time history of the femur loading

and the peak load value, as determined by the analysis, should compare to within 10 percent of the dynamic test results.

7.1.2 Discrepancies

Failure to satisfy all validation criteria does not automatically preclude the model from being validated. The applicant and the FAA ACO engineer should evaluate whether the deviations impact the ability of the model to predict credible results and determine if deviations from the validation criteria are acceptable. In addition, the applicant may present evidence to show that the deviation is within the inherent reliability and statistical accuracy of the test results. The applicant should quantify any discrepancies between the results obtained from analysis and the dynamic test data.

7.1.3 Computer Hardware and Software

Certification work performed by the applicant's computer model should be performed on the same hardware and software platform on which the validation was conducted. The model should be developed using only production versions of the software. The use of a "Beta" or other non-production software release is not allowed, except under controlled circumstances. For example, there may be situations where the software vendor is working with the applicant to improve the correlation of the model to test results. This may be acceptable if the applicant provides the FAA with documentation that the FAA finds both suitable and acceptable for all software changes made from the production version.

If the computer model is transferred to a different hardware platform, the applicant must revalidate the model as necessary to ensure that the results do not reflect any significant differences. However, if the software provider can offer documentation that hardware changes yield a negligible impact, the applicant may supply this documentation in lieu of revalidating the model.

Any change to the software version, including a change from "Beta" version to production version, will also require revalidation of the computer model. As in the case for hardware changes, if the software provider can offer documentation that a change in software version yields a negligible impact, revalidation of the model will not be necessary.

7.2 Documentation of Validation

The applicant is entitled to validation documentation, supplied by the FAA, indicating that the computer model is capable of generating certification data. This will allow the applicant to avoid revalidating the same model each time it produces certification data. The applicant and the ACO should negotiate the form this validation documentation will take (letter, formal memorandum, or other suitable form). In addition, once an applicant has provided sufficient evidence that a computer model is capable of generating certification data, the ACO and applicant should agree upon the content of the validation documentation. Possible items to include in the validation documentation are as follows:

- The FAA's acceptance of the computer model to produce certification data.
- Identification of the software version and hardware platform used to build and run the computer model.
- A description of any limitations on the application of the computer model.
- The FAA's expectations for how the applicant will maintain configuration control of the model.
- Other items as agreed to between the ACO and the applicant.

8. APPLICATION OF COMPUTER MODEL IN SUPPORT OF DYNAMIC TESTING

There will be occasions when the applicant wishes to determine the critical loading scenario for a particular seating system. This section provides guidance on those items to consider when performing trade studies with the purpose of identifying the most critical configuration/installation. A final certification test to the requirements of 14 CFR parts 23, 25, 27, or 29, §§ 23.562, 25.562, 27.562, or 29.562, will be required to certify this critical configuration/installation.

Sections 8.1 to 8.3 specify the conditions when a computer model may be used to provide engineering analysis and rationale in support of dynamic testing. These conditions do not form an exhaustive list of items to consider, but are the most common.

8.1 Determination of Worst Case for a Seat Design

Upon completion of the computer analysis, the results from the simulation may be used to determine the worst case or critical loading scenario for a particular seating system. This includes the following:

a. Identifying components of seat structure that are critically loaded.

b. The selection of the critical seat track position.

c. An evaluation of the restraint system.

d. An evaluation of the yaw condition to address loading on the seat frame and movement of the occupant out of the restraint system.

8.2 Determination of Worst Case Scenario for Seat Installation

Results of a validated computer model may be used to select the worst case seat system installation as a candidate for dynamic testing. In determining the most critical seat installation, each seating system shall be analyzed in its production installation configuration. For example, an analysis to determine a worst case seating system may include the following:

a. Comparing seating systems installed in an over-spar versus non over-spar configuration.

b. Seating systems installed at different positions in the fuselage, which will result in various restraint anchor positions relative to the occupant and seat structure.

8.3 Determination of Occupant Strike Envelope

The results of the computer analysis may be used to determine the occupant strike envelope with aircraft interior components. Each seating system should be analyzed in its production installation configuration. The occupant strike envelope will determine if a potential for head strike exist and, if so, which items are required in the test setup during the HIC evaluation tests.

