U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: AIRPLANE SIMULATOR AND VISUAL SYSTEM EVALUATION

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Change:

1. PURPOSE. This advisory circular sets forth one means that would be acceptable to the Administrator for the evaluation of airplane simulators to be used in training programs or for airmen checking under Title 14 Code of Federal Regulations (CFR). The reader is cautioned that this is not an all encompassing document and that applicable regulations should be referenced to assure compliance with the provisions therein. It should also be noted that this Advisory Circular applies to the evaluation of airplane simulators only. Criteria for the evaluation of helicopter simulators are currently being developed and will be set forth in a similar document.

2. CANCELLATION. Advisory Circular 121-14C, Aircraft Simulator And Visual System Evaluation and Approval, dated August 29, 1980, is canceled. Operators having simulator improvement or acquisition projects in process, under contract or started under an interim simulator upgrade plan which was approved in accordance with FAR Part 121, Appendix H, have 90 days from the effective date of this advisory circular to notify the National Simulation Program Manager (NSPM) of those projects which the operator desires to complete under the provisions of AC 121-14C.

3. BACKGROUND. As the state-of-the-art in simulator technology advances, more effective use has been made of the aircraft simulator in both training and checking of flight crewmembers. The increasing complexity and operating costs of the modern turbojet and its operating environment point to greater use of the advanced technology now available in airplane simulators. Simulators can provide more in-depth training than can be accomplished in the airplane. There is also a very high percentage of transfer of learning from the simulator to the airplane. The additional use of simulators, in lieu of the airplane, results in safer flight training, cost reductions for the operators, and achieves the benefit of fuel conservation and a decrease in noise pollution. During the last 10 years, as simulator technology has improved, changes to the FAR were made to permit the increased use of simulators in air carrier training programs. In the late 1960's, visual attachments appeared on the market. Since that time, a breakthrough in computerization has permitted the development of computer-generated image visual systems. In December 1973, FAR Amendments 61-62 and 121-108 permitted additional use of visual simulators. Amendments to Section 121.439 of the FAR permitted a simulator approved for the landing

maneuver to be substituted for the airplane in a pilot recency of experience qualification. These changes to the FAR constituted a significant step toward the development of Amendments 61-69 and 121-161 issued June 24, 1980, which contain the Federal Aviation Administration (FAA) Advanced Simulation Plan. To support this plan, the National Simulator Evaluation Program was established by the FAA in October 1980. FAA Southern Region Headquarters is responsible for oversight of this program. This program is administered and directed by the National Simulator Program Manager.

4. DISCUSSION.

a. The procedures and criteria for simulator evaluations under the National Simulator Evaluation Program are contained in this advisory circular. A simulator is certified to the standards herein by the NSPM and recommended for approval, for use within an operator's training program, to the operator's principal operations inspector (POI) or certificate holding district office, as appropriate.

b. Under the current regulatory structure, only Section 121.407 addresses simulator approval criteria. While it is clear that simulators operated by an air carrier certificated under Part 121 require evaluation under Section 121.407, clarification is needed as to what is required for simulators to be certified for use in programs other than for an operator certificated under Part 121. All simulators used for training or certification of airmen under Title 14 CFR fall under the direction of the National Simulator Evaluation Program. A simulator will be evaluated under the procedures of this advisory circular if it is used in a training program approved under Parts 121, 125 or 135 or if it is used by an operator in the course of conducting the Pilot-in-Command Proficiency Check required by FAR 61.58 or the issuance of an airline transport pilot certificate or type rating in accordance with the provisions of FAR 61.157. FAA evaluations of simulators owned and operated by foreign operators may be performed if such simulators are being used by a U.S. operator to train or certificate U.S. airmen, in accordance with bilateral agreements between countries or as deemed appropriate by the Administrator on a case-by-case basis.

c. Under the National Simulator Evaluation Program concept, a simulator is evaluated for a specific operator by an FAA Simulator Evaluation Specialist. Based on a successful evaluation, the NSPM will then certify that the simulator meets the criteria of a specific level. Based on the certification by the NSPM that the simulator meets the standards specified in this advisory circular, simulator approval for a particular training program will then be determined by the POI in the case of Parts 121, 125 or 135 certificate holders or by the district office responsible for oversight of a training center when the training center is using the simulator to conduct portions of the checks required by FAR Sections 61.58 or 61.157. Simulators used for purposes other than those stated in paragraph 4b, above, should also meet the standards of this Advisory Circular, but may be evaluated by the local FAA Flight Standards District Office (FSDO) as deemed appropriate by the NSPM.

d. Operators contracting to lease simulators already evaluated and approved at a particular level for an aircraft type are not subject to the simulator evaluation process. However, they are required to obtain FAA approval to use the simulator in their approved training programs.

5. DEFINITIONS.

a. An Airplane Simulator is a device which duplicates a specific airplane's cockpit and is capable of closely representing the actual aircraft through various ground and flight regimes. The evaluation of simulators should be conducted in accordance with this advisory circular. Any device which does not meet the simulator provisions set forth herein should be considered a training device.

b. Simulator Data includes the various types of data used by the simulator manufacturer and the applicant to design, manufacture, and test the flight simulator. Normally, the airplane manufacturer will provide airplane data to the simulator manufacturer, which in the case of airplane not yet certificated will be predicted data.

c. Flight Test Data for the purpose of this advisory circular are performance tests electronically recorded in the aircraft and verified as accurate by the company performing the test. Other data, such as photographic data, may be considered flight test data after evaluation by the NSPM. For new generation airplane issued an original type certificate after June 1980 or significant amendments to an original type certificate, or in a supplemental type certificate which would result in handling quality changes in the airplane's performance, only manufacturer's flight test data will be accepted for initial approval. Exceptions to this policy must be submitted to the NSPM for review and consideration. For a new type of airplane, predicted data validated by actual airplane flight test data, which has not received final approval by the manufacturer, can be used for an interim period as determined by the FAA. In the event predicted data are used in programming the simulator, it should be updated as soon as practicable when actual airplane flight test data becomes available. Unless specific conditions warrant otherwise, simulator programming should be updated within six months after release of the final flight test data package by the aircraft manufacturer.

