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of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: AIRCRAFT ONBOARD WEIGHT AND BALANCE SYSTEMS

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FOREWORD

This advisory circular (AC) gives manufacturers and installers an acceptable means of compliance to meet the installation, operation, and airworthiness requirements for aircraft onboard weight and balance systems (OBWBS).

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CHAPTER 1. INTRODUCTION

1-1. PURPOSE.

a. This advisory circular (AC) will show you how to gain Federal Aviation Administration (FAA) approval of aircraft onboard weight and balance systems (OBWBS). We at the FAA recommend you use additional documents, referenced throughout this AC, to help you show compliance with the regulatory requirements of your type or supplemental type certification program. The documents supplement the engineering and operational judgment used to form the basis of any compliance findings on OBWBS.

b. This AC is not mandatory and does not constitute a regulation. It describes an acceptable means, but is not the only means, to show you how to gain certification for OBWBS. However, if you use the means described in this AC, you must follow it entirely. Because the method of compliance presented is not mandatory, the term "must" applies only to an applicant who chooses to follow this particular method in its entirety.

1-2. WHO DOES THIS AC AFFECT.

a. Chapter **2** provides guidance for type certificate holders who are installing an OBWBS under Title 14 of the Code of Federal Regulations (14 CFR) parts 23, 25, 27, or 29.

b. Chapter **3** provides guidance for operational certificate holders who are required to have an approved weight and balance control program under 14 CFR parts 91 subpart K, 121, 125, or 135.

1-3. WHAT TYPES OF CERTIFICATION GUIDANCE IS COVERED IN THIS AC.

This guidance is for applicants seeking certification through:

- Type certification (TC),
- Supplemental type certification (STC),
- Amended type certificate (ATC),
- Amended supplemental type certificate (ASTC), or
- Parts Manufacturer Approval (PMA).

1-4. WHY USE AN OBWBS VS. STANDARD PRACTICE.

a. For many years, international best practice has allowed the use of standardized passenger weights to calculate the aircraft's take-off weight and center of gravity (CG) as part of an approved weight and balance control program. Using standardized weights assumed that the individual weights of passengers averaged out to a mean weight. When the aircraft's passenger load is calculated this way it would not cause the aircraft weight limitation to be exceeded.

However, differences between the actual passenger load weight and the calculated passenger load weight can occur when using these standard passenger weights due to variation in actual passenger weights. To help eliminate these differences, an aircraft OBWBS can calculate the actual weight and CG of the aircraft (within accuracy tolerances of the OBWBS), and therefore remove the need to use standard passenger weights.

b. Calculating an aircraft's weight and CG accurately before flight is essential to comply with the certification limits established for the aircraft. These limits include various weight and CG limits, such as zero fuel, taxi, takeoff, flight, and landing limits. Aircraft manufacturers specify a maximum certificated take-off weight as well as CG limitations, and provide data on the performance capabilities of the aircraft. The most restrictive condition for a given take-off determines the allowable take-off weight and CG limitations.

c. An OBWBS certified to weigh an aircraft and compute CG from equipment onboard the aircraft can be the primary means of providing weight and balance information if it receives certification and operational approval.

d. The design of the OBWBS, and the OBWBS operating procedures and system limitations must all be consistent with how the OBWBS determines the weight and CG location used to dispatch the aircraft.

CHAPTER 2. CERTIFICATION PROCESS FOR INSTALLING AN OBWBS

2-1. OBWBS ACCEPTABLE MEANS OF COMPLIANCE. To install an OBWBS you must meet the certification guidelines in this AC. Coordinate the certification program with the responsible FAA Aircraft Certification Office as described in FAA Order 8110.4C, *Type Certification*, through the certification program notification (CPN) process, Order 8110.48, *How to Establish the Certification Basis for Changed Aeronautical Products*, or in Order 8110-42, *Parts Manufacturer Approval Procedure*. The OBWBS must also be approved for operation by the FAA's Flight Standards Operations inspectors. See chapter **3** of this AC for guidance on how to obtain approval as a primary dispatch system for operations.

a. Certification Plan. Prepare a certification plan that covers the installation of the OBWBS equipment. We recommend that you submit it early in the certification process. Include the following items:

(1) Project description and schedule,

(2) System description, including the aircraft system interfaces and any aircraft system modifications made to accommodate the OBWBS installation,

(3) Certification basis and means of compliance,

(4) Communication and coordination,

(5) Human factors plan,

(6) Test plan,

(7) Conformity plan,

(8) Continued airworthiness plan, and

(9) Compliance documentation.

b. Means of Compliance. An acceptable means of compliance with the applicable airworthiness regulations must address the following regulations as a minimum:

Instructions for Continued Airworthiness and Maintenance Manuals	14 CFR § 21.50(b)
Equipment Function and Installation	14 CFR §§ 23, 25, 27, 29.1301
Equipment, Systems, and Installations	14 CFR §§ 23, 25, 27, 29.1309
Pilot Compartment	14 CFR §§ 23, 25, 27, 29.771(a)
High-intensity Radiated Fields (HIRF) Protection	14 CFR §§ 23.1308, 25, 27.1317, 29.1317

Cockpit Controls	14 CFR §§ 23, 25, 27, 29.777(a)
Instrument Arrangement and Visibility	14 CFR §§ 23, 25, 27, 29.1321
Warning, Caution, and Advisory Lights	14 CFR §§ 23, 25, 27, 29.1322
Electrical Systems and Equipment – General	14 CFR §§ 23, 25, 27, 29.1351
Circuit Protective Devices	14 CFR §§ 23, 25, 27, 29.1357
Hydraulic Systems	14 CFR §§ 23, 25, 27, 29.1435
Pressurization and Pneumatic Systems	14 CFR §§ 23, 25, 27, 29.1438
Weight & Center of Gravity	14 CFR §§ 23, 25, 27, 29.1519
Instructions for Continued Airworthiness	14 CFR §§ 23, 25, 27, 29.1529
Aircraft Flight Manual – General	14 CFR §§ 23, 25, 27, 29.1581
Operating Limitations	14 CFR §§ 23, 25, 27, 29.1583
Lightning and Static Electricity	14 CFR §§ 23.867 and 25.1316
Fire Protection	14 CFR §§ 23.1359, 25.869, and 29.1359
Loading Information	14 CFR §§ 23.1589, 27.1589, and 29.1589
Electronic Equipment	14 CFR §§ 23.1431 and 25.1431
Electric Cables	14 CFR §§ 23.1365 and 27.1365
Switches	14 CFR §§ 23.1367 and 27.1367
Instrument Systems	14 CFR §§ 25.1333 and 29.1333

(1) Demonstrate the system accuracy, operational accuracy, and repeatability of the installed OBWBS. See paragraphs **2-2** and **2-3** in the AC for guidance.

(2) Demonstrate system accuracy for the maximum time period allowed between OBWBS calibration on the installed OBWBS.

(3) Include limitations and systems operating instructions in the AFM/AFMS and the instructions for continued airworthiness.

