

APPENDIX 1. SIMULATOR STANDARDS

1. DISCUSSION. This appendix describes the minimum simulator requirements for qualifying Level A, Level B, Level C, and Level D airplane simulators. An operator desiring evaluation of an airplane simulator not equipped with a visual system (nonvisual simulator) must comply with Level A simulator requirements except those pertaining to visual systems. Appropriate FAR as indicated in paragraph 3 of this AC must be consulted when considering particular simulator requirements. The validation and functions tests listed in appendices 2 and 3 must also be consulted when determining the requirements of a specific level simulator. For Levels C and D qualification, certain simulator and visual system requirements included in this appendix must be supported with a statement of compliance and, in some designated cases, an objective test. Compliance statements will describe how the requirement is met, such as gear modeling approach, coefficient of friction sources, etc. The test should show that the requirement has been attained. In the following tabular listing of simulator standards, required statements of compliance are indicated in the comment column.

| 2. <u>GENERAL</u>  | SIMULATOR LEVEL |   |   |   | COMMENTS |
|--|-----------------|---|---|---|----------|
|  | A               | B | C | D |          |
| a. Cockpit, a full-scale replica of the airplane simulated. Direction of movement of controls and switches identical to that in the airplane. The cockpit, for simulator purposes, consists of all that space forward of a cross-section of the fuselage at the most extreme aft setting of the pilots' seats. Additional required crewmember duty stations and those required bulkheads aft of the pilot seats are also considered part of the cockpit and must replicate the airplane. | X               | X | X | X |          |
| b. Circuit breakers that affect procedures and/or result in observable cockpit indications properly located and functionally accurate.   | X               | X | X | X |          |

SIMULATOR STANDARDS (Cont'd)

## SIMULATOR LEVEL

## COMMENTS

|   | A | B | C | D |  |
|---|---|---|---|---|--|
| c. Effect of aerodynamic changes for various combinations of drag and thrust normally encountered in flight corresponding to actual flight conditions, including the effect of change in airplane attitude, thrust, drag, altitude, temperature, gross weight, center of gravity location, and configuration. | X | X | X | X |  |
| d. Ground operations generically represented to the extent that allows turns within the confines of the runway and adequate control on the landing and roll-out from a crosswind approach to a running landing.   | X |   |   |   |  |
| e. All relevant instrument indications involved in the simulation of the applicable airplane automatically responded to control movement by a crewmember or external disturbances to the simulated airplane; i.e., turbulence or windshear.   | X | X | X | X | Numerical values must be presented in the appropriate units for U.S. operations, for example, fuel in pounds, speeds in knots, altitudes in feet, etc. |
| f. Communications and navigation equipment corresponding to that installed in the applicant's airplane with operation within the tolerances prescribed for the applicable airborne equipment.   | X | X | X | X | See appendix 3, par. 1, for further information regarding long-range navigation equipment.   |
| g. In addition to the flight crewmember stations, two suitable seats for the instructor/check airman and FAA inspector. The NSPM will consider options to this standard based on  | X | X | X | X |  |

SIMULATOR STANDARDS (Cont'd)

SIMULATOR LEVEL

COMMENTS

|  | A | B | C | D |  |
|--|---|---|---|---|--|
| unique cockpit configurations. These seats must 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 but must be equipped with similar positive restraint devices.          |   |   |   |   |  |
| h. Simulator systems must simulate the applicable airplane system operation, both on the ground and in flight. Systems must be operative to the extent that normal, abnormal, and emergency operating procedures appropriate to the simulator application can be accomplished. | X | X | X | X |  |
| i. Instructor controls to enable the operator to control all required system variables and insert abnormal or emergency conditions into the airplane systems.  | X | X | X | X |  |
| j. Control forces and control travel which correspond to that of the replicated airplane. Control forces should react in the same manner as in the airplane under the same flight conditions.  | X | X | X | X |  |
| k. Significant cockpit sounds which result from pilot actions corresponding to those of the airplane.  | X | X | X | X |  |

SIMULATOR STANDARDS (Cont'd)

