AC 121-14B

DATE 10/16/78

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
Washington, D.C.

FAR GUIDANCE MATERIAL

Subject: AIRCRAFT SIMULATOR AND VISUAL SYSTEM EVALUATION AND APPROVAL

1. PURPOSE. This advisory circular sets forth one means that would be acceptable to the Administrator for approval of aircraft simulators or other training devices requiring approval under Section 121.407 of the Federal Aviation Regulations.

2. CANCELLATION. AC 121-14A, Aircraft Simulator Evaluation and Approval, dated February 9, 1976, is canceled.

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 size, complexity, and operating costs of the modern turbojet transport and its operating environment point to greater use of the advanced technology now available in aircraft simulators. Simulators can provide more in-depth training than can be accomplished in the aircraft. There is also a very high percentage of transfer of learning from the simulator to the aircraft. The ultimate goal is 100 percent transfer at which time all training and checking could be accomplished in the simulator. The additional use of simulators in lieu of the aircraft results in great cost reductions for the operator and achieves the benefit of fuel conservation and a decrease in noise and exhaust 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

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time, a breakthrough in computerization has permitted the development of computer-generated light image visual systems. In December 1973, FAR Amendments 61-62 and 121-108 permitted additional use of visual simulators. Amendments to §121.439 of the FAR permitted a simulator approved for the landing maneuver to be substituted for the aircraft in a pilot recency of experience qualification. These changes to the FAR constituted a significant step toward the optimum use of aircraft simulators in flight training and checking.

4. SCOPE OF APPROVAL. Approval procedures which follow apply to specific maneuvers, procedures, and crewmember functions for which the user requests approval.

5. DEFINITIONS.

a. 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 aircraft manufacturer will provide aircraft data to the simulator manufacturer, which in the case of aircraft not yet flying will be predicted data. In the case of aircraft already flying, data obtained from the Airplane Flight Manual, Aircraft Type Inspection Report, or actual aircraft flight test data should be used. The data should be applicable to the specific aircraft and should be acceptable to the Administrator. In the event predicted data is used in programing the simulator, it should be updated as soon as practicable when actual aircraft flight test data becomes available.

b. The Customer Acceptance Test Guide is a group of simulator tests agreed to by a simulator manufacturer and its customer to verify the simulator's performance against the customer's simulator design specifications.

c. The Functional Test Guide is a group of simulator tests designed to verify that the performance characteristics of the simulator agrees with those of the airplane. This test guide is developed by an applicant and presented to the FAA when the applicant seeks approval of its simulator. The functional test guide should contain enough tests to demonstrate that the simulator's performance both static and dynamic agrees with that of the airplane in each area of training and checking for which approval is sought.

6. EVALUATION AND APPROVAL OF PROCEDURAL TRAINERS AND SIMULATION DEVICES. The operational evaluation philosophy contained in this circular is applicable to all pilot and flight engineer training and simulation devices for which the applicant seeks FAA approval as provided in §121.407. Any device which

does not meet the aircraft simulator requirements set forth in this circular will be considered a training device.

7. AIRCRAFT SIMULATOR REQUIREMENTS - GENERAL. When the applicant determines the aircraft simulator will meet the FAA approval requirements, the FAA should be notified with sufficient lead time to assure a mutually satisfactory date for an FAA evaluation. As appropriate, the following general requirements should be evaluated during the FAA aircraft simulator evaluation and approval process:

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

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 reasonably 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 aircraft should be entirely automatic in response to control movement by a crewmember.

e. 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 aircraft under actual flight conditions for any given change in forces applied to the controls, in the applied power, or in aircraft configurations.

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

g. Communications and navigation equipment should correspond to that installed in the applicant's aircraft and should operate within the tolerances prescribed for the actual airborne equipment.

h. In addition to the flightcrew stations, there should be two suitable seat accommodations for the Instructor/Check Airman and FAA Inspector. Operators who have the Check

Airman/Instructor occupy a crew position seat need only provide one additional observer seat. These seats should provide adequate vision to the pilot's panel and forward windows in visual system models. "Grandfather rights" prevail on previously approved simulators; however, efforts should be made to improve surveillance visibility. These observer seats need not represent the aircraft seats.