d. Approval Test Guide (ATG) is a document containing a group of tests required for FAA evaluation of the simulator. ATG's are designed to verify that the performance characteristics of the simulator agree with those of the airplane and that all applicable regulatory requirements have been met. This test guide is presented to the FAA, along with the evaluation application.

e. National Simulator Program Manager (NSPM) is responsible for the overall administration and direction of the National Simulator Evaluation Program.

f. Simulator Evaluation Specialist is an FAA technical specialist especially trained to evaluate simulators and to provide expertise on matters concerning aircraft simulation within that person's assigned region.

g. Visual System Response Time is the completion of the visual display scan of the first video field containing different information resulting from an abrupt control input.

h. Upgrading for the purpose of this advisory circular means the improvement or enhancement of a simulator or a simulator's motion or visual system for the purpose of achieving more training or certification credit for that simulator.

6. SIMULATOR EVALUATION POLICY.

a. Initial Evaluations.

(1) In order to ensure an adequate transfer of learning from the simulator to the airplane, the simulator must be evaluated in each of the areas critical to the accomplishment of the airman training and airman evaluation process. This includes evaluating the simulator's fidelity in directional, longitudinal, and lateral control and capabilities in the areas of preflight, control checks, taxi, takeoff, climb, cruise, descent, approach, landing, and certain additional requirements depending on the sophistication of the simulator. The simulator's motion system, visual system, and if applicable, flight engineer's station will also need to be evaluated to ensure their proper operation. Instructor controls must be operational to the extent necessary to assure completion of the tests required for initial approval.

(2) It is desirable to evaluate the simulator as objectively as possible. However, pilot acceptance is also an important consideration in the evaluation process. Therefore, evaluation of a simulator involves two types of tests designed to show that the simulator can simulate the airplane with sufficient fidelity to conduct the amount of training or checking requested. These tests include functional tests from Appendix 2 of this advisory circular which allow a qualitative assessment of the simulator by an FAA pilot type rated in the aircraft, and performance tests from Appendix 3 of this advisory circular. Functional tests are designed to provide a basis for evaluating a simulator's capability to perform over a typical training period and to verify the operational fidelity of the simulator's controls, instruments and systems. Performance tests are designed to provide a quantitative validation of the simulator's fidelity. They objectively compare simulator and airplane performance within a specified performance tolerance. Each of the two types of tests is designed to complement the other and be supportive of required training objectives.

(3) If a problem with the simulator is detected by the FAA Simulator Evaluation Specialist in a performance test, the test may be repeated. If the simulator still does not meet the tolerance of Appendix 3, the operator may verify simulator fidelity by showing that the simulator test results match other airplane data which relates to the performance test in question. In the event a performance test(s) does not meet specified criteria but is not considered critical to the level of evaluation being conducted, the NSPM may conditionally certify the simulator at that level and the operator will be given a specified

period of time to correct the problem and submit the ATG changes to the NSPM for evaluation. Alternatively, if it is determined that the results of a performance test would have a detrimental effect on the level of evaluation being conducted, the NSPM may certify the simulator to a lesser level based upon the evaluation completed. For example, if a Phase I evaluation is requested and the simulator fails to meet the spiral stability test tolerances throughout a time history, the evaluation could continue at the visual simulator level because a dynamic check in this area is not required for visual simulator evaluation.

(4) If a problem is suspected in the handling qualities of a simulator during a functional test and performance testing does not support that finding, the NSPM may conditionally certify the simulator. In this case, the questionable area will be observed by the FAA in training/checking operations to determine if correction is necessary. If it is determined that a problem in handling qualities exists, resulting in a need for a hardware or software change, a special evaluation may be scheduled in accordance with the provisions of paragraph 6c. The affected area will receive the primary emphasis and related areas will be reviewed to ensure that they have not been affected.

(5) Performance tolerances listed in Appendix 3 should not be confused with design tolerances specified for simulator manufacture. Performance tolerances are maximum tolerances to ensure satisfactory transfer of learning.

b. Recurrent Evaluations.

(1) For a simulator to retain its current status, it will be evaluated on a recurring basis using the currently approved ATG. Unless otherwise determined by the NSPM, recurring evaluations will be accomplished every four months by a Simulator Evaluation Specialist. Each recurrent evaluation will consist of functional tests and approximately 1/3 of the performance tests in the ATG. The goal is to complete each ATG annually.

(2) In the interest of conserving simulator time, the following program alternative to the normal 8-hour recurrent evaluation procedures for advanced simulators is available to all operators:

(a) At least 1/3 of all the performance tests will be performed and certified by operator personnel between FAA recurrent evaluations. Complete coverage will be required through any three consecutive recurrent evaluations. These tests and results will be reviewed by the FAA Simulator Evaluation Specialist at the outset of each evaluation.

(b) Twenty percent of those tests conducted by the operator for each recurrent evaluation will then be selected and repeated by the Simulator Evaluation Specialist.

(c) Ten percent of those tests not performed by the operator will also be selected by the FAA for execution during each recurrent evaluation.

(d) Operators must notify the NSPM in writing of their intent to enter the optional program. The test procedures above will then be exercised at the next recurrent evaluation. If the above procedures can be accommodated with less than eight hours of simulator time, subsequent recurrent evaluations for that simulator will be planned for four hours, a reduction of 50% from the current eight normally required.

c. Special Evaluations.

(1) Between recurring evaluations, if deficiencies are discovered or it becomes apparent that the simulator is not being maintained to initial evaluation tolerances, a special evaluation of the simulator may be scheduled by the NSPM to confirm its performance.

(2) The simulator will retain its status unless the NSPM can no longer certify original simulator performance criteria to the POI based on the special evaluation. However, the POI shall advise operators if a deficiency is jeopardizing training requirements wherein arrangements shall be made to resolve the deficiency in the most effective manner.

d. Operator Participation.

(1) During initial and recurrent evaluations, the operator's pilots may assist in the accomplishment of the functional and performance tests at the discretion of the FAA Simulator Evaluation Specialist.