## SIMULATOR LEVEL

## COMMENTS

|  | SIMULATOR LEVEL |   |   |   | COMMENTS   |
|--|-----------------|---|---|---|--|
|  | A               | B | C | D |  |
| <p>l. Sound of precipitation, windshield wipers, and other 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.</p>  |                 |   | X | X | Statement of Compliance.   |
| <p>m. Realistic amplitude and frequency of cockpit noises and sounds, including precipitation, windshield wipers, precipitation static, and engine and airframe sounds. The sounds shall be coordinated with the weather representations required in FAR Part 121, Appendix H, Phase III (Level D), Visual Requirement No. 3.</p>  |                 |   |   | X | Tests required for noises and sounds that originate from the airplane or airplane systems. |
| <p>n. Ground handling and aerodynamic programming to include:</p> <p>(1) Ground effect--for example: roundout, flare, and touchdown. This requires data on lift, drag, pitching moment, trim, and power in ground effect.</p> <p>(2) Ground reaction--reaction of the airplane upon contact with the runway during landing to include strut deflections, tire friction, side forces, and other appropriate data, such as weight and speed, necessary to identify the flight condition and configuration.</p> |                 | X | X | X | Statement of Compliance.<br>Tests required.  |

SIMULATOR STANDARDS (Cont'd)

SIMULATOR LEVEL

COMMENTS

|  | A | B | C | D |                 |
|--|---|---|---|---|-----------------|
| (3) Ground handling characteristics-- steering inputs to include crosswind, braking, thrust reversing, deceleration, and turning radius.   |   |   |   |   |                 |
| o. Windshear models which provide training in the specific skills required for recognition of windshear phenomena and execution of recovery maneuvers. Such models must be representative of measured or accident derived winds, but may include simplifications which ensure repeatable encounters. For example, models may consist of independent variable winds in multiple simultaneous components. Wind models should be available for the following critical phases of flight:<br><br>(1) Prior to takeoff rotation.<br>(2) At liftoff.<br>(3) During initial climb.<br>(4) Short final approach.<br><br>The FAA Windshear Training Aid presents one acceptable means of compliance with simulator wind model requirements. The ATG should either reference the FAA Windshear Training Aid or present ariplane related data on alternate |   |   | X | X | Tests required. |

SIMULATOR STANDARDS (Cont'd)

SIMULATOR LEVEL

COMMENTS

|  | A | B | C | D |  |
|--|---|---|---|---|--|
| methods implemented. Wind models from the Royal Aerospace Establishment (RAE), the Joint Airport Weather Studies (JAWS) Project and other recognized sources may be implemented, but must be supported or properly referenced in the ATG.                      |   |   |   |   |  |
| p. Representative crosswinds and instructor controls for wind speed and direction.   | X | X | X | X |  |
| q. Representative stopping and directional control forces for at least the following runway conditions based on airplane related data.<br><br>(1) Dry<br>(2) Wet<br>(3) Icy<br>(4) Patchy Wet<br>(5) Patchy Icy<br>(6) Wet on Rubber Residue in Touchdown Zone |   |   | X | X | Statement of Compliance. Objective tests required for (1), (2), (3), Subjective check for (4), (5), (6). |
| r. Representative brake and tire failure dynamics (including antiskid) and decreased brake efficient due to brake temperatures based on airplane related data.   |   |   | X | X | Statement of Compliance. Tests required for decreased braking efficiency due to brake temperature.       |

SIMULATOR STANDARDS (Cont'd)

SIMULATOR LEVEL

COMMENTS

|   | A | B | C | D |   |
|---|---|---|---|---|---|
| <p>s. A means for quickly and effectively testing simulator programming and hardware. This may include an automated system which could be used for conducting at least a portion of the tests in the ATG.</p>   |   |   | X | X | Statement of Compliance.  |
| <p>t. Simulator computer capacity, accuracy, resolution, and dynamic response sufficient for the qualification level sought.</p>  | X | X | X | X | Statement of Compliance. FAR 121, Appendix H, specifies computer standard for Phases II & III (Levels C and D). |
| <p>u. Control feel dynamics which replicate the airplane simulated. Free response of the controls shall match that of the airplane within the tolerance given in appendix 2. Initial and upgrade evaluation will include control free response (column, wheel, and pedal) measurements recorded at the controls. The measured responses must correspond to those of the airplane in takeoff, cruise, and landing configurations.</p> <p>(1) For airplanes with irreversible control systems, measurements may be obtained on the ground if proper Pitot static inputs are provided to represent conditions typical of those encountered in flight. Engineering validation or airplane manufacturer rationale will be submitted as justification to ground test or omit a configuration.</p> |   |   | X | X | Tests required. See appendix 2, par. 3.   |