(4) If software is used,

(a) You must meet the requirements in:

- Radio Technical Commission for Aeronautics (RTCA), Inc. document RTCA DO 178B, *Software Conditions in Airborne systems and Equipment Certification*, dated December 1, 1992, or the most current revision, and

- Society of Automotive Engineers (SAE) International Aerospace Recommended Practice (ARP) 4754, *Certification Considerations for Highly Integrated or Complex Aircraft Systems*, dated November 1, 1996, or the most current revision.

(b) For additional guidance see FAA advisory circulars:

- AC 23.1309-1, *Equipment Systems and Installations in Part 23 Airplanes*,
- AC 25.1309-1, *System Design and Analysis*,
- AC 27-1, *Certification of Normal Category Rotorcraft*, and
- AC 29-2, *Certification of Transport Category Rotorcraft*.

(6) If the hardware contains complex electrical devices performing functions that cannot be evaluated by tests or analysis, meet the requirements in:

- RTCA DO-254, *Design Assurance Guidance for Airborne Electronic Hardware*, or the most current revision, and
- AC 20-152, *RTCA/DO-254 Design Assurance Guidance for Airborne Electronic Hardware*.

(7) You must also follow the environmental requirements in RTCA/DO-160F, *Environmental Conditions and Test Procedures for Airborne Equipment*, dated December 6, 2007, or the most current revision.

2-2. CERTIFYING THE OBWBS ACCURACY UNDER ENVIRONMENTAL INFLUENCES. As part of compliance with the airworthiness requirements, you must demonstrate the accuracy within the specified tolerances and the reliability of the installed OBWBS. Certification of an OBWBS installation on a 14 CFR part 23, 25, 27, or 29 aircraft should include demonstrations of the OBWBS system accuracy and the OBWBS operational accuracy. Work with your aircraft certification office (ACO) to determine which method to use to demonstrate the OBWBS system and operational accuracy requirements. See paragraph **2-3** of this AC for a description of methods.

a. Weight and Balance Curtailment. If a method in this AC determines that a weight curtailment is required, apply the curtailment to both structural and performance limited weights. Examples of performance-limited weights include weights limited by takeoff distance, accelerate-stop distance, takeoff climb, obstacle clearance, en route climb, approach climb, landing climb, and landing distance. This weight accuracy is used to determine CG accuracy to ensure that the calculated CG remains within the certificated CG limits.

b. Ground Tests. When ground tests are required you can reduce the total number of aircraft ground tests by using a validated simulation of the aircraft and the OBWBS installation. The fidelity and accuracy of the simulation model should be substantiated with actual aircraft ground tests. Simulation validation is necessary in order to establish that the simulation matches the actual aircraft behavior. The results from further simulated ground tests carried out with the validated simulator may then be used in lieu of further physical ground tests.

c. Terms.

(1) OBWBS System Accuracy. An OBWBS achieves its most accurate weight and balance measurements on a motionless aircraft in a controlled (temperature regulated, no winds, fixed aircraft configuration, no payload movement) environment. This accuracy is the OBWBS system accuracy.

(2) OBWBS Operational Accuracy. The accuracy of the OBWBS weight and balance measurements may decrease when the aircraft is disturbed by temperature changes, winds, aircraft configuration changes (flaps, slat motion) or payload shifting (passenger movement). The OBWBS is expected to operate routinely in this disturbed environment. This accuracy is the OBWBS operational accuracy.

d. OBWBS Display of Weight and Balance Measurements. An OBWBS can display weight and balance measurements that take into account the established operational accuracy of the system and any necessary curtailments. If so, the displayed OBWBS output can be compared directly to the applicable operational weight and balance limits. On the other hand, the OBWBS system may display weight and balance measurements that are affected by disturbances, that is, the displayed measurements do not take the operational accuracy into account. For this type of OBWBS, displayed values must be adjusted to account for operational accuracy before being compared to the applicable operational weight and balance limits.

e. Basic Principles of OBWBS Accuracy Demonstration Methods. The following basic principles apply to three gear tricycle configurations. Adapt these principles appropriately for other configurations.

(1) Determining CG.

(a) The CG position (system or operational) accuracy derives from weight accuracy through the geometry of the airplane landing gear and the load measured on each landing gear. The OBWBS separately measures the load on the nose gear and the load on the main gear. The sum of the measured loads on all landing gear, and the weight of the landing gear itself, is the total airplane weight. The CG position calculated using the measured weight on the main landing gear and nose gear is the measured CG position.

(b) The (system or operational) CG position accuracies can be determined from the actual main gear and nose gear load accuracies for the OBWBS installation.

(2) Calculating Under Operational and Environmental Conditions. The cumulative operational accuracy of two or more operational or environmental conditions can be calculated by taking the square root of the sum of the squares of the accuracies (addition in quadrature), or you can demonstrate through analysis or test. You choose which of these methods to employ. Provide charts, graphical look-up tables, numerical tables or step-by-step instructions in the AFM/AFMS to determine the operational accuracy due to two or more operational or environmental conditions for a specific departure. The OBWBS may calculate and display that operational accuracy using operational or environmental condition data provided to the OBWBS, or you can refer to the AFM/AFMS for limitations.

(3) Controlled Environment Measurements. For all the following accuracy determination methods (see paragraph **2-3** of this AC), you must first obtain weight and CG measurements from the OBWBS with the aircraft in a controlled environment. To establish the OBWBS system accuracy in a controlled environment the aircraft should be in a hangar sitting on precision aircraft scales. AC 120-27E, *Aircraft Weight and Balance Control*, provides instructions on how to accomplish precision airplane weight measurements.

(4) Additional Curtailments. Consider airframe manufacturer-provided guidance regarding application of additional curtailments in adverse environmental conditions (such as wind gusts greater than 35 knots) or unique environments (such as airports with elevations above 6,000 feet) that exceed the parameters assumed in the AFM/AFMS specific limitations and conditions (see paragraph **2-9** of this AC). Determine any additional curtailments by analysis and verify by testing that duplicates or simulates the operational conditions. The AFM/AFMS limitations can state that in operational use, such additional curtailments need only be applied when applicable conditions exist.

2-3. OBWBS ACCURACY DETERMINATION METHODS.

a. Takeoff Performance Based Method.

(1) This method examines the influence of OBWBS system and operational weight and balance accuracies on aircraft takeoff performance. OBWBS operational accuracies that result in at most a ± 1.5 knot error change in either V_1 or V_2 speed, or a 100 foot increase in takeoff or accelerate-stop distance, whichever is greater, are accepted without weight curtailments for OBWBS operational accuracy. OBWBS operational accuracies that result in greater errors than these require appropriate curtailment.

(2) From the minimum value of V_1 to the maximum value of V_2 speed, determine the size of the weight error that results in at most a ± 1.5 knot change in V_1 or V_2 speed, or a 100 foot increase in the takeoff or accelerate-stop distances, whichever is greater, for the full range of takeoff weights.

(3) These errors may be used to determine a corresponding operational weight accuracy for a given takeoff weight. This operational weight accuracy is used to determine CG accuracy.