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

j. An Instructor Control Console should be installed to enable the Instructor/Check Airman or FAA Inspector (when applicable) to control the visual attachment (if installed) and insert abnormal or emergency conditions into the aircraft systems.

8. AIRCRAFT SIMULATOR INITIAL OPERATIONAL EVALUATION. The FAA evaluation will cover each maneuver and procedure for which the applicant has requested specific approval. The Functional Test Guide will be used in evaluating Flight Controllability (i.e., static stability, longitudinal stability - including configuration changes, roll rates, etc.). Simulator performance and system operation should be evaluated from each flight crewmember position. This should include the cockpit check, system operation, normal, abnormal and emergency procedures using the operator's manuals and checklists. Any shortcomings in the equipment that would preclude realistic simulation of the procedure, maneuver, or system operation should be identified. The following illustrates a typical sequence of ground and flight maneuvers which should be evaluated:

a. Preflight. Accomplish a thorough preflight of all switches, indicators, and systems at all crewmembers' stations.

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) Aborted takeoff.

(5) Normal takeoff.

(6) Takeoff with engine failure at V_1.

(7) Crosswind takeoff (maximum which has been demonstrated).

(8) Instrument takeoff.

(9) Landing gear, flap, slat operation (gear and flap retraction times).

(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 (one and two engines inoperative).

NOTE: During the above 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) Unusual attitudes.

(7) Specific flight characteristics.

(8) All systems operations associated with normal in-flight functions.

(9) 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 and with engine(s) inoperative.

(2) Landing gear and flap operation (time to extend), normal and abnormal extension.

(3) All engines approach and landing.

(4) Engine(s) out approach and landing (in the case of three- and four-engine aircraft, two engines inoperative).

(5) ILS approaches and landings:

(i) Normal.

(ii) Engine inoperative.

(iii) Category I.

(iv) Category II.

(v) Category III (if applicable).

(6) Nonprecision approaches.

(7) Circling approach (if appropriate).

(8) No flap approach.

(9) Auto-coupler, auto-throttle, auto-land approaches.

(10) Manually controlled ILS with and without flight director.

(11) All engines operating missed approach.

(12) Engine out missed approach.

(13) Rejected landing.

(14) Crosswind approach and landing.

(15) Navigation and communciations.

(16) 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. All Other Items for Which Operational Approval Has Been Requested.

9. AIRCRAFT SIMULATOR MOTION. Visual and nonvisual simulators should have motion to be approved for any of the maneuvers authorized in FAR 61, Appendix A, and FAR 121, Appendices E and F. To provide the maximum degree of realism, a six (6) axis freedom of motion system is desirable.

10. QUARTERLY EVALUATIONS. To ensure the continuing fidelity of the simulator, all simulators requiring approval under FAR 121.407 will be evaluated on a quarterly basis after the initial approval. Quarterly evaluations of simulators approved for the landing maneuver should include tests designed to evaluate some of the landing requirements outlined in paragraph 13 of this circular. A multi-channel recorder will be required for the landing maneuver tests. The performance requirements contained in this circular should be applied in quarterly evaluations.

11. SIMULATOR PERFORMANCE REQUIREMENTS. The specific performance standards contained in the customer's acceptance test guide should be used as a basis for determining that the simulator is performing to meet the performance requirements for an initial simulator approval. The following is a guide to the minimum performance standards acceptable for initial simulator approval. These standards should also be applied to quarterly evaluations. The applicant should provide a means of checking the performance requirements outlined in this paragraph. This may be accomplished by force gauges and, in those checks requiring more detailed readouts, by a multichannel recorder or a combination thereof, that may be required to accurately evaluate the programed data.

a. Performance Characteristics. (Weight and center of gravity optional within normal operating range.)

(1) Landing gear operating time: +/-3 seconds.

(2) Wing flap operating time: +/-3 seconds.

(3) Takeoff acceleration time to V_1: +/-5%.

(4) Calibration of gyrocompass and turn and bank indicator in standard rate turns and 30° banked turns: +/-5% of time to turn 180°.

(5) Minimum control speed - air: +/-5 knots.

(6) Stall warning speeds, stick shaker, buffet, stall: +/-5 knots.

(7) Propeller feathering time: +/-3 seconds (where applicable).

(8) Manifold pressure for a given BMEP and RPM: +/-1 inch (where applicable).