(2) Only FAA personnel should manipulate the pilot controls during the functional check portion of an FAA evaluation.

7. PROCEDURES FOR SIMULATOR INITIAL OR UPGRADE EVALUATIONS.

a. The correct sequence of events for an initial or upgrade evaluation is diagramed in Appendix 4 of this advisory circular. An operator desiring initial or upgrade evaluation for a simulator must submit its request in writing to the NSPM through the POI or responsible FAA FSDO. This request should contain a statement certifying that the operator has successfully completed each test in the operator's ATG, that the simulator meets all of the specifications of this advisory circular, that specific hardware and software configuration control procedures have been established, and that the pilot(s) designated by the operator confirm that it is representative of the airplane in all functional test areas. The request should also show the current modification level of the operator's airplane fleet and of the simulator to be evaluated.

b. The operator should also submit an ATG which includes the following:

(1) The performance tests and procedures for conducting the tests described in Appendix 3 of this advisory circular. For Phase II and III evaluation, the ATG should also address each requirement from Appendix 3 which specifically relates to Phase II or III. The ATG should include a statement of compliance for each Phase II or III requirement and, in some cases designated in Appendix 3, a performance test which will serve to validate simulator performance.

(2) Airplane data specified in Appendix 3 to support each test. Airplane data documents included in an ATG may be photographically reduced only if such reduction will not alter the graphic scaling or cause difficulties in scale interpretation.

(3) Operator's simulator test results recorded on a multichannel recorder, line printer, or other acceptable means. These results should be easily compared to the supporting data by employing cross plotting, overlays or transparencies, or other acceptable means. The test guide will then show the documented proof of compliance with the simulator performance tests in Appendix 3. In the case of a simulator upgrade, an operator should run the performance tests for the current evaluation level. Performance test results offered in a test guide for a previous initial or upgrade evaluation should not be offered to validate simulator performance as part of a test guide offered for a succeeding phase. For tests involving time histories, flight test data sheets, or transparencies thereof and simulator test results should be clearly marked with appropriate reference points to ensure an accurate comparison between simulator and airplane with respect to time. Operators using line printers to record time histories should clearly mark that information taken from the line printer data sheet for cross-plotting on the airplane data. The original recordings of simulator test results should be inserted into a separate volume as a reference document of the ATG. Simulator and flight test data parameters, which are not necessary to validate a performance test, need not be cross-plotted. The cross-plotting of the operator's simulator data to airplane data is essential to verify simulator performance in each test. During an evaluation, the FAA will devote its time to detailed checking of selected tests from the ATG. The FAA evaluation will therefore serve to validate the operator's simulator tests.

(4) Flight test data or other supporting data submitted for each test to an incremental scale which is easily comparable to the tolerances shown in Appendix 3 of this advisory circular for that test.

c. In the interest of time, the purchasing operator may accomplish the ATG performance tests while the simulator is located at the manufacturer's facility or the prior owner's facility in the event of the sale of the simulator to another operator. If the ATG is accomplished in this manner, the operator must validate simulator performance by repeating at least 1/3 of the performance tests in the ATG and submit those tests to the NSPM after the simulator has been installed and prior to FAA initial evaluation at the operator's facility. The ATG must be clearly annotated to indicate when and where each test was accomplished.

d. Within 10 working days of receiving the ATG, the NSPM will coordinate with the operator to set a mutually acceptable date for the evaluation. To avoid unnecessary delays, operators are encouraged to work closely with the NSPM during the ATG development process prior to making formal application.

e. Initial and upgrade evaluations will be conducted in the same sequence as the ATG's and evaluation requests are received by the NSPM.

Tentative evaluation dates will not be established until all concerns regarding ATG's have been resolved.

f. Following the initial or upgrade evaluation, a completed master ATG containing the following format should be submitted to the NSPM: table of contents; reference page listing all verification data used; glossary of terms and symbols used in the test guide; and for each test included in the test guide, the name of the test, the test objective, the test conditions, and the test procedures, the recording procedure, the tolerances allowed, and the airplane flight test data or other approved data with the operator and FAA evaluation results cross-plotted on that data or compared in a manner acceptable to the NSPM.

g. The original simulator test results of the operator's evaluation and the FAA's evaluation should be submitted along with the master ATG under separate cover. The simulator test results should be presented in a manner that is easily cross-referenced to the data in the test guide.

h. A copy of the master ATG should accompany the master ATG submittal. The NSPM will then return the master ATG and the simulator test results to the POI for approval. This material will remain on file at the FAA certificate holding FSDO for use in recurrent simulator evaluations. The master ATG should be reviewed by the NSPM and approved by the POI prior to the first recurrent evaluation of the simulator.

i. All simulator initial evaluations and subsequent recurrent evaluations after the date of this advisory circular will be conducted according to the guidance herein except as provided for in paragraph 2 and paragraph 9. A previously approved simulator will retain its original approval as long as the simulator is maintained to the same tolerances for which it was initially approved. However, operators are encouraged to make every effort to amend previously approved test guides to be consistent with the guidelines herein.

8. UPGRADING OF SIMULATORS, MOTION SYSTEMS, AND VISUAL SYSTEMS.

a. Operators should notify the POI of simulator hardware and programming changes which are necessary for the upgrading of a simulator to the next succeeding level and of new motion or visual systems.

b. Changes to simulator hardware and programming, which are required for simulator upgrade, will not affect the current status of the simulator unless an evaluation by an FAA Simulator Evaluation Specialist shows that the change has had a detrimental effect on the simulator. However, new motion or visual system upgrade modifications will require an evaluation of that system under this advisory circular as a part of the next scheduled recurrent evaluation of the simulator.