(4) The operational accuracies derived from the impact on takeoff performance help determine the range of the allowable operational and environmental conditions for the OBWBS without curtailment for OBWBS operational accuracies. For example, assume the OBWBS operational accuracy results in at most a ± 1.5 knot change in V_1 or V_2 speed, or a 100 foot increase in the takeoff or accelerate-stop distances, whichever is greater, over a specific range of wind gust or wind velocities for a given temperature day and given takeoff weight. The AFM/AFMS limitations section for a given temperature day may then list this wind gust range as a limitation on the use of the OBWBS results without curtailment for operational accuracy.

(5) The AFM/AFMS calls out operational accuracies as a function of the range of the operational and environmental conditions (see paragraph **2-9** of this AC). The OBWBS weight and balance results may be used for takeoff without curtailment for operational accuracy only when the takeoff speed accuracy constraints specified in paragraph **2-3.a(1)** of this AC are met and the OBWBS measured CG position ± the CG position operational accuracy remains within the takeoff limits of the CG envelope.

- The OBWBS measured weight ± weight operational accuracy results in no more than a ± 1.5 knot change in V_1 or V_2 speed, or a 100 foot increase in the takeoff or accelerate-stop distances, whichever is greater, and

- The OBWBS measured CG position ± CG position operational accuracy remains within the takeoff limits of the CG envelope.

(6) If the cumulative OBWBS operational accuracy does not meet the criteria of paragraph **2-3.a(5)** of this AC, the OBWBS results must be curtailed for operational accuracy before using them for takeoff.

(7) The operator should use an actual takeoff weight corresponding to the measured weight plus weight operational accuracy, and the most adverse CG position corresponding to the measured CG position plus or minus the operational CG accuracy. The operator may need to remove or shift payload to keep these values within the weight and balance envelope. See appendix **4** of this AC for an example of this method applied to a B767-300ER.

b. Specific Operations Method. This method uses OBWBS weight and balance measurements taken while the aircraft is subjected to a pre-defined range of environmental disturbances in order to establish operational accuracy and procedural adjustments (i.e., weight and/or CG envelope curtailments). Operational accuracy levels, expressed as maximum weight, and CG errors experienced are then applied as curtailments to the original manufacturer's envelope, as published in the type certificate data sheet, AFM/AFMS, or weight and balance manual. This method offers the smallest hurdle to determination of an envelope for OBWBS operation, but will typically result in the largest curtailments when compared to the other methods offered.

(1) To demonstrate the OBWBS operational accuracy, you should:

- Establish the proposed range of operational and environmental conditions in which the OBWBS will operate. These conditions determine the content of the limitations and conditions as described in paragraph **2-9** of this AC.

- Ground test the OBWBS under each of the conditions identified in the limitations and conditions as described in paragraph **2-9.a** of this AC. You can use analysis as an alternative to testing if you can substantiate the analysis approach.

- For example, suppose the aircraft manufacturer provides environmental or operational limitations, or procedures, that ensure the airplane always operates within the certified weight and CG envelope. Your OBWBS installation may operate within those same restrictions without demonstration.

(2) Use the OBWBS operational accuracy to identify all operational limitations (such as weight and/or CG envelope curtailments when operating at specific points in the range of limitation values) determined through this process in the AFM/AFMS.

c. Weight and Balance Procedures Method (Load Buildup Method). The OBWBS operational accuracy may be compared to existing OEM and FAA recommended procedures for computing weight and balance values for a given aircraft configuration. These procedures, also known as load buildup methods, have acceptable accuracies as proven in past service experience. The load buildup method weight and CG accuracies as derived from analysis of these procedures help determine the range of the allowable operational and environmental conditions for the OBWBS without curtailment for OBWBS operational accuracies. The curtailed envelope applicable when using the load buildup method also applies to the OBWBS weight and CG measurements as long as OBWBS operational accuracy remains equal to or better than the accuracy determined for the load buildup method. Curtail the limits of the CG envelope for any OBWBS operational accuracy that is worse than the accuracy of the load buildup method.

(1) Assess the load buildup method's operational accuracy by considering a variety of factors recommended by the aircraft manufacturer and AC 120-27E, *Aircraft Weight and Balance Control*, as guidance material. See figure **1** in this AC.

FIGURE 1. FACTORS TO CONSIDER FOR LOAD BUILDUP METHOD.

Factor	**Effect on Weight**	**Effect on CG**
Scale accuracy during reweigh	X	X
Fuel quantity indicating accuracy	X	X
Allowable weight/CG variation prior to "reestablishment" of operational empty weight (or allowance for potential variation due to use of fleet weights)	X	X
Variation in catering/provisioning	X	X
Variation in male/female ratio	X	X

Passenger weight variation	X	X
Crew weight variation	X	X
Baggage weight variation	X	X
Cargo weight variation	X	X

(2) Tolerable errors associated with each factor are as follows:

(a) Scale accuracy for reweigh **–** Typically 0.2% of basic empty weight (BEW), based upon reported scale accuracy for analog scale systems or 0.1% of BEW for digital scale systems. Analog accuracy value may be used for aircraft for which the aircraft OEM guidance does not recommend or require the use of digital scales.

(b) Fuel quantity indicating accuracy – Typically 3% of full capacity. See:

- SAE AS-405C, *Fuel and Oil Quantity Instruments*, dated July 2001, or the most current revision;

- Military document MIL-G-8798, *General Specifications for Fuel-Quantity, Capacitor-Type Gage System*, dated September 30, 1992, or the most current revision, or

- MIL-G-26988C, *General Specification for Liquid Quantity Gage*, dated Sep 28, 1995, or the most current revision.

(c) Operational Empty Weight Variation – ½ of one percent of the mean aerodynamic chord (MAC) and ½ of one percent of maximum landing weight, as outlined in AC 120-27E.

(d) Variation in catering/provisioning – Amount of variation that could be expected to exist, undetected, in galley provisioning. Typically 20% of the standard galley stock or galley cart weights.

(e) Variation in male/female ratio – Amount of variation in ratio of male to female passengers permitted without adjusting passenger weights in use, typically 10% deviation from ratio upon which passenger weights were based, as outlined in AC 120-27E.

(f) Passenger weight variation – Typically a 1% variation in passenger weight plus a 2% variation in carry-on baggage and personal item weights, defined as tolerable error by AC 120-27E.

(g) Crew weight variation – Typically a 25% variation in the standard crewmember weights, or that amount found to be justified based upon sampling or survey of crewmember weights.

(h) Baggage weight variation – Typically a 2% variation in baggage weight (including both checked and designed heavy weight bags), as defined as tolerable error by AC 120-27E.

(i) Cargo weight variation – Typically a 1% variation in actual cargo weight verses reported cargo weight, based upon typical scale accuracy.

(3) The items eligible for consideration do not include those which originate from human error factors, such as baggage miscount, incorrect passenger count, omitted cargo weights or omitted jump seat occupants. The cumulative accuracy of the load buildup method may be calculated by taking the square root of the sum of the squares of the factor accuracies (addition in quadrature), or demonstrate through analysis or test. You choose which of these methods to employ.

(4) In demonstrating the OBWBS operational accuracy, you should:

- Establish the proposed range of operational and environmental conditions in which the OBWBS will operate. These conditions determine the content of the limitations and conditions as described in paragraph **2-9.a** of this AC.