(9) Critical altitude piston engine similators: +/-800 feet or +/-10%.

(10) N_1 /N_2 relationship, turbine engine for a given EPR: +/-2%.

(11) Climb performance (all engines operative and engine(s) inoperative): +/-100 feet, or +/-5%.

(12) Speed vs. thrust in level flight at cruise altitude: +/-5 knots, 3%, or .03 mach.

b. Static Longitudinal Stability. Control forces during climb, cruise, approach, and landing should represent the applicable aircraft. The simulator should return to trim within +/-5 knots from a speed within 15% of trim speed. The direction of the elevator force, pull or push, should be in the same direction as the applicable aircraft elevator force.

c. Control Forces. Aircraft simulator control forces in the following areas should be within +/-3 pounds, or 10% of the forces encountered in the airplane whichever is greater (rudder forces, +/-5 pounds or +/-10%).

(1) Configuration changes to include gear, flaps, speed brakes (if applicable), power, and combinations thereof.

(2) Stick forces per "G".

d. Roll Rates. Airplane simulator roll rates in each operational configuration should be within +/-2 seconds or 10%.

e. Limited Data Area. In the following areas of performance where a minimum of data exists, adequacy of simulation should be based on training and checking requirements.

(1) Compressibility changes.

(2) Buffet at high mach numbers.

(3) Dutch roll.

(4) Emergency descent.

(5) Any other items that logically fall into this category.

12. SIMULATOR VISUAL SYSTEM REQUIREMENTS. Visual systems may be approved for a specific maneuver, procedure, or function

provided an evaluation indicates that the training and checking objectives can be accomplished as well as in the aircraft.

a. General Requirements.

(1) The visual scene should accurately portray the environment equivalent to that which the pilot observes on the related simulator cockpit instrument display resulting from the manipulation of the controls and the effects of varying wind conditions.

(2) The visual display may be either a monoview or duoview display. If a monoview display is used, it should be capable of transfer for display at either pilot station.

(3) The scene should comprise the airfield, surrounding area, airport ramp, and taxiway.

(4) Representations of buildings or other outstanding features should be suitably detailed to produce a realistic effect on picture presentation.

(5) Functional airfield and approach lighting should be ALSF-I or ALSF-II with intensity controls to vary degree of brightness. Approach, runway, and strobe lighting intensities should be independently variable. Realistic colors for approach, runway, and taxiway lighting are required. These cues should be considered for depth perception and the psychological effect of realism. Computer-generated image (CGI) systems should have the capability of portraying runway texture or surface.

(6) The aircraft landing lights should be operational.

(7) The optical system should be capable of providing at least a 45° field of vision. Focus should be automatic in order to keep at optimum that part of the picture which is significant to the pilot.

(8) An instructor's control panel should be provided to allow control of all aspects of the visual system; i.e., cloudbase, visibility in miles and feet, ILS frequency selector, environmental lighting controls, VASI, etc.

(9) Visual systems approved for instrument takeoffs and/or instrument approach procedures should have a means of reducing visibility to reasonably simulate the appropriate weather conditions.

(10) Operators possessing visual systems that do not meet all the requirements contained in this paragraph and have

received prior approval will have "grandfather rights." These systems will be eligible for continued approval for all maneuvers originally approved provided they are maintained to the level of acceptability demonstrated at original approval.

(11) All operators that purchased or placed firm order for CGI visual systems prior to July 1, 1974, and had those systems installed and approved by January 1, 1976, have "grandfather rights." These systems will be eligible for continued approval for all maneuvers originally approved without the feature of runway texture or surface. This includes Category II approaches and landings required by AC 120-29. All systems purchased by operators after July 1, 1974, should have runway texture or surface to be eligible for approval of maneuvers that require a visual segment; i.e., no flap approach, engine out at V_1, approach with engine(s) inoperative, landing in sequence from an ILS, rejected landing, etc.

(12) The "grandfather rights" referred to in this circular apply only to the original operator and are not transferable.

b. Performance Criteria. The performance capabilities of the visual system should meet at least the following:

(1) Cloudbase - From zero feet to a value in excess of 2,000 feet.

(2) Visibility - From zero to a value in excess of 10 miles.

(3) Terrain illumination - Night, day, or dusk.