9. APPLICATION OF COMPUTER MODELING IN LIEU OF DYNAMIC TESTING

There will be occasions when the applicant wishes to certify a seat that is based on a similar certificated design concept (a family seat design) but one differs structurally in order to accommodate a particular installation. When the applicant intends to use the results of computer modeling to provide engineering/certification data in lieu of dynamic testing, the results from this validated model may be applied to the modifications specified in Sections 9.1 and 9.2.

9.1 Seat System Modification

Analysis based on a validated computer simulation may be used to substantiate seat designs or installations that have been modified from a certificated configuration. These modifications may include changes to primary and non-primary load path structural members.

Note that changes to seat joints or fittings are <u>not</u> eligible for certification by analysis. Geometric or material changes to joints or fittings will require new certification testing. Any additional testing that is required should be coordinated between the applicant and the ACO.

There will be instances when a modified seat design results in a structural member (in the primary load path) that must react a dynamic load or stress greater than that reacted during the baseline design test. Note that the modified part is not necessarily the part that has increased criticality. For a non-critical structural member, i.e., the ultimate margin of safety of the baseline design (see Section 11.6) is greater than or equal to 1.0, the modified design ultimate margin of safety must be greater than or equal to 0.5.

For critical structural members, the ultimate margin of safety for the baseline design structural member is less than or equal to 0.5. In this case, design changes to the seat cannot result in an ultimate margin of safety that is reduced greater than 25 percent from the original margin. In those cases where a design change reduces the ultimate margin of safety, the ultimate margin of safety for the structural element in question must be greater than or equal to 0.1. In all cases, the ultimate margins of safety must be positive.

9.2 Seat Installation Modification

Analysis based on a validated computer simulation may be used to substantiate configuration changes to seat installations. The primary application is to show compliance for HIC (reference Section 7.1.1.4 for restrictions on HIC compliance findings).

9.3 Applicability

The material in Sections 9.1 and 9.2 is not applicable to changes to the seat-floor attachment structure. If the attachment hardware or materials are altered from the certificated baseline seat design (which includes the seat-to-track fitting and track substantiated under TSO-C127/127a), a new series of dynamic tests will be required.

10. SEAT CERTIFICATION AND COORDINATION PROCESS

This section contains certification guidelines an applicant may follow when they wish to use computer modeling to generate engineering data to demonstrate compliance to 14 CFR parts 23, 25, 27, or 29, §§ 23.562, 25.562, 27.562, or 29.562. It defines the procedures that are involved concerning FAA coordination, guidelines for the preparation and validation of the computer model, and the minimum documentation requirements for FAA data submittal.

10.1 FAA Coordination

The FAA coordination process presented in this document is extracted from FAA Order 8110.4B. FAA coordination is essential to ensure the proper and timely execution of any certification program. The guidelines presented will assist in the implementation of computer modeling as a means of compliance.

10.2 Certification Plan

The use of computer modeling to generate technical data in support of the establishment of dynamic test conditions or in lieu of dynamic test shall be negotiated with the FAA ACO. If the FAA establishes a Type Certification Board (TCB), negotiations should occur during the preliminary and interim TCB meeting. Regardless of the presence of a TCB, since a TCB is not always required for STC projects, the applicant's role is as follows:

a. Acquaint the FAA personnel with the project.

b. Discuss and familiarize the FAA with the details of the design.

c. Identify, with the FAA, applicable certification compliance paragraphs.

d. Negotiate with the FAA where the applicant will utilize computer modeling, and specify the intent and purpose of the analysis.

e. Establish means of compliance either by test, by rational analysis (i.e., computer modeling), or both, with respect to the certification requirements.

f. Establish the validation criteria for the computer model relative to its application for certification.

g. Prepare and obtain FAA ACO approval of the certification plan.