- Ground test the OBWBS under each of the conditions identified in the limitations and conditions as described in paragraph **2-9.a** of this AC.

- Use the OBWBS operational accuracy to identify any operational limitations (such as weight and/or CG envelope curtailments when operating at specific points in the range of limitation values) determined through this process in the AFM or AFMS.

d. OBWBS Operational Demonstration Method. This method may be used to evaluate OBWBS operational accuracy during revenue service for a trial period, or in non-revenue operation as part of a planned ground test program.

(1) Continue to use the original weight and balance program, as applicable, during the demonstrations with the OBWBS installed for evaluation purposes only.

(2) During a trial period in revenue service, the current load buildup system is used as the primary means of performing the weight and balance functions for the airplane, and records all OBWBS measurements.

(3) Ground tests can demonstrate equivalent safety between an OBWBS implementation and the current load buildup system by comparing to precision aircraft scale weighing. Note that differences between the scale and load buildup CG's may exist that would not be considered as part of the load buildup CG error. These differences include load buildup curtailments as described in AC 120-27E, *Aircraft Weight and Balance Control*, as well as differences in the weights being compared (for example, taxi weight vs. takeoff weight).

(4) In determining the OBWBS operational accuracy, use the OBWBS system accuracy that is at least as accurate as, or better than, the current load buildup system.

(5) The limits of the OBWBS weight and CG envelope must be curtailed for any OBWBS operational accuracy that exceeds the accuracy of the load buildup method.

(6) Design the demonstration plan to allow multiple tests at multiple airplane weight and CG configurations. Include sufficient trials in the demonstration plan to show to a confidence interval of at least 95% that the statistics of the OBWBS weight and balance measurements are at least as accurate as the original program being used. Conduct a minimum of twenty five weighing trials.

(7) At least 30% of the tests should be at weights within 10% of maximum airplane takeoff weight; at least 10% of the tests should be at weights within 10% of the minimum airplane takeoff weight; and the tests should cover the aircraft weight and CG envelopes.

(8) Also, test applicable environmental considerations throughout the operating envelope. During a revenue service demonstration, the actual airplane weight can be obtained with a precision scale weighing of the loaded airplane prior to departure.

2-4. SAFETY ASSESSMENT PROCESS GUIDANCE.

a. System Safety Assessments and Analyses. You must identify the levels of hazard associated with installation and use of the system. Determine the maximum acceptable levels of "probability of failure" for the system as installed on the aircraft. Show that the system complies with safety objectives. You can find references for additional guidance on conducting safety assessments and analyses in appendix **1** of this AC.

b. Dispatching an aircraft with calculated aircraft weight or CG within its certificated weight or CG limits when the aircraft is actually outside its weight or CG limits is hazardous/severe-major or catastrophic level of hazard depending on the magnitude of the weight or CG error. Hazard severity can be mitigated by manufacturers' recommended risk reduction strategies to protect against severely overloading the aircraft, or severely loading the aircraft out of balance, such as recommended operating and training procedures for loading the aircraft, or other independent reasonableness checks on the OBWBS measured weight and CG position.

c. Dispatching an aircraft with calculated aircraft weight or CG within its certificated weight or CG limits when the calculated aircraft weight or CG is incorrect, but within the certified limits, is a minor, major, hazardous/severe-major, or catastrophic level of hazard depending on the magnitude of the weight or CG error. This error can have an effect on aircraft configuration or operational performance factors such as trim setting. Hazard severity can be mitigated by manufacturers' recommended risk reduction strategies to protect against severely overloading the aircraft, or severely loading the aircraft out of balance, such as recommended operating and training procedures for loading the aircraft, or other independent reasonableness checks on the OBWBS measured weight and CG position.

d. Failure conditions. Any failure condition of the OBWBS must not affect the functioning of other systems nor reduce the integrity of other systems if the OBWBS interfaces with other aircraft systems.

2-5. SYSTEM DESIGN CONSIDERATIONS. Design the OBWBS on objectives and principles of the fail-safe concept, which considers the effects of failures and combinations of failures in defining a safe design. The fail-safe design concept uses the following design principles in order to ensure a safe design. The use of only one of these principles is seldom adequate. A combination of two or more is usually needed to provide a fail-safe design, that is, to ensure that major failure conditions are remote, hazardous failure conditions are extremely remote, and catastrophic failure conditions are extremely improbable:

a. Designed integrity and quality, including life limits to ensure intended function and prevent failures.

b. Redundancy or backup systems to enable continued function after any single or any number of failures.

c. Isolation of systems, components, and elements so the failure of one does not cause the failure of another.

d. Proven reliability so multiple independent failures are unlikely to occur at one time.

e. Failure warning or indication.

f. Flight crew procedures specifying corrective action for use after failure detection.

g. The capability to check a component's condition.

h. Designed failure effect limits, to sustain damage, to limit the effects of a failure.

i. Designed failure path to control and direct the effects of a failure in a way that limits its safety impact.

j. Margins or Factors of Safety to allow for any undefined or unforeseeable adverse conditions.

k. Error Tolerance that considers adverse effects of foreseeable errors during the aircraft's design, test, manufacture, operation, and maintenance.

l. Other design considerations include:

(1) Use of other aircraft systems (electrical, hydraulic, pneumatic).

(2) Connections to other aircraft systems.

(3) Environmental hazards identification and qualification testing.

2-6. DISPLAY SYSTEM. The OBWBS must display the collected data (weight and CG) in a form easily understood by the flight crew. The display hardware can be stand-alone or interfaced with existing equipment, such as a multi-function display, flight management system, printer, or other compatible display systems. The actual display format used will depend on the onboard display hardware, the options made available by OBWBS, and the features desired by the user. The indicated weight and CG position must as a minimum account for the system accuracy of the OBWBS. Regardless of what format is used, the display presentation must show the crew data that's organized and easily used. Find additional guidance on applicable display systems in:

- Section **2-1.b,** Means of Compliance, in this AC,
- AC 25-11, *Transport Category Airplane Electronic Display Systems*, and
- AC 23.1311-1B, *Installation of Electronic Displays in Part 23 Airplanes.*

2-7. BACKUP SYSTEM. If the OBWBS fails to function properly, use an alternative method of determining aircraft weight and CG location for dispatch. This alternative method must be approved for operations requiring an operating certificate.

2-8. TEST CONSIDERATIONS. Show that the OBWBS meets appropriate industry-adopted environmental qualification standards, including radiated emissions, for equipment operating in an airborne environment. If using an OBWBS in aircraft flight operations show that it has no adverse impact or interferes with other aircraft systems. A manufacturer, installer, or operator can test and validate to ensure proper operation and non-interference with other installed systems. Determine the accuracy of the OBWBS by test or by analyses that are verified by testing.

a. Ground Test. Conduct a certification ground test for each OBWBS installation. The level of testing required will be determined by the scope of the installation. Items to consider for ground test include:

(1) Self test functions (built in test equipment).

(2) Evaluation of all OBWBS aircraft interfaces.

(3) Evaluation of identified failure modes.