9. GRANDFATHER RIGHTS. Section 121.407 of the FAR requires that simulators must maintain the performance, functional, and other characteristics that are required for approval. Except as provided for in paragraph 2 of this advisory circular, all initial and recurrent evaluations of those simulators, visual systems and motion systems approved after the effective date of this advisory circular will be conducted in accordance with the provisions herein. Simulators, visual systems and motion systems approved prior to this advisory circular will continue to maintain their current approval as long as they meet the standards under which they were originally approved regardless of operator. Any simulator upgraded to Phase I, II, or III standards or any visual system or motion system upgrade requires an initial evaluation of that simulator, visual system or motion system. A simulator having Phase I status resulting from a landing maneuver approval under Advisory Circular 121-14B should meet the Phase I requirements in Appendix H of Part 121 in the event of the sale or transfer of the simulator from one operator to another prior to its use by the new operator.

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APPENDIX 1. SIMULATOR STANDARDS - GENERAL

1. SIMULATOR.

a. The cockpit should represent a full-scale mockup of the airplane simulated. Where movement of controls and switches is involved, the direction of movement should be identical to that in the applicant's airplane.

b. Circuit breakers that affect procedures and functions resulting in observable cockpit indications should be functionally accurate.

c. The effect of aerodynamic changes for various combinations of drag and thrust normally encountered in flight should correspond to actual flight conditions. The effect of change in aircraft attitude, thrust, drag, altitude, temperature, gross weight, center of gravity location, and configuration should be included.

d. All relevant instrument indications involved in the simulation of the applicable airplane should be entirely automatic in response to control movement by a crewmember.

e. Communications and navigation equipment should correspond to that installed in the applicant's airplane and should operate within the tolerances prescribed for the actual airborne equipment. See Appendix 2, paragraph 2.m., for further information regarding long-range navigation equipment.

f. In addition to the flight crewmember stations, there should be two suitable seats for the Instructor/Check Airman and FAA Inspector. Operators who have the Check Airman/Instructor occupy a flightcrew position seat need only provide one additional observer seat. The NSPM will consider options to this standard based on unique cockpit configurations. These seats should provide adequate vision to the pilot's panel and forward windows in visual system models. Observer seats need not represent those found in the airplane.

g. Simulator systems should simulate the applicable airplane system operation, both on the ground and in flight. Major systems should be operative to the extent that normal operating procedures, and abnormal and emergency procedures included in the operator's programs can be accomplished.

h. Instructor controls should be installed to enable the operator to control all required visual system variables and insert abnormal or emergency conditions into the airplane systems.

i. The rate of change of simulator instrument readings and of control forces should correspond to the rate of change which would occur on the applicable airplane under actual flight conditions for any given change in forces applied to the controls, in the applied power, or in airplane configurations.

j. Control forces and degree of control travel should correspond to that which would occur in the airplane under actual flight conditions.

k. For Phase I Simulators Aerodynamic Programming Should Include:

(1) Ground effect--for example; roundout, flare, and touchdown. This requires data on lift, drag, and pitching moment in ground effect.

(2) Ground reaction--reaction of the airplane upon contact with the runway during landing to include strut deflections, tire friction, and side forces.

(3) Ground handling characteristics--steering inputs to include crosswind, braking, thrust reversing, deceleration, and turning radius.

(4) Multichannel recorders capable of recording Appendix 3 performance tests for Phase I, II and III simulators.

2. MOTION SYSTEMS. A motion system having a minimum of 3 degrees freedom of motion shall be installed and operative. Phase II and III simulators require a minimum of 6 degrees freedom of motion.

3. VISUAL SYSTEMS.

a. The visual system should be capable of meeting all the standards of this appendix and Appendices 2 and 3 which apply to the level of approval sought. The visual system should be compatible with aerodynamic programming.

b. The optical system for visual and Phase I simulators should be capable of providing at least a 45° field of vision. A minimum of 75° horizontally and 30° vertically is required for Phase II and III visual systems.

The "continuous minimum field-of-view" as required for Phase II and III simulators allows that "gaps shall occur only as they would in the airplane simulated or as required by visual system hardware." For all Phase III systems, due to the daylight requirement, continuous means no gap.

For Phase II simulators where individual displays are aligned in the horizontal plane, no gaps are allowed as in Phase III. It is understood that it may be necessary to better adapt the 30° vertical coverage to window geometry and/or to training maneuvers. This results in display modules which are not aligned in the horizontal plane, thus prohibiting juxtaposed techniques. The gap that results from nonhorizontal alignment of modules will be allowed, provided the gap is held to the minimum demanded by the engineering application employed. It is suggested that the minimum gap be justified with a natural obstruction to vision where possible, such as a windscreen post. Moreover, a vertical field per module that will meet the total windscreen/training maneuver requirements while allowing horizontal alignment with no gap is encouraged.

c. Visual systems evaluated under this advisory circular or previously approved under AC 121-14C should incorporate a means for recording the visual response time for comparison with airplane data.

APPENDIX 2. SIMULATOR FUNCTIONAL TESTS

1. DISCUSSION. Functional tests are subjective tests of simulator characteristics and system operation evaluated from each flight crewmember position by a pilot rated in the airplane simulated. As appropriate, these should include the cockpit check, system operation, normal, abnormal and emergency procedures using the operator's operating procedures and checklists.

Initial evaluations will include functional checks from paragraph 2 of this appendix as appropriate. At the request of a POI, the Simulator Evaluation Specialist may elect to focus on simulator operation during a special aspect of an operator's training program during the functional check portion of a recurrent evaluation. Such a functional evaluation may include a portion of a LOFT scenario or special emphasis items within the operator's training program. Unless directly related to a requirement for the current certification level, the results of such an evaluation would not affect the simulator's current status.

2. SIMULATOR FUNCTIONAL TESTS. The ground and flight maneuvers which may be evaluated, as appropriate to the type of airplane, are discussed below.

a. Preflight. Accomplish a thorough preflight of all switches, indicators, and systems at all crewmembers' and instructor's stations, and determine that the cockpit design is identical to that of the airplane simulated as appropriate to the training objectives.

b. Engine Start.

(1) Normal start.
(2) Alternate start procedures.
(3) Abnormal and emergency procedures during start.

c. Taxi.

(1) Thrust response.
(2) Ground handling.
(3) Brake operation (normal and alternate/emergency).
(4) Abnormal and emergency procedures associated with ground operations.

d. Takeoff and Climb.