SIMULATOR STANDARDS (Cont'd)

## SIMULATOR LEVEL

## COMMENTS

|   | A | B | C | D |  |
|---|---|---|---|---|--|
| (2) For 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 alternate test method results, such as computer data plots, which were obtained concurrently. Repeat of the alternate method during the initial evaluation may then satisfy this test requirement.   |   |   |   |   |  |
| v. 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 150/300 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 occur within the system dynamic response limit of 150/300 milliseconds but not before the resultant motion onset. The test to determine compliance with these requirements should include simultaneously recording the analog output from the pilot's control column, wheel, and pedals, the output from an accelerometer attached to the motion system platform located at an acceptable location near the pilots' seats, the output signal to the pilots' seats, the output signal to the visual system display (including visual system | X | X | X | X | <p>Tests required.</p> <p>For Levels A and B, response must be within 300 milliseconds.</p> <p>For Levels C and D, response must be within 150 milliseconds.</p> |

SIMULATOR STANDARDS (Cont'd)

SIMULATOR LEVEL

COMMENTS

|  | A | B | C | D |  |
|--|---|---|---|---|--|
| <p>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 verify that the simulator system transport delays or time lags are less than 150/300 milliseconds and that the motion and visual cues relate to actual airplane responses. For airplane response, acceleration in the appropriate rotational axis is preferred.</p> <p>As an alternative, a transport delay test may be used to demonstrate that the simulator system does not exceed the specified limit of 150/300 milliseconds.</p> <p>This test shall measure all the delay encountered by a step signal migrating from the pilots' control through the control loading electronics and interfacing through all the simulation software modules in the correct order, using a handshaking protocol, finally through the normal output interfaces to the motion system, to the visual system and instrument displays. A recordable start time for the test should be provided by a pilot flight control input. The</p> |   |   |   |   |  |

SIMULATOR STANDARDS (Cont'd)

SIMULATOR LEVEL

COMMENTS

|  | A | B | C | D |   |
|--|---|---|---|---|---|
| test mode shall permit normal computation time to be consumed and shall not alter the flow of information through the hardware/software system. The transport delay of the system is then the time between the control input and the individual hardware responses. It need only be measured once in each axis, being independent of flight conditions.  |   |   |   |   |   |
| w. Aerodynamic modeling which, for airplanes issued an original type certificate after June 1980, includes low-altitude level-flight ground effect, Mach effect at high altitude, effects of airframe icing, normal and reverse dynamic thrust effect on control surfaces, aeroelastic representations, and representations of nonlinearities due to sideslip based on airplane flight test data provided by the manufacturer. |   |   |   | X | Statement of Compliance. Tests required. See appendix 2, par. 4, for further information on ground effect. Mach effect, aeroelastic representations, and nonlinearities due to sideslip are normally included in the simulator aerodynamic model, but the Statement of Compliance must address each of them. Separate tests for thrust effects and a Statement of Compliance and demonstration of icing effects are required. |

SIMULATOR STANDARDS (Cont'd)

SIMULATOR LEVEL

COMMENTS

|  | A | B | C | D |   |
|--|---|---|---|---|---|
| x. Aerodynamic and ground reaction modeling for the effects of reverse thrust on directional control.  |   | X | X | X | Statement of Compliance.<br>Tests required. |
| y. Self-testing for simulator hardware and programming to determine compliance with simulator performance tests as prescribed in appendix 2. 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. |   |   |   | X | Statement of Compliance.<br>Tests required. |
| z. Diagnostic analysis printouts of simulator malfunctions sufficient to determine compliance with the Simulator Component Inoperative Guide (SCIG). These printouts shall be retained by the operator between recurring FAA simulator evaluations as part of the daily discrepancy log required under FAR Section 121.407(a)(5).  |   |   |   | X | Statement of Compliance.                    |
| aa. Timely permanent update of simulator hardware and programming subsequent to airplane modification.   | X | X | X | X |   |
| bb. Daily preflight documentation either in the daily log or in a location easily accessible for review.   | X | X | X | X |   |