10.3 Technical Meeting

The details of the computer model are defined during scheduled technical meetings between the applicant and the FAA ACO. The applicant should prepare a document for the FAA describing the purpose of the analysis, the validation methods, and the data submittal format. As a minimum, the following items should be contained in the document:

a. A description of the seat system to be modeled.

b. A description of the software to be utilized in the analysis. This should include the operating assumptions and limitations of the software.

c. A description of how compliance will be shown.

d. A description of material data sources.

e. Validation methods, including a description and justification of the failure modes/theories.

f. Interpretation of results.

g. Substantiation documentation and data submittal package.

The document, referred to as the Certification Plan Document, should be developed in conjunction with the seat design evaluation phase and approved by the FAA as early in the certification process as possible.

11. DOCUMENTATION REQUIREMENTS FOR COMPLIANCE

The applicant must create a document that provides the analytical results and comparisons to test data when computer modeling is submitted as engineering data. This document will be known as the Validation and Analysis Report (VAR).

The VAR defines the methodology used to demonstrate compliance to 14 CFR parts 23, 25, 27, or 29, §§ 23.562, 25.562, 27.562, or 29.562. The VAR addresses these methodologies when computer modeling results are submitted as engineering data. In addition, the VAR **must** document the validation criteria identified in Sections 7.1.1.1 to 7.1.1.6.

Sections 11.1 to 11.6 identify *additional* documentation requirements of the VAR. The ACO and the applicant should negotiate any further requirements.

11.1 Purpose of Computer Model

The applicant must define the purpose of the computer model as either:

a) Application of computer modeling in support of dynamic testing (Sec. 8), or,
b) Application of computer modeling in lieu of dynamic testing (Sec. 9).

The VAR must list the 14 CFR requirements relevant to the certification of the seating system. The VAR will emphasize how the computer model would be used to demonstrate compliance for each stated requirement.

11.2 Overview of Seating System

The VAR must contain an overview of the design of the seating system. This overview will describe the seat layout in the aircraft, the occupant restraint type, and the attachment method of the restraint. If applicable, the VAR will describe the adjustment positions required during takeoff and landing. In addition, the VAR will contain a description of any special occupant protection features included in the seat/restraint system design.

11.2.1 Seat Structure

The VAR must provide a description of the seat's critical components, primary load paths, energy absorbing features, the attachment hardware of the seat, and the floor attachments/seat tracks. The VAR will describe the material properties of the primary structural and energy absorbing components, along with the method of fabrication. Special attention should be given to describing which primary structural members are designed to displace, deform, elongate, or crush in order to dissipate kinetic energy.

11.2.2 Restraint System

The VAR must provide a description of the restraint system, including part number, and any other devices designed to restrain the occupant in the seat or reduce the occupant's movement under emergency landing conditions. This may include the shoulder and lap belts, load limiting devices, belt locking devices, pretensioners, and inflatable restraints. The VAR must also describe how the restraint system and its devices are anchored and list the material properties of the restraint system.

11.2.3 Unique Energy Absorbing Features in the Installation

Unique energy absorbing features are components, other than the seat and restraint system, that are designed to limit the load imposed on the seating system or occupant. Examples may include energy absorbing subfloor structure or inflatable devices mounted on the airframe but not considered a part of the seat/restraint system.

11.3 Software and Hardware Overview

The VAR must contain a brief description of the software and hardware used to perform the analysis, including the following information:

a. Type and platform of computer hardware;

b. Software type and versions; and

c. Basic software formulation.

11.4 Description of Computer Model

The VAR must contain a detailed description of the computer model, including the input data. The VAR must also include a discussion on the topics presented in sections 11.4.1 through 11.4.7.

11.4.1 Engineering Assumptions

The applicant must document assumptions used for the analysis. Assumptions may include, but not be limited to, simplification of the physical structure, the use of a particular material model, methods used for applying boundary conditions, failure theories, and the method of load application. The VAR must provide a rational support for the use of the assumption. The applicant may be required to demonstrate that the assumptions do not negatively affect the analytical results.

Those components that are not critical to the performance of the seating system and do not influence the outcome of the analysis may be omitted from the model. However, the mass of the system must be preserved. The VAR must list all components that are excluded from the analysis and provide justification for the exclusion of those components from the model.