(1) Powerplant checks (engine parameter relationships).
(2) Acceleration characteristics.
(3) Nose wheel and rudder steering.
(4) Rejected takeoff.
(5) Normal takeoff.
(6) Takeoff with engine failure at critical engine failure speed.
(7) Crosswind takeoff (maximum which has been demonstrated).
(8) Instrument takeoff.
(9) Landing gear, flap, leading edge device operation.

(10) Area departure.
(11) Climb performance - normal and engine/engines out.
(12) Abnormal and emergency procedures associated with takeoff and climb.
(13) Minimum control speed with most critical engine inoperative.

NOTE: During the preceding checks, particular attention should be paid to rotation characteristics, handling characteristics, and rudder forces required with engine inoperative.

e. Cruise.

(1) Performance characteristics (speed vs. power).
(2) Turns with/without spoilers.
(3) High speed buffet/mach tuck, overspeed warning.
(4) Normal and steep turns.
(5) Approach to stalls (stall warning, buffet and "G" break).
(6) Specific flight characteristics.
(7) All systems operations associated with normal in-flight functions.
(8) Abnormal and emergency procedures associated with cruise configuration.

f. Descent.

(1) Normal descent.
(2) Abnormal and emergency procedures associated with descents.

g. Approach and Landing.

(1) Maneuvering with all engines operative.
(2) Landing gear, flap operation, speed brake, normal and abnormal extension.
(3) All engines approach and landing.
(4) Engine out approach and landing (in the case of three- and four-engine aircraft, one and two engines inoperative).
(5) PAR approach and landing if applicable.
(6) ILS approaches and landings:

(a) Normal.
(b) Engine inoperative (as required by pertinent FAR).
(c) Category I, if applicable.
(d) Category II, if applicable.
(e) Category III, if applicable.

(7) Nonprecision approaches.
(8) Circling approach if applicable.
(9) No flap approach.
(10) Auto-coupler, auto-throttle, auto-land approaches if applicable.
(11) Manually controlled ILS with and without flight director.

(12) All engines operating missed approach.
(13) Engine out missed approach (as required by pertinent FAR).
(14) Rejected landing.
(15) Crosswind approach and landing.
(16) Navigation and communications.
(17) Abnormal and emergency procedures associated with approach and landing.

h. Landing Roll and Taxi In.

(1) Spoiler operation.
(2) Reverse thrust operation.
(3) Directional control and ground handling.
(4) Normal brake and anti-skid operation.
(5) Alternate/emergency brake operation.

i. Engine Shutdown and Parking.

(1) Systems operation.
(2) Parking brake operation.

j. Motion System.

(1) For Phase I, II, and III Simulators, special effects including:

(a) Runway rumble, oleo deflections, effects of groundspeed and uneven runway characteristics.
(b) Buffets on the ground due to spoiler/speedbrake extension and thrust reversal.
(c) Bumps after lift-off of nose and main gear.
(d) Buffet during extension and retraction of landing gear.
(e) Buffet in the air due to flap and spoiler/speedbrake extension.
(f) Approach-to-stall buffet.
(g) Touchdown cues for main and nose gear.
(h) Nosewheel scuffing.
(i) Thrust effect with brakes set.

k. For Phase II and III simulators, representative brake and tire failure dynamics (including antiskid) and decreased brake efficiency due to high brake temperatures based on airplane related data. These representations should be realistic enough to cause pilot identification of the problem and implementation of appropriate procedures. Simulator pitch, side loading and directional control characteristics should be representative of the airplane.

l. For Phase II and III simulators, sound of precipitation and significant airplane noises perceptible to the pilot during normal operations and the sound

of a crash when the simulator is landed in excess of landing gear limitations. Significant airplane noises should include noises such as engine, flap, gear and spoiler extension and retraction and thrust reversal to a comparable level as that found in the airplane. The sound of a crash should be related in some logical manner to landing in an unusual attitude or in excess of the structural gear limitations of the airplane.

m. For Phase II and III simulators, operational principal navigation systems, including electronic flight instrument systems, INS, and OMEGA, will be evaluated if installed. The Simulator Evaluation Specialist will include in his report to the POI the effect of the system's operation and its limitations.

n. Visual System Functional Checks relating to the certification level sought.

(1) Accurate portrayal of environment relating to simulator attitudes.	Visual, I, II, III
(2) With final picture resolution, the distances at which runway features are visible should not be less than those listed below. Distances are measured from runway threshold to an airplane aligned with the runway on an extended 3° glide slope.	Visual, I, II, III
(a) Runway and taxiway definition, strobe lights, approach lights, runway edge white lights and VASI lights from 5 miles of the runway threshold.	
(b) Runway centerline lights from 3 miles.	
(c) Threshold lights (red and green) and touchdown zone lights from 2 miles.	
(d) Markings should be adequate to recognize threshold, centerline and touchdown zone markings within range of landing lights for night scenes.	
(3) Representative airport scene content including:	
(a) Airport taxiways.	Visual, I, II, III
(b) Ramps and terminal buildings which correspond to an operator's LOFT scenario.	I, II, III
(c) Surface on runways.	Visual, I, II, III

(d) Surface on taxiways and ramps. I, II, III

(1) Representative lighting for the runway in use including runway edge and centerline lighting, VASI and approach lighting of appropriate colors and taxiway lights. Visual, I, II, III

(2) Operational landing lights Visual, I, II, III

(3) Instructor controls of: Visual, I, II, III
(a) Cloudbase
(b) Visibility in miles and RVR in feet
(c) Airport selection
(d) Airport lighting

(4) Visual cues to assess sink rates and depth perception during landings. I, II, III

(5) Visual system compatibility with aerodynamic programming I, II, III

(6) Dusk and night visual scene capability II, III

(7) Minimum of 3 specific airport scenes II, III

(8) General terrain characteristics and significant landmarks II, III

(9) At and below an altitude of 2,000 ft. height above the airport and within a radius of 10 miles from the airport, weather representations, including the following: II, III

(a) Variable cloud density

(b) Partial obscuration of ground scenes; the effect of a scattered to broken cloud deck.