SIMULATOR STANDARDS (Cont'd)

## SIMULATOR LEVEL

## COMMENTS

|  | A | B | C | D |  |
|--|---|---|---|---|--|
| 3. <u>MOTION SYSTEM.</u>   |   |   |   |   |  |
| a. Motion (force) cues perceived by the pilot representative of the airplane motions, i.e., touchdown cues, should be a function of the simulated rate of descent. | X | X | X | X |  |
| b. A motion system having a minimum of three degrees of freedom.   | X | X |   |   |  |
| c. A motion system which produces cues at least equivalent to those of a six-degrees-of-freedom synergistic platform motion system.                                |   |   | X | X | Statement of Compliance. Tests required. |
| d. A means for recording the motion response time for comparison with airplane data.   | X | X | X | X | See 2.v. of this appendix.               |
| e. Special effects programming to include:   |   | X | X | X |  |
| (1) Runway rumble, oleo deflections, effects of groundspeed and uneven runway characteristics.   |   |   |   |   |  |
| (2) Buffets on the ground due to spoiler/speedbrake extension and thrust reversal.   |   |   |   |   |  |
| (3) Bumps after lift-off of nose and main gear.  |   |   |   |   |  |

SIMULATOR STANDARDS (Cont'd)

SIMULATOR LEVEL

COMMENTS

|   | A | B | C | D |  |
|---|---|---|---|---|--|
| <p>(4) Buffet during extension and retraction of landing gear.</p> <p>(5) Buffet in the air due to flap and spoiler/speedbrake extension.</p> <p>(6) Stall buffet to, but not necessarily beyond, the FAA certificated stall speed, <math>V_s</math>.</p> <p>(7) Representative touchdown cues for main and nose gear.</p> <p>(8) Nosewheel scuffing.</p> <p>(9) Thrust effect with brakes set.</p>   |   |   |   |   |  |
| <p>f. Characteristic buffet motions that result from operation of the airplane (for example, high-speed buffet, extended landing gear, flaps, nosewheel 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. General</p> |   |   |   | X | Statement of Compliance. Tests required. |

SIMULATOR STANDARDS (Cont'd)

## SIMULATOR LEVEL

## COMMENTS

|  | A | B | C | D |   |
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| purpose disturbance models that approximate demonstrable flight test data are acceptable. Tests with recorded results which allow the comparison of relative amplitudes versus frequency are required.                           |   |   |   |   |   |
| 4. <u>VISUAL SYSTEMS.</u>  |   |   |   |   |   |
| a. Visual system capable of meeting all the standards of this appendix and appendices 2 and 3 (Validation and Functions and Subjective Tests Appendices) as applicable to the level of qualification requested by the applicant. | X | X | X | X |   |
| b. Optical system capable of providing at least a 45 degrees horizontal and 30 degrees vertical field of view simultaneously for each pilot.   | X | X |   |   |   |
| c. Continuous minimum collimated visual field of view of 75 degrees horizontal and 30 degrees vertical per pilot seat. Both pilot seat visual systems shall be able to be operated simultaneously.                               |   |   | X | X | Wide angle systems providing cross cockpit viewing must provide a minimum of 150 degrees horizontal field of view; 75 degrees per pilot seat operated simultaneously. |
| d. A means for recording the visual response time for visual systems qualified under AC 121-14C and subsequent.  | X | X | X | X |   |

SIMULATOR STANDARDS (Cont'd)