(4) Airfield and approach lighting - On or off with appropriate intensity variations.

(5) Linear motion should cover an area in excess of 10 miles from approach end to 3 miles on missed approach end and 3 miles on either side of the runway.

(6) Linear velocities - Up to 250 knots, vertical rate of climb of 5,000 feet per minute, a "G" force of at least one transverse "G" for takeoff (capability of visual to accelerate with simulator on brake release).

(7) Angular motion - The following parameters are those desired to ensure synchronization of visual to simulator motion.

(i) Heading unlimited.

(ii) Roll unlimited.

(iii) Pitch - plus or minus 30°.

(iv) Rate of change of heading, pitch, and roll should be commensurate with simulator capabilities.

c. Picture Resolution. With the final picture resolution, the distances at which runway features are visible should not be less than those listed below. Distances are equivalent distances measured from runway threshold to an aircraft aligned with the runway on an extended 3° glide slope.

(1) Recognize runway and taxiways - minimum of 5 miles.

(2) Longitudinal separation of striped block on runway minimum of 2 miles for daylight scenes and within the range of the landing lights for night scenes.

(3) Complete runway detail - minimum of 1/2 mile for daylight scenes.

(4) Strobe, approach, and runway edge white lights - minimum of 5 miles.

(5) Centerline lights - minimum of 3 miles.

(6) Threshold lights (red and green) - minimum of 2 miles.

(7) Touchdown zone lights - minimum of 2 miles.

(8) VASI lights - minimum of 5 miles.

13. SIMULATOR LANDING MANEUVER REQUIREMENTS. The following is a guide to the additional requirements which should be met for approval of a simulator for the landing maneuver. Simulator and visual requirements listed in paragraphs 7, 11, and 12 also apply. Appendix 1 is an example illustrating a group of tests which might be included in a functional test guide to demonstrate compliance with these requirements when seeking initial approval of a simulator for the landing maneuver.

a. General.

(1) Actual aircraft flight test data should be used for simulator programing for the landing maneuver. If aircraft data is not available for any specific parameter, the operator should stipulate the basis/source of the data provided and a means of verification of this data. Each instance of this type will be evaluated by the Air Carrier Division, Flight Standards Service, to determine its acceptability.

(2) Electronic force gauges and multichannel recorder printouts are required to verify data relating to certain specific checks for the landing maneuver.

(3) Simulators and visual systems operating under "grandfather rights" should not be considered for landing maneuver approval.

(4) Although tolerances are specified in this paragraph for dynamic tests, other criteria such as the general trends and shapes of the flight variables concerned will also be considered in the evaluation of dynamic tests.

b. Ground Handling. The simulator should be programed to realistically portray the aircraft during ground operations. This should include transient effects of cockpit lateral acceleration and pitching effects in the motion. The following specific areas will be evaluated:

(1) Response to nosewheel steering.

(2) Response to nosewheel release from a turn.

(3) Speed effect on nosewheel steering response.

(4) Minimum radius turn.

(5) Rate of turn versus nosewheel angle.

(6) Rudder pedal steering (if applicable).

(7) Static and dynamic control forces.

(8) Asymmetrical braking and thrust response as it affects directional control.

(9) Engine failure.

(10) Crosswind.

(11) Pitching effects resulting from braking and engine power changes (reversing).

(12) Takeoff rotation.

(13) It is desirable to include the effects of runway contaminants (water, snow, ice) as they affect directional control and stopping distance.

c. Specific Effects. During a normal takeoff and landing motion cues of the following types should exist.

(1) Runway rumble reflecting effects of groundspeed.

(2) Buffets due to spoiler extension and thrust reversal, if such effects are applicable.

(3) Bumps after lift-off of nose and main gear should reflect those felt in the aircraft.

(4) Buffet during extension and retraction of landing gear.

(5) Buffet due to flap extension.

(6) Approach-to-stall buffet.

(7) Touchdown cues for main and nose gear.

d. Air/Ground Transition.

(1) Hands off landing flare +/-10 feet or +/-10% of altitude whichever is greater. The altitude, vertical speed, airspeed, and pitch attitude should have the same tendencies as the aircraft.

(2) Landing flare stick forces +/-3 pounds with an average pitch change of +/- 1/2°.