(c) Gradual break out

(d) Patchy fog

(e) The effect of fog on airport lighting

(f) Category II and III weather conditions for operators authorized to operate under those conditions.

(10)	A capability to present ground and air hazards such as another airplane crossing the active runway or converging airborne traffic.	II, III
(11)	Visual scenes portraying representative physical relationships which are known to cause landing illusions for some pilots including short runway, landing over water, runway gradient, visual topographic features, and rising terrain.	III
(12)	Special weather representations of entering light, medium, and heavy precipitation near a thunderstorm on takeoff, approach, and landings at and below an altitude of 2,000 feet HAA and within a radius of 10 miles from the airport.	III
(13)	Wet and, if appropriate for the operator, snow-covered runway representations, including runway lighting effects of reflections for wet and partially obscured lights for snow or suitable alternative effects.	III
(14)	Realistic color and directionality of airport lighting.	III
(15)	Weather radar presentations in aircraft where radar information is presented on the pilot's navigation instruments. Cloud echos should correlate to the visual scene.	III

APPENDIX 3. SIMULATOR PERFORMANCE TESTS

1. DISCUSSION. Simulator performance and system operation should be objectively evaluated by comparing each performance test conducted in the simulator to airplane performance. The performance of nonvisual and visual simulators should be compared to the best airplane performance data available for each test. Phase I, II, and III simulators should be compared to flight test data. This will be accomplished by matching each flight test condition and response in the simulator.

To facilitate the comparison of performance between the simulator and the airplane, a multichannel recorder or line printer should be used to record each performance test in the simulator. The results of the multichannel recorder or line printer should be compared to the source data to confirm simulator performance. The ATG provided by the operator should describe clearly and distinctly how the simulator will be set up and flown to accurately duplicate the flight test data. Use of a driver program designed to automatically duplicate the flight test with accuracy and dependability is encouraged, but procedures should be included to positively determine that the driver is doing nothing more than accurately flying the simulator. All test results should, therefore, reflect the real time output to the flightcrew so that the simulator would be in trim and would continue to fly if the driver was disengaged. This appendix contains the tests and tolerances which should be included in the operator's ATG. Phase I, II and III simulators will be compared to flight test data in all tests. For aircraft certificated prior to June 1980, an operator may, after reasonable attempts have failed to obtain suitable flight test data, indicate to the NSPM in the ATG where flight test data is unavailable or unsuitable for a specific test. For such a test, alternative data should be submitted in the ATG to the NSPM for approval.

Submittals for approval of data other than flight test must include an explanation of validity with respect to available flight test information. The tolerances specified in the following table of performance tests generally indicate the test results required such as static or dynamic time history. In the case of simulators approved under previous advisory circulars, the tolerances of this appendix may be used in subsequent recurrent evaluations for any given test providing the operator has submitted a proposed ATG revision to the NSPM and has received FAA approval.

Unless otherwise indicated, tests should represent aircraft performance at normal operating weights and centers of gravity. If a test is supported by aircraft data at one extreme gross weight or center of gravity, another test supported by aircraft data as close as possible to the other extreme should be included.

2. TABLE OF SIMULATOR PERFORMANCE TESTS. The ground and flight tests which should be evaluated, as appropriate to the type of airplane, are listed below. Dynamic tests are those tests which involve comparison of simulator to airplane performance over continuous time (time history). Recorded time histories are not required for visual and nonvisual simulator evaluations. However, sufficient static data points should be provided to validate simulator performance for each test in this appendix except for taxi and landing checks which are not required for visual and nonvisual simulator evaluations.

Although tolerances may be specified for dynamic tests, other criteria such as general trends (such as over-shoots) and signatures of flight variables are of major consideration. It should be understood that even for static tests, airplane and or simulator data can be, and usually is, obtained from a dynamic exercise.

Where an asterisk(*) appears in the tolerance column for a particular test, the following appropriate airplane and simulator parameters and tolerances should be available for comparison:

pitch angle and angle of attack ± 1 1/2°
roll angle ± 2°
yaw angle ± 2°
airspeed ± 3 KTS
altitude: 0-100 feet, ± 10 feet; 100-500 feet, ± 10%; 500 feet and above, ± 50 feet maximum

The nature of dynamic flight test data will require normalizing of some traces and subsequent judicious application of the above tolerances. When difficulties arise in matching simulator performance to airplane performance throughout a time history, differences may be rationalized by providing a comparison of elevator, aileron and rudder surface position.

NOTES: 1. All airspeeds should be clearly annotated as to indicated, calibrated, etc. Like types of airspeed will be offered for comparison in any test.
2. Where 2 tolerances are given, the less restrictive may be used unless otherwise indicated.

a. FLIGHT CONDITION CODES

(1) Ground/Takeoff
(2) First Segment Climb
(3) Second Segment Climb (if applicable to flap change)
(4) Enroute Climb
(5) Cruise
(6) Descent
(7) Approach
(8) Landing

b. TEST	TOLERANCES	FLIGHT CONDITIONS
(1) STATIC CONTROL CHECKS.**		
(a) Column Position vs Force and Surface Position Calibration	± 2° Elevator ± 5 lbs or 10%	1
(b) Wheel Position vs Force and Surface Position Calibration;	± 1° Aileron ± 2° Spoiler ± 3 lbs or 10%	
(c) Rudder Pedal Position vs Force and Surface Position Calibration;	± 2° Rudder ± 5 lbs or 10%	1
(d) Nosewheel Steering Force	± 3 lbs or 10%	1
(e) Rudder Pedal Steering Calibration Force	± 5 lbs or 10%	1
(f) Pitch Trim Calibration Indicator vs Computed	± 1/2°	1
(g) Alignment of Power Lever Angle (Cross Shaft Angle) vs Selected Engine Parameter (EPR, N_1)	± 5°	1