(4) Evaluation of location of OBWBS controls, and the presentation of pertinent weight and CG data to the flight crew.

b. Flight Test. Base the level of flight test required to validate a particular OBWBS installation on the type of aircraft, and aircraft system architecture. Conduct a certification flight test for the first OBWBS installation to verify the installation integrity and demonstrate that the installed OBWBS has no adverse impact on other aircraft systems. We give credit for previously certified installations, simulation and ground testing. We will evaluate the actual requirement for a flight test for each installation, and we will include operational and environmental considerations.

2-9. AIRCRAFT FLIGHT MANUAL/AIRCRAFT FLIGHT MANUAL SUPPLEMENT. You, the applicant, must determine if there are any limitations of the system and, if so, how they will affect aircraft operations. Include any limitations affecting operations in the AFM/AFMS. As a minimum, provide instructions in the limitations section of the AFM/AFMS that include the following:

a. Limitations and Conditions. Total system accuracy, system accuracy, and the effects upon accuracy due to environmental and operational limitations, must determine the limitations of the OBWBS and how those limitations are accounted for by the OBWBS and the procedures described within the AFM/AFMS. All limitations and conditions must be identified to ensure the aircraft does not operate outside the certified CG envelope. Include all limitations affecting flight operations in the following items, as applicable:

(1) Environmental:

(a) Wind velocity and direction. Conduct ground tests, or analysis verified by tests, for an aircraft of known weight and CG to determine the effects of winds. You must test the effects of headwinds, tailwinds, and cross winds.

(b) De-icing fluids. De-icing fluids depart the aircraft during roll-out. Conduct ground tests, or analysis verified by tests, to determine a reasonable weight and then subtract from the aircraft weight as displayed on the OBWBS with de-icing fluid. The effect of de-icing fluids on aircraft CG calculations must also be addressed.

(c) Rain, snow, ice, frost, dew. If ground tests or analysis provide data supporting a reduction in aircraft weight with these factors present, as compared to the OBWBS displayed weight, then you can reduce aircraft weight by a standard weight used for the factor. The effect of rain, snow, ice, frost, and dew on aircraft CG calculations must also be addressed.

(d) Ground slope, both lateral and longitudinal. The OBWBS must have a means to account for ground slope, or provide guidance to compensate for the effects of ground slope.

(e) Environmental temperature, barometric pressure. Demonstrate the effects on accuracy through tests or analysis over the temperature and pressure range that will be used.

(2) Configuration of aircraft to conduct a weighing. Establish aircraft weighing configuration during the ground test program. State the established aircraft weighing configuration in the AFM/AFMS. Use this configuration for all operational aircraft weighing:

(a) Wing flap and stabilizer positions.

(b) Oleo strut extension.

(c) Engine and auxiliary power unit thrust.

(d) Fuel load and its location.

(e) Entrance and cargo door position.

(f) Passenger, serving carts, and crew positioning.

(g) Wing flap, stabilizer, entrance door(s), and cargo door(s) positioning.

(h) Stairways, jetway, or ground service connections.

b. Restricted areas of operation. As applicable.

c. Restricted times of operation. As applicable.

d. Operational considerations for normal/abnormal procedures.

e. Recommended method of zero fuel weight and CG computation.

2-10. INSTRUCTIONS FOR CONTINUED AIRWORTHINESS (ICA).

a. During the certification process of the aircraft onboard weight and balance system installation, complete the ICA in accordance with:

- 14 CFR § 21.50(b).
- 14 CFR §§ 23, 25, 27, 29.1529.
- Appendix G of 14 CFR part 23,
- Appendix H of 14 CFR part 25,
- Appendix A of 14 CFR parts 27, 29.
- FAA Order 8110.54, *Instructions for Continued Airworthiness, Responsibilities, Requirements, and Content*.

b. Format the ICA so it is compatible with other maintenance instructions for the aircraft.

c. The ICA is required for the OBWBS, and any required information relating to the interface of the system with the aircraft. Address all applicable OBWBS installed under a particular modification within the ICA. Address the integrity of system, maintenance instructions of the OBWBS and include calibration instructions and intervals. Calibration must consider the effect of unsprung hardware weight, including any changes to that weight. You must specify periodic checks in the ICA to ensure the OBWBS reliability and accuracy remain acceptable.

d. Each ICA must contain an "Airworthiness Limitations" section.

2-11. MASTER MINIMUM EQUIPMENT LIST (MMEL). Develop a proposed MMEL with appropriate justification. Develop procedures for safely dispatching the aircraft using the MMEL. Determine any MMEL allowance considering criticality of the OBWBS functionality. MMEL allowances must be substantiated based on the OBWBS functional hazard assessment. The MMEL must include an alternate method based on an acceptable conventional weight buildup to determine aircraft weight and CG location to be used if the OBWBS fails to function properly. Submit the proposed MMEL, justification, and procedures to the flight operations evaluation board chairman in the aircraft evaluation group for FAA evaluation and approval. If you have modified the OBWBS, revise the MMEL to address the OBWBS hardware or software changes. Submit the MMEL with the OBWBS equipment changes to the FAA for approval. The FAA approving office (for example, flight standards district office) will coordinate with ACO engineering when evaluating the revised MMEL.

CHAPTER 3. OPERATIONAL APPROVAL PROCESS FOR ONBOARD WEIGHT AND BALANCE SYSTEMS

3-1. OPERATIONAL APPROVAL GUIDANCE. This chapter is for certificate holders required to have an approved weight and balance control program under 14 CFR parts 91 Subpart K, and 14 CFR parts 121, 125, or 135. Compliance with these guidelines allows you to use a certified OBWBS for primary dispatch. See AC 120-27E, *Aircraft Weight and Balance Control*, chapter 2, paragraphs 211, 212, 213, and 214.

3-2. BACKUP SYSTEM. If you are an operator, use the guidance in the AC 120-27E to develop a backup system based on a conventional weight buildup. If you develop and receive approval for a backup system, the FAA may grant you relief to include an OBWBS in the operator's minimum equipment list (MEL).

3-3. OPERATIONS SPECIFICATIONS. If you obtain operational approval for use of an OBWBS, operations specifications (OpSpecs) will be issued by the FAA. OpsSpecs paragraphs E096 and A096 will be issued to certificate holders and program managers who are authorized to use only actual weights and an OBWBS. Operators that wish to use average weights, and a conventional load build-up system, as a back-up weight and balance system, will be issued OpSpec paragraphs A097-A099, as applicable, A011, and E096. Operators authorized to use average weights as a back-up system will not be issued A096. For 14 CFR part 91 operators, a letter of authorization (LOA) number A096 or A097-A099 and A011 as applicable, can be issued.