(3) Rotation stick forces +/-3 pounds or +/-10% whichever is greater.

(4) Takeoff acceleration time and distance to V_R, V_{LO}, and to 35 feet. +/-5% time and +/-5% distance or 200 feet whichever is greater.

(5) Stopping time and distance from initial breaking to full stop +/-5% time and +/-5% distance or 200 feet whichever is greater.

(6) It is desirable to include the effects of windshear and turbulence as it effects aircraft control.

e. Lateral Control.

(1) Cross control (steady sideslip) +/-2° wheel 1° bank and slip.

(2) Roll overshoot +/-1°.

(3) Roll response bank angle and heading deviation +/-10% or 2° within the first three seconds.

(4) Spiral stability +/-5% of time.

(5) Dutch roll dynamics +/-10% of the period and time to half amplitude.

(6) Engine out trim +/-1° bank and slip.

f. Longitudinal Control.

(1) Minimum control speed ground +/-5 knots.

(2) Minimum unstick speed +/-3 knots.

(3) Minimum rotate speed +/-3 knots.

(4) Longitudinal trims +/-.05 EPR; 1 unit of stabilizer trim; 1° pitch attitude.

(5) In-flight acceleration-deceleration +/-7% time.

(6) Flap change dynamics - Pitch, angle of attack, rate of climb, and airspeed variations from trim versus time +/-20%.

(7) Power change dynamics - Pitch, angle of attack, rate of climb, and airspeed variations from trim versus time +/-20%.

(8) Short period dynamics +/-10% of the period and time to half amplitude.

(9) Phugoid dynamics +/-10% of the period and time to half amplitude.

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APPENDIX 1

EXAMPLE - LANDING MANEUVER APPROVAL TESTS

A. MOTION SYSTEM CHECKS

1. Frequency Response Check.
2. Leg Balance Check.
3. Turn Around Check.
4. Special Effects.

B. CONTROL CHECKS

1. Pitch Control Force Static/Dynamic.
2. Roll Control Force Static/Dynamic.
3. Rudder Control Force Static/Dynamic.
4. Nosewheel Steering Force Static/Dynamic.
5. Rudder Pedal Steering Force.

C. TAXI

1. Nosewheel Scuffing.
2. Response to Nosewheel Release from a Turn.
3. Minimum Radius Turn.
4. Rate of Turn Versus Nosewheel Steering Angle.
5. Speed Effect on Nosewheel Steering.

D. TAKEOFF

1. Ground Acceleration Time and Distance.
2. Minimum Control Ground.
3. Minimum Rotate Speed.
4. Minimum Unstick Speed.

5. Normal Takeoff. *

6. Engine Out Takeoff. *

7. Crosswind Takeoff. *

E. CLIMB

1. Normal Climb.

2. Engine Out Second Segment Climb.

3. Engine Out Approach Climb.

4. Engine Out Landing Climb.

F. LONGITUDINAL CONTROL

1. Power Change Dynamics.

2. Flap Change Dynamics.

3. Gear and Flap Change Forces.

4. Gear and Flap Operating Times.

5. Longitudinal Trim Changes.

6. Longitudinal Maneuvering Stability.

7. Short Period Dynamics.

8. Phugoid Dynamics.

G. LATERAL CONTROL

1. Minimum Control Air.

2. Roll Response.

3. Roll Overshoot.

4. Spiral Stability.

5. Engine Out Trim.

6. Rudder Response.

7. Cross Control.

8. Dutch Roll Dynamics.

9. Stick Shaker, Airframe Buffet, Stall Speeds.

H. LANDING

1. Normal Landing. *

2. Hands Off Landing. *

3. Crosswind Landing. *

4. Stopping Time and Distance Wheel Brakes Only.

5. Stopping Time and Distance Reverse Thrust.

I. VISUAL SYSTEM

1. Visual Pitch, Roll, and Yaw Response.

2. Visual Cut-Off Angle and Distance.

3. No Flap Approach.

4. 50% PWR Approach.

5. ILS Capture and Approach on Autopilot.

J. SPECIAL EFFECTS

* For these tests at least the following aircraft data should be available to compare with the time history from the simulator multichannel recorder: pitch control force, roll control force, rudder control force, pitch attitude, angle of attack, airspeed, altitude, and time.

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