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Ames Research Center

Virtual-Image Display System for Flight Simulators

The problem:

Conventional visual flight simulators present television or movie displays of outside scenes to the pilot only. These simulators cannot provide coordinated flight training for the crews of large aircraft because the copilot cannot participate effectively in the simulation of cabin activities. Moreover, such displays lack the realism of actual flight, since they cannot provide real world visual cues with high fidelity, particularly for the critical aircraft takeoff and landing maneuvers.

The solution:

A dual TV monitor and collimated lens system in the windscreens