11.4.2 Finite Element Modeling of the Physical Structure

The VAR must provide a description of the finite element mesh of the structure. It will describe how the critical components of the structure were modeled and provide the rationale for the selection of the element types that were used to represent the structure. In addition, the applicant must describe the limitations of the mesh element used. If the mesh element is either unconventional or is a new element, the VAR must provide the mathematical formulation of that element, engineering assumptions made during the element's formulation, and any limitations that apply to its usage.

11.4.3 Material Models

The applicant must document the material models used in the analysis. This may include a list of the materials used by the analysis software and a general description of the material properties. In addition, the applicant must identify the source of the material data.

Any material data acquired through in-house tests must be supported by appropriate documentation that describes the basis of such test, test methods, and results. This includes proprietary data.

11.4.4 Constraints

Constraints are boundary conditions applied in the model. This includes single and multi-point constraints, contact surfaces, rigid walls, and tied connections. The applicant must document the boundary conditions applied in the model and discuss how the model boundary conditions correspond to the test conditions. The VAR must also provide a description of contact definitions and nodal constraints. Finally, the VAR must document the values used to represent frictional constants and the validity of such values.

11.4.5 Load Application

Loads that are applied in the computer model may include concentrated forces and moments, pressure, enforced motion, and initial conditions. The VAR must contain a description of how external loads are applied to the model, and list all nodal points affected by the load application. The VAR must also provide a copy of the acceleration/deceleration profile time history.

11.4.6 Occupant Simulation

The use of appropriate occupant models depends on the objective of the analysis and should be negotiated with the FAA. If the analysis is used to certify a seat/restraint system to the requirements of 14 CFR parts 23, 25, 27, or 29, §§ 23.562(b), 25.562(b), 27.562(b), or 29.562(b), then a validated occupant model (see paragraph 6) representing a 50^{th} percentile male per 49 CFR part 572, Subpart B, or an equivalent approved model shall be used. The VAR must describe the development and validation of the occupant model.

11.4.7 General Analysis Control Parameters

General analysis control parameters are features of a program that control, accelerate, and terminate an analysis. This may include parameters that enhance the performance of the software for reducing the computational time or the use of subroutines that facilitate the post-processing of results.

The VAR must include a summary of the control parameters used for a particular analysis. There should be ample justification for parameters that may influence the outcome of the analysis. As an example, the analyst should show that the artificial scaling of mass for reducing computational time is acceptable and does not negatively influence the results of the model. Section 6 of this AC provides a description of mass scaling.

11.5 Analytical Result Interpretation

This section contains guidance and recommendations for the output, filtering, and the general methods of reporting analytical data. The purpose is to achieve uniformity in the practice of reporting analytical results. The use of the following recommendations will provide a basis for a meaningful comparison to test results from different sources.

11.5.1 Energy Balance

The applicant must evaluate the presence of hourglass modes (also known as zero-energy modes) to determine if they are located at critical structural components. If this evaluation determines that these modes are present, the applicant must assess the hourglass modes to quantify their influence on the accuracy of the analysis. The applicant will need to correct the model if it does not attain the appropriate energy balance. The VAR must contain a summary of the ratio of initial energy to final energy and provide a comparison of hourglass energy to total energy.

11.5.2 Data Output

The transient analysis should generate data at channel class 1000. This will maintain an equivalent practice with the instrumentation requirements specified in SAE J211, and it will allow for a meaningful comparison between analytical data and test data.

If the output of the data channels is dependent on the integration time step of the analysis, and its sample rate is higher than channel class 1000, the data should be reduced to be consistent with channel class 1000 prior to filtering. The VAR must document any deviations to this practice.

11.5.3 Data Filtering

The filtering practices of SAE J211 apply for all applications.

11.6 Ultimate Margin of Safety

The ultimate margin of safety represents the ultimate strength of the structure over the strength required to carry the ultimate load. For the structural substantiation of the seat/restraint system and attachment structure, the ultimate margin of safety must show a positive value. The VAR must document the ultimate margins of safety for those structural elements identified as critical by the ACO and the applicant.

DRAFT

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