APPENDIX 1. RELATED REGULATIONS AND DOCUMENTS

Regulations	Title
14 CFR Part 21	Certification Procedures for Products and Parts
14 CFR Part 23	Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes
14 CFR Part 25	Airworthiness Standards: Transport Category Airplanes
14 CFR Part 27	Airworthiness Standards: Normal Category Rotorcraft
14 CFR Part 29	Airworthiness Standards: Transport Category Rotorcraft
14 CFR Part 43	Maintenance, Preventive Maintenance, Rebuilding, and Alteration
14 CFR Part 119.49	Contents of Operations Specifications
14 CFR Part 121.153	Aircraft Requirements: General
14 CFR Part 121.373	Continuing Analysis and Surveillance
14 CFR Part 121.419	Pilots and Flight Engineers: Initial, Transition, and Upgrade Ground Training
14 CFR Part 121.422	Aircraft Dispatchers: Initial and Transition Ground Training
14 CFR Part 121.693	Load Manifest: All Certificate Holders
14 CFR Part 91	General Operating and Flight Rules
14 CFR Part 135	Operating Requirements: Commuter and On-Demand Operations
14 CFR Part 125	Certification and Operations: Airplanes Having a Seating Capacity of 20 or More Passengers or a Maximum Payload Capacity of 6000 Pounds or More

Advisory Circulars	Title
AC 23.1309-1C	Equipment, Systems, and Installations in Part 23 Airplanes

AC 23.1311-1B	Installation of Electronic Displays in Part 23 Airplanes
AC 25.1309-1A	System Design and Analysis
AC 25-11	Transport Category Airplane Electronic Display Systems
AC 25.19	Certification Maintenance Requirements
AC 27-1B, Change 1	Certification of Normal Category Rotorcraft
AC 29-2C, Change 1	Certification of Transport Category Rotorcraft
AC 120-16	Air Carrier Maintenance Programs
AC 120-27E	Aircraft Weight and Balance Control

FAA Orders	Title
Order 8110.4C	Type Certification
Order 8110.48	How to Establish the Certification Basis for Changed Aeronautical Products
Order 8110-42	Parts Manufacturer Approval Procedure
Order 8110.54	Instructions for Continued Airworthiness, Responsibilities, Requirements, and Content

Industry Documents	Title
SAE ARP 4754	Certification Considerations for Highly-Integrated or Complex Aircraft Systems
SAE ARP 4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
RTCA DO-178B	Software Considerations in Airborne Systems and Equipment Certification
RTCA DO-160F	Environmental Conditions and Test Procedures for Airborne Equipment
RTCA DO-254	Design Assurance Guidance for Airborne Electronic Hardware

APPENDIX 2. TERMS AND DEFINITIONS

Backup System	Backup means of computing aircraft weight and balance for dispatching the aircraft instead of the primary one.
Failure	An occurrence that affects the operation of a component, part, or element so it can no longer function as intended (Includes both loss of function and malfunction). Note: Errors may cause failures, but are not considered to be failures.
Load Buildup System	Method of establishing an aircraft's weight and center of gravity with the assumptions established in AC 120-27E, *Aircraft Weight and Balance Control*, includes, average passenger weight, average bag weight, male to female passenger ratio, fuel weight.
Maximum Zero Fuel Weight	The maximum permissible weight of an aircraft with no disposable fuel and oil.
Onboard Weight and Balance System	Weighs the aircraft and payload, and computes the aircraft center of gravity from equipment onboard the aircraft. The system displays the actual weight, and balance information for use in primary dispatch of the aircraft.
Primary Dispatch System	A system that generates aircraft weight and balance data used to dispatch an aircraft for flight.
Redundancy	The presence of more than one independent means for accomplishing a given function or flight operation.
System	A combination of components, parts, and elements, which are interconnected to perform one or more functions.

APPENDIX 3. EFFECTS OF WEIGHT AND CG ON AIRCRAFT PERFORMANCE

As referenced in section **2-3.b(5)** of this AC, use the following formulas to determine how aircraft performance is affected by different weights and CG.

Let the measured weight $W_{\mathbf{m}}$, the sum of the actual weight $W_{\mathbf{a}}$, and the weight error $W_{\mathbf{e}}$, where the weight error is due to inaccuracy inherent in the system and to operational disturbances, be expressed as a percentage of $W_{\mathbf{a}}$ as:

$$W_{\mathbf{m}} = W_{\mathbf{a}} + W_{\mathbf{e}} = (1 + \alpha) \times W_{\mathbf{a}}$$

and let $0 \leq \alpha < 1$.

Let the measured CG location be $CG_{\mathbf{m}}$ be defined as the sum of the actual CG location $CG_{\mathbf{a}}$ and the CG location error $CG_{\mathbf{e}}$, where the CG location error is due to inaccuracy inherent in the system and to operational disturbances:

$$CG_{\mathbf{m}} = CG_{\mathbf{a}} + CG_{\mathbf{e}} = (1 + \alpha) \times CG_{\mathbf{a}}$$

and let $0 \leq \alpha < 1$.

The ratio of the actual weight/erroneous weight and the actual CG position/erroneous CG position will establish a non-dimensional percentage accuracy bound on the acceptable, allowable inaccuracies in the OBWBS measurements as a function of flight phase and functional hazard severity.

For example, in takeoff, with all other factors held constant (i.e. airplane configuration and runway conditions,) the airplane takeoff velocity is proportional to the square root of the airplane weight. The ratio of the takeoff velocity V_1 at weight W_1 to takeoff velocity V_2 at weight W_2 is given by:

$$(V_2 / V_1) = (W_2 / W_1)^{½}$$

So, the ratio of the actual weight/measured weight verses the actual takeoff velocity to assumed takeoff velocity is given by:

$$(V_{actual} / V_{assumed}) = (W_{\mathbf{a}} / (1 + \alpha) \times W_{\mathbf{a}})^{½} = (1 / (1 + \alpha))^{½}$$

or rearranging the equation, the actual velocity needed for takeoff in terms of the velocity assumed to be needed for takeoff will be:

$$V_{actual} = V_{assumed} / (1 + \alpha)^{½}$$

If the measured airplane weight is 10% higher than the actual weight, for example, then:

$$V_{actual} = V_{assumed} / (1 + 0.1)^{½} = 0.95 \times V_{assumed}$$

APPENDIX 3. EFFECTS OF WEIGHT AND CG ON AIRCRAFT PERFORMANCE, continued

the crew might find the airplane can takeoff at a shorter distance down the runway than expected, and at a slower velocity than expected based on what the OBWBS measured weight indicated.

If the measured airplane weight is 10% lower than the actual weight, for example then:

$$V_{actual} = V_{assumed} / (1 - 0.1)^{½} = 1.05 \times V_{assumed}$$

and the crew might find the airplane takes off longer distance down the runway than expected, and at a higher velocity than expected based on what the OBWBS measured weight indicated. The percentage error in weight measurement (and thus accuracy) can be related to a takeoff performance impact and its hazards.

In the same manner the effect of weight errors (and thus accuracies) on takeoff distance can be assessed. With all other factors held constant (i.e. airplane configuration and runway conditions) the airplane takeoff distance is proportional to the square of the airplane weight. The ratio of the takeoff distance S_1 at weight W_1 to takeoff distance S_2 at weight W_2 is given by:

$$(S_2 / S_1) = (W_2 / W_1)^2$$

So, the ratio of the actual weight/measured weight verses the actual takeoff distance to assumed takeoff distance is given by:

$$(S_{actual} / S_{assumed}) = (W_{\mathbf{a}} / (1 + \alpha) \times W_{\mathbf{a}})^2 = (1 / (1 + \alpha))^2$$

or rearranging the equation, the actual distance needed for takeoff in terms of the assumed distance needed for takeoff will be:

$$S_{actual} = S_{assumed} / (1 + \alpha)^2$$

If the measured airplane weight is 10% higher than the actual weight, for example, then:

$$S_{actual} = S_{assumed} / (1 + 0.1)^2 = 0.83 \times S_{assumed}$$

and the crew finds the airplane can takeoff a shorter distance down the runway than expected based on what the OBWBS measured weight indicated.