**Column, wheel and pedal position vs force shall be measured at the controls for Phase II or III evaluations.

(2) TAXI.		
(a) Minimum Radius Turn	± 10 ft	1
(b) Rate of Turn Versus Nosewheel Steering Angle	Rate of Turn ± 2°/sec or 10%	1
(3) TAKEOFF.		
(a) Ground Acceleration Time and Distance	± 5% time and distance or ± 5% of time and ± 200 ft. of distance	1
(b) Minimum Control Speed, Ground	± 5 knots	1
(c) Minimum Rotate Speed	± 3 knots	1
(d) Minimum Unstick Speed	± 3 knots	1
(e) Types of Takeoff Required through 500 feet AGL		1
1 Normal	*	1 and 2
2 Engine Out Takeoff	*	1 and 2
3 Crosswind Takeoff	*	1 and 2

b. TEST	TOLERANCE	FLIGHT CONDITIONS
(4) CLIMB.		
(a) Normal Climb	± 5% climb rate or 100 FPM whichever is greater	4
(b) Engine Out Second Segment Climb	"	3
(c) Engine Out Approach Climb	"	7
(5) LONGITUDINAL CONTROL.		
(a) Power Change Forces or Power Change Dynamics	± 5 lb. or ± 20% ± 20% or ± 1-1/2° pitch, ± 3 kts., ± 100'/min.	5
(b) Flap Change Forces or Dynamics	± 5 lbs or 20% ± 20% or ± 1-1/2°, ± 3 kts, ± 100'/min.	3 and; 7 or 8
(c) Gear Change Forces or Gear Change Dynamics	± 5 lbs or ± 20% ± 20% or ± 1-1/2°, ± 3 kts, ± 100'/min.	1 and 7
(d) Gear and Flap Operating Times	± 3 sec or ± 20% Time	1 and 7
(e) Longitudinal Trim	± 1 unit trim; 1° pitch; .05 EPR	7 and 8
(f) Longitudinal Maneuvering Stability (Stick Force/G)	± 5 lbs or ± 10% Stick Force	5, 7 and 8
(g) Longitudinal Static Stability	± 5 lbs or ± 10%	5
(h) Short Period Dynamics	*	5
(i) Phugoid Dynamics	± 10% of period and Time to 1/2 (or double) amplitude or ± .02 in damping ratio	5
(j) Stick Shaker, Airframe Buffet, Stall Speeds	± 3 knots	3 and; 7 or 8
(6) LATERAL CONTROL.		
(a) Minimum Control Speed, Air	± 5 knots	1 or 8
(b) Roll Response	± 10% of Roll Rate or ± 2°/sec.	5 and; 7 or 8
(c) Roll Overshoot	± 2° or 10% of Bank	7 or 8

b. TEST (6) Continued	TOLERANCE	FLIGHT CONDITIONS
(6) LATERAL CONTROL (Continued)		
(d) Spiral Stability	Correct Trend ± 3° bank or 10% in 30 secs.	7 or 8
(e) Engine Out Trim	± 1 unit of rudder trim	3 and; 7 or 8
(f) Rudder Response	± 2°/sec. or ± 10% of yaw rate per pedal or surface deflection	7 or 8
(g) Cross Control	For a given rudder position, ± 5° or ± 10% of wheel or surface deflection; ± 1° bank/slip	7 or 8
(h) Dutch Roll Dynamics	± 1 sec or ± 10% of period and time 1/2 (or double) amplitude or .02 damping ratio	5 and; 7 or 8
(7) LANDING.		8
(a) Normal Landing	*	
(b) Hands OFF Landing	*	
(c) Crosswind Landing	*	
(d) Engine Out Landing	*	
(e) Stopping Time and Distance Wheel Brakes	± 5% time, ± 5% or ± 200 ft. of distance	
(f) Stopping Time and Distance Reverse Thrust	± 5% time, ± 5% or ± 200 ft. of distance	
(8) MOTION SYSTEM CHECKS.		
NOTE: Operator certified test results of tests (a), (b) and (c) below will alleviate the requirement to rerun these tests during initial evaluations.		
(a) Frequency Response Check.	As specified by the operator for simulator acceptance	
(b) Leg Balance Check.	"	
(c) Turn Around Check.	"	
(d) Simulator Response Check, Phase II and III as compared to airplane response	+ 150 milliseconds (see paragraph 3.i.)	

b. TEST (Continued)	TOLERANCE	FLIGHT CONDITIONS
(9) VISUAL SYSTEM CHECKS.		
(a) For visual simulators and Phase I simulators, visual system response from pilot control input to visual system output compared to aircraft movement from a similar pilot control input.	+ 300 milliseconds	1
(b) For Phase II and III simulators, see paragraph 3.i. of this appendix.		

3. PHASES II AND III TESTS/STATEMENTS OF COMPLIANCE. The following requirements require a statement of compliance and, in some designated cases, a supporting test. Compliance statements will describe how the requirement is met, such as gear modeling approach, coefficient of friction sources, etc. These requirements are progressive in nature such that Phase III would include all of the Phase II requirements.

a. For Phase II simulators representative modeling of crosswind and 3-dimensional windshear dynamics based on airplane related data.

b. For Phase II simulators representative stopping and directional control forces for at least the following runway conditions based on airplane related data. The compliance statement should be supported by tests with recorded results of stopping times and distances.

(1) Dry.
(2) Wet.
(3) Icy.
(4) Patchy wet.
(5) Patchy icy.
(6) Wet on rubber residue in touchdown zone.

c. For Phase II simulators, representative brake and tire failure dynamics (including antiskid) and decreased brake efficiency due to brake temperatures based on airplane related data.

d. For Phase II simulators, a means for quickly and effectively testing simulator programming and hardware. This could include an automated system which could be used for conducting at least a portion of the tests in the ATG.

e. For Phase II simulators, expanded simulator computer capacity, accuracy, resolution, and dynamic response to meet Phase II demands. Resolution equivalent to that of at least a 32-bit word length computer is required for critical aerodynamic programs.

f. For Phase II simulators, a motion system which provides motion cues equal to or better than a six post synergistic platform motion system.

g. For Phase II simulators, performance tests are required to verify that control feel dynamics represent the airplane simulated. Dynamic damping cycles (free response of the controls) shall match that of the aircraft within 20% of the period and damping. Initial/upgrade evaluations will require that control free response dynamics (column, wheel, and pedal) be measured at and recorded directly from the controls, and correspond to that which would occur in the airplane in the takeoff, cruise, and landing configurations. For airplanes with irreversible control systems, measurements may be obtained on the ground if proper pitot static inputs are provided to represent airspeeds typical of those encountered in flight. Likewise, it may be shown that for some airplanes, takeoff, cruise, and landing configurations have like effects. Thus, one may suffice for another. If either or both considerations apply, engineering validation or airplane manufacturer rationale will be submitted as justification to ground test or for eliminating a configuration. For Phase II and III simulators requiring static and dynamic tests at the controls, special test fixtures will not be required during initial evaluations if the operator's ATG shows both test fixture results and an alternate approach for recurrent evaluations, such as computer plots which were conducted concurrently. Repeat of the alternate method during the initial evaluation would then satisfy this test requirement.

h. For Phase II simulators, a test to verify that radio navigation aids are properly oriented to the airport runway layout. One VOR and one ILS localizer for one airport area must be shown by airport runway diagram or other appropriate source data to be accurate to within $\pm$ 1% of VOR range and $\pm$ 1° of bearing to the VOR and the ILS localizer measured from the point where the glide slope merges with the runway centerline with the simulated aircraft aligned with the centerline of the visual runway. Computer readouts are preferred to flight instrumentation.

i. For Phase II simulators, relative responses of the motion system, visual system, and cockpit instruments shall be coupled closely to provide integrated sensory cues. These systems shall respond to abrupt pitch, roll, and yaw inputs at the pilot's position within 150 milliseconds of the time, but not before the time, when the airplane would respond under the same conditions. Visual scene changes from steady state disturbance shall not occur before the resultant motion onset but within the system dynamic response tolerance of 150 milliseconds. The test to determine compliance with these requirements shall include simultaneously recording the analog output from the pilot's control column, wheel, and rudders, the output from an accelerometer attached to the motion system platform located at an acceptable location near the pilot's seats, the output signal to the visual system display (including visual system analog delays), and the output signal to the pilot's attitude indicator or an equivalent test approved by the Administrator. The test results in a comparison of a recording of the simulator's

response to actual airplane response data in the takeoff, cruise, and landing configuration. The intent is to check the architecture of the hardware and software to determine that there are no detrimental transport delays and that the cues of motion and vision relate to actual aircraft responses. For aircraft response, acceleration in the appropriate rotational axis is preferred. Ten percent of peak acceleration is suggested as an appropriate response point.

j. For Phase II simulator visual systems, test procedures to quickly confirm visual system color, RVR, focus, intensity, level horizon, and attitude as compared to the simulator attitude indicator.

k. For Phase II simulators, a minimum of ten levels of occulting. This capability should be demonstrated by a visual model through each channel.

l. For Phase III simulators, characteristic buffet motions that result from operation of the airplane (for example, high-speed buffet, extended landing gear, flaps, nose-wheel scuffing, stall) which can be sensed at the flight deck. The simulator must be programmed and instrumented in such a manner that the characteristic buffet modes can be measured and compared to airplane data. Airplane data are also required to define flight deck motions when the airplane is subjected to atmospheric disturbances such as rough air and cobblestone turbulence. General purpose disturbance models that approximate demonstrable flight test data are acceptable. An objective test with recorded results is required.

m. For Phase III simulators, aerodynamic modeling for aircraft for which an original type certificate is issued after June 1980, including low-altitude level-flight ground effect, mach effect at high altitude, effects of airframe icing, normal and reverse dynamic thrust effect on control surfaces, aero-elastic representations, and representations of nonlinearities due to side slip based on airplane flight test data provided by the manufacturer. A test for each effect is required.

n. For Phase III simulators, realistic amplitude and frequency of cockpit noises and sounds, including precipitation, static discharge, and engine and airframe sounds. The sounds shall be coordinated with the weather representations required in FAR Part 121, Appendix H, Phase III visual requirement No. 3. A test with recorded results is required.

o. For Phase III simulators, self-testing for simulator hardware and programming to determine compliance with Phase I, II, and III simulator requirements as prescribed in paragraph 2.b. of this appendix. Evidence of testing must include simulator number, date, time, conditions, tolerances, and appropriate dependent variables portrayed in comparison to the airplane standard. Automatic flagging of "out-of-tolerance" situations is encouraged.

p. For Phase III simulators, diagnostic analysis printouts of simulator malfunctions sufficient to determine MEL compliance. These printouts shall be retained by the operator between recurring FAA simulator evaluations as part of the daily discrepancy log required under FAR 121.407(a)(5).

q. For Phase III simulator visual systems, daylight, dusk, and night visual scenes with sufficient scene content to recognize airport, the terrain, and major landmarks around the airport and to successfully accomplish a visual landing. The daylight visual scene must be part of a total daylight cockpit environment which at least represents the amount of light in the cockpit on an overcast day. Daylight visual system is defined as a visual system capable of producing, as a minimum, full color presentations, scene content comparable in detail to that produced by 4,000 edges or 1,000 surfaces for daylight and 4,000 light points for night and dusk scenes, 6-foot lamberts of light at the pilot's eye (highlight brightness), 3-arc minutes resolution for the field of view at the pilot's eye, and a display which is free of apparent quantization and other distracting visual effects while the simulator is in motion. The simulator cockpit ambient lighting shall be dynamically consistent with the visual scene displayed. For daylight scenes, such ambient lighting shall neither "washout" the displayed visual scene nor fall below 5-foot lamberts of light as reflected from an approach plate at knee height at the pilot's station and/or 2-foot lamberts of light as reflected from the pilot's face. All brightness and resolution requirements must be validated by an objective test.

r. For Phase III simulator visual systems, Phase II visual requirements in daylight as well as dusk and night representations.

APPENDIX 4 - TEST GUIDE APPROVAL PROCESS

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