SIMULATOR LEVEL

COMMENTS

|   | A | B | C | D |  |
|---|---|---|---|---|--|
| <p>e. Verification of visual ground segment and visual scene content at a decision height on landing approach. The ATG should contain appropriate calculations and a drawing showing the pertinent data used to establish the airplane location and visual ground segment. Such data should include, but is not limited to:</p> <ul style="list-style-type: none"> <li>(1) Airport and runway used.</li> <li>(2) Glide slope transmitter location for the specified runway.</li> <li>(3) Position of the glide slope receiver antenna relative to the airplane main landing wheels.</li> <li>(4) Approach and runway light intensity setting.</li> <li>(5) Airplane pitch angle.</li> </ul> <p>The above parameters should be presented for the airplane in landing configuration and a main wheel height of 100 feet (30 meters) above the touchdown zone. The visual ground segment and scene content should be determined for a runway visual range of 1,200 feet or 350 meters.</p> | X | X | X | X |  |
| <p>f. For the NSPM to qualify precision weather minimum accuracy on simulators qualified under previous advisory circulars, operators must provide the information required in e. above.</p>  | X | X | X | X |  |

SIMULATOR STANDARDS (Cont'd)

## SIMULATOR LEVEL

## COMMENTS

|  | A | B | C | D |   |
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| g. Visual cues to assess sink rate and depth perception during takeoff and landing.  |   | X | X | X |   |
| h. Test procedures to quickly confirm visual system color, RVR, focus, intensity, level horizon, and attitude as compared to the simulator attitude indicator.   |   |   | X | X | Statement of Compliance.<br>Tests required. |
| i. Dusk scene to enable identification of a visible horizon and typical terrain characteristics such as fields, roads, bodies of water.  |   |   | X | X | Statement of Compliance.<br>Tests required. |
| j. A minimum of ten levels of occulting. This capability must be demonstrated by a visual model through each channel.  |   |   | X | X | Statement of Compliance.<br>Tests required. |
| k. Daylight, dusk, and night visual scenes w/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 |   |   |   | X | Statement of Compliance.<br>Tests required. |

SIMULATOR STANDARDS (Cont'd)

SIMULATOR LEVEL

COMMENTS

or 1,000 surfaces for daylight and 4,000 light points for night and dusk scenes, 6 foot-lamberts of light measured at the pilot's eye position (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 and will be retested at least yearly by the NSPM. Testing may be accomplished more frequently if there are indications that the performance is degrading on an accelerated basis. Compliance of the brightness capability may be demonstrated with a test pattern of white light using a spot photometer.

(1) Contrast Ratio. A raster drawn test pattern filling the entire visual scene (three or more channels) shall consist of a matrix of black and white squares no larger

| A | B | C | D |
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|   |   |   |   |

SIMULATOR STANDARDS (Cont'd)

SIMULATOR LEVEL

COMMENTS

than 10 degrees and no smaller than 5 degrees per square with a white square in the center of each channel.

Measurement shall be made on the center bright square for each channel using a 1 degree spot photometer. This value shall have a minimum brightness of 2 foot-lamberts. Measure any adjacent dark squares. The contrast ratio is the bright square value divided by dark square value.

Minimum test contrast ratio result is 5:1.

Note: Cockpit ambient light levels should be maintained at Level D (Phase III) requirements.

(2) Highlight Brightness Test.  
 Maintaining the full test pattern described above, superimpose a highlight area completely covering the center white square of each channel and measure the brightness using the 1 degree spot photometer. Light points or light point arrays are not acceptable. Use of calligraphic capabilities to enhance raster brightness is acceptable.

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SIMULATOR STANDARDS (Cont'd)

SIMULATOR LEVEL

COMMENTS

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|---|---|---|---|---|--|
| <p>(3) Resolution will be demonstrated by a test pattern of objects shown to occupy a visual angle of 3 arc-minutes in the visual scene from the pilot's eyepoint. This should be confirmed by calculations in the statement of compliance.</p>   |   |   |   |   |  |
| <p>(4) Light point size - not greater than 6 arc-minutes measured in a test pattern consisting of a single row of light points reduced in length until modulation is just discernible, a row of 40 lights will form a 4 degree angle or less.</p> |   |   |   |   |  |
| <p>(5) Light point contrast ratio - not less than 25:1 when a square of at least 1 degree filled (i.e., light point modulation is just discernible) with light points is compared to the adjacent background.</p>                                 |   |   |   |   |  |