If the measured airplane weight is 10% lower than the actual weight, for example, then:

$$S_{actual} = S_{assumed} / (1 - 0.1)^2 = 1.23 \times S_{assumed}$$

And the crew find the airplane takes off at a longer distance down the runway than expected as based on what the OBWBS measured weight indicated. A large enough error or inaccuracy, in percent of actual airplane weight, can result in a takeoff distance that exceeds available runway

APPENDIX 3. EFFECTS OF WEIGHT AND CG ON AIRCRAFT PERFORMANCE, continued

length or doesn't allow for enough stopping distance if the crew elects to abort the takeoff. The percentage error in weight measurement (and thus accuracy) can be related to a takeoff performance impact and its hazards.

APPENDIX 4. TAKEOFF PERFORMANCE BASED METHOD EXAMPLE

4-1. TAKEOFF PERFORMANCE BASED METHOD GUIDANCE. As referenced in section **2-3.c.(7)** of this AC, this guidance will help an OBWBS applicant determine the operational accuracy for an OBWBS installed on a B767-300ER fleet using the takeoff performance based method.

a. OBWBS operational accuracies that result in at most a ± 1.5-knot error or change in V_1 or V_2, or a 100 foot increase in takeoff or accelerate-stop distance, whichever is greater, are accepted without curtailments or procedural adjustments for OBWBS operational accuracy.

b. OBWBS operational accuracies that result in greater than a ± 1.5 knot error or change in V_1 or V_2, or more than a 100 foot increase in takeoff or accelerate-stop distance, whichever is greater, require appropriate curtailment for operational accuracy.

c. The applicant uses this guidance to map out an analysis approach that determines the need to curtail for the accuracy of the OBWBS-reported weight and CG position when using the OBWBS in operational conditions.

d. Review information published in the B767-300ER Airplane Flight Manual (AFM). The AFM may present the information used to determine airplane takeoff performance speeds and required takeoff runway length as graphs. Interpolation may be required for weights not exactly shown on these charts. An applicant may use a computer program or parametric equations that can be shown to accurately represent the approved AFM data set.

4-2. THE EFFECT OF WEIGHT CHANGE ON V_1 SPEED.

a. The applicant uses the AFM data to first determine the effect of airplane weight variation on V_1 to establish the relationship between incremental weight change and resulting incremental V_1 speed change. Use this relationship to determine the magnitude of weight error that results in a ± 1.5- knot change in V_1.

b. By definition the V_1 speed is at or below V_R. For many airplanes the ratio of V_1 to V_R varies from 1.0 (per regulation) to some lower limit (e.g., 0.7 for the B767-300ER per AFM operationally defined limits). In general, a change in V_R will not result in a change in V_1 of greater magnitude than the change in V_R . Therefore, the applicant may evaluate the effect of weight changes on V_R and then relate this change to V_1 using the appropriate ratio for the AFM operationally defined limits for the airplane type.

c. In this example, the applicant determines that across takeoff flap settings of 5, 15 and 20 degrees, the effect of airplane weight on V_R as a function of the airplane's weight can be represented as follows:

(1) In the weight range of 200,000 pounds to 250,000 pounds, the applicant sees that a change in weight of 10,000 pounds results in a 3.5 knot change in V_R, and that this relationship holds across the airplane weight range. This range is dubbed the low-weight "band."

APPENDIX 4. TAKEOFF PERFORMANCE BASED METHOD EXAMPLE, continued

(2) In the weight range of 250,000 pounds to 350,000 pounds, the applicant sees that a change in weight of 10,000 pounds results in a 3 knot change in V_R, and that this relationship holds across the airplane weight range. This range is dubbed the mid-weight "band."

(3) In the weight range of 350,000 to 430,000 pounds, the applicant sees that a change in weight of 10,000 pounds results in a 2.5 knot change in V_R, and that this relationship holds across the airplane weight range. This range is dubbed the high-weight "band."

d. The relationships in these bands can scale by the ratio of V_1/V_R for those performance scenarios using a V_1/V_R ratio less than 1.0.

e. The OBWBS accuracies resulting in at most a ± 1.5-knot change in V_1 in each band when using a V_1/V_R ratio of 1.0 are therefore:

- ± 1.5 knot change × (10,000 pounds/ 3.5 knot change) = ± 4,286 pounds in the low-weight band, or ± 4300 pounds with rounding. This weight offset corresponds to an OBWBS weight accuracy of 2.15% at 200,000 pounds to 1.72% accuracy at 250,000 pounds over the low-weight band.

- ± 1.5 knot change × (10,000 pounds/ 3 knot change) = ± 5,000 pounds in the mid-weight band. This weight offset corresponds to an OBWBS weight accuracy of 2% above 250,000 pounds to 1.43 % accuracy at 350,000 pounds over the mid-weight band.

- ± 1.5 knot change × (10,000 pounds/ 2.5 knot change) = ± 6,000 pounds in the high- weight band. This weight offset corresponds to an OBWBS weight accuracy of 1.71% above 350,000 pounds to 1.4 % accuracy at 430,000 pounds over the high-weight band.

f. Alternatively, the applicant can fit a curve across these bands in order to smooth out the discontinuities or jumps in weights at the band edges.

4-3. THE EFFECT OF WEIGHT CHANGE ON V_2 SPEED.

a. The analysis of the effect of airplane weight change on V_2 is similar to the analysis of the effect of airplane weight change on V_1, except that V_2 AFM data are readily available. There is no need to relate the analysis to V_R data.

b. With respect to V_2, the applicant determines from the AFM data that across takeoff flap settings of 5, 15 and 20 degrees of flap.

(1) In the weight range of 200,000 pounds to 250,000 pounds, the applicant sees that a change in weight of 10,000 pounds results in a 2.75 knot change in V_2, and that this relationship holds across the low-weight band.

APPENDIX 4. TAKEOFF PERFORMANCE BASED METHOD EXAMPLE, continued

(2) In the weight range of 250,000 pounds to 350,000 pounds, the applicant sees that a change in weight of 10,000 pounds results in a 2.5 knot change in V_2 and that this relationship holds across the mid-weight band.

(3) In the weight range of 350,000 to 430,000 pounds, the applicant sees that a change in weight of 10,000 pounds results in a 2 knot change in V_2 and that this relationship holds across the high-weight band.

c. The OBWBS accuracies that result in at most a ± 1.5 -knot change in V_2 in each band are therefore:

- ± 1.5 knot change × (10,000 pounds/ 2.75 knot change) = ± 5,454 pounds in the low- weight band, or ± 5400 pounds with rounding. This weight offset corresponds to an OBWBS weight accuracy of 2.7% at 200,000 pounds to 2.16% accuracy at 250,000 pounds over the low-weight band.

- ± 1.5 knot change × (10,000 pounds/ 2.5 knot change) = ± 6,000 pounds in the mid-weight band. This weight offset corresponds to an OBWBS weight accuracy of 2.4% above 250,000 pounds to 1.71% accuracy at 350,000 pounds over the mid-weight band.

- ± 1.5 knot change × (10,000 pounds/ 2 knot change) = ± 7,500 pounds in the high- weight band. This weight offset corresponds to an OBWBS weight accuracy of 2.14% above 350,000 pounds to 1.74 % accuracy at 430,000 pounds over the high-weight band.

d. Once again, the applicant can fit a curve across these bands in order to smooth out the discontinuities or jumps in weights at the band edges.

4-4. THE EFFECT OF WEIGHT CHANGE ON TAKEOFF/ACCELERATE-STOP DISTANCE.

a. For an uncorrected (i.e., no runway slope, no wind) takeoff at flaps 5, the applicant determines from AFM data that at the most extreme all-engines-operating takeoff distance situation, a change in 5000 pounds of weight in the high-weight band means a 500 foot difference in takeoff distance, and for less extreme conditions, a change of 5,000 pounds in weight means a change of up to 400 feet in the all-engines-operating takeoff distance across the low-weight to mid-weight bands.

b. The OBWBS accuracies that result in at most a 100-foot increase in the all-engine takeoff distance are therefore on the order of:

- ± 100 foot change × (5,000 pounds / 400 foot change) = ± 1,250 pounds or ± 1,300 pounds after rounding. This weight offset corresponds to an OBWBS weight accuracy of 0.52 % above 250,000 pounds to 0.37% accuracy at 350,000 pounds over the low to mid-weight band.

APPENDIX 4. TAKEOFF PERFORMANCE BASED METHOD EXAMPLE, continued

- ± 100 foot change × (5,000 pounds / 500 foot change) = ± 1,000 pounds in the most extreme takeoff distance situation. This weight offset corresponds to an OBWBS weight accuracy of 0.29% above 350,000 pounds to 0.23% accuracy at 430,000 pounds over the high-weight band.

4-5. OBWBS OPERATIONAL ACCURACY AND OBWBS-MEASURED WEIGHT CURTAILMENT.

a. OBWBS operational accuracies that result in at most a ± 1.5-knot error or change in V_1 or V_2, or a 100 foot increase in takeoff or accelerate-stop distance, whichever is greater, are accepted without curtailments or procedural adjustments for OBWBS accuracy.

b. The applicant notes that the weight changes in paragraph **4-4** of this appendix that result in more than a 100 foot change in takeoff/accelerate-stop distance all result in less than a ± 1.5-knot change in V_1 or V_2 (see paragraphs **4-2** and **4-3** of this appendix, respectively). Therefore the weight change that results in a 100 foot change to the takeoff/accelerate-stop distances does not set the maximum operational accuracy for OBWBS use without curtailment.

c. The applicant notes that the weight changes in paragraph **4-3** of this appendix that result in a 1.5-knot change in V_2 will change V_1 by more than 1.5 knots (see paragraph **4-2** of this appendix). Therefore, the weight change that results in a 1.5-knot change in V_2 does not set the maximum operational accuracy for OBWBS use without curtailment.

d. The applicant notes that the weight changes in paragraph **4-2** of this appendix that result in a 1.5-knot change in V_1 will not change V_2 by more than 1.5 knots (see paragraph **4-3** of this appendix). Therefore, the weight change that results in a 1.5-knot change in V_1 *does* set the maximum operational accuracy for OBWBS use without curtailment.

e. Therefore, the applicant concludes that the reported weights from the OBWBS can be used without curtailment for OBWBS operational accuracy as long as the OBWBS-reported weight is within:

- ± 4,300 pounds of the actual airplane weight in the low-weight band.
- ± 5,000 pounds of the actual airplane weight in the mid-weight band.
- ± 6,000 pounds of the actual airplane weight in the high-weight band.

f. In general, the required OBWBS weight accuracy can be expressed in terms of the ratio of these weight uncertainties per band to the actual airplane weight in that band.

g. For example, at an actual weight of 200,000 pounds the OBWBS operational accuracy needs to be ± 2.15 % to use the reported weight without operational curtailment, and for an actual weight of 430,000 pounds the OBWBS operational accuracy needs to be ± 1.4 % to use the reported weight without operational curtailment for OBWBS accuracy.

APPENDIX 4. TAKEOFF PERFORMANCE BASED METHOD EXAMPLE, continued

h. Now, per the guidance in paragraph **2-2.d(3)** of this AC, the applicant determines the OBWBS system accuracy by obtaining weight and CG measurements from the aircraft while it sits on precision aircraft scales within a controlled environment such as hanger.

i. Suppose for example the OBWBS-reported weight during the system accuracy testing is within:

- ± 1,000 pounds of the actual airplane weight in the low-weight band.
- ± 2,000 pounds of the actual airplane weight in the mid-weight band.
- ± 2,500 pounds of the actual airplane weight in the high-weight band.

j. Then the applicant knows that operational conditions such as configuration changes, wind gusts and winds, temperature changes, passenger movement, etc., can result in up to the following weight errors before the need to curtail the weight and CG envelope for the operational accuracy of the OBWBS:

- ± 3,300 pounds of additional uncertainty about the actual airplane weight in the low-weight band,
- ± 3,000 pounds of additional uncertainty about the actual airplane weight in the mid-weight band, and
- ± 3,500 pounds of additional uncertainty about the actual airplane weight in the high-weight band.

k. Alternatively, if the measured OBWBS system accuracies in these weight bands exceed the weight accuracies resulting in no more than 1.5-knot change in V_1, the OBWBS cannot be used without curtailment for OBWBS accuracy at any time.

l. This example illustrates the importance of the OBWBS system accuracy. The better the system accuracy, in general, the larger the operational environment within which the applicant may use the OBWBS system weight measurements without curtailment for OBWBS accuracy.

4-6. CONCLUSIONS.

a. This example shows how an applicant can map out an analysis approach to systematically consider the effect of weight changes on V_1, V_2 and takeoff/accelerate-stop distances. This analysis determines the operational accuracies that result in at most a ± 1.5 -knot error or change in V_1 or V_2, or a 100 foot increase in takeoff or accelerate-stop distance,

APPENDIX 4. TAKEOFF PERFORMANCE BASED METHOD EXAMPLE, continued

whichever is greater, which can be accepted without curtailments or procedural adjustments for OBWBS accuracy. OBWBS operational accuracies that result in greater than ± 1.5 knot error or change in V_1 or V_2, or more than a 100 feet increase in takeoff or accelerate-stop distance, whichever is greater, require appropriate curtailment for OBWBS accuracy.

b. The analysis method shown in this example can be readily modified to consider the effects of pressure altitude, outside air temperature, winds, and runway slope, as appropriate, when determining the relationship of change in weight to change in takeoff/accelerate-stop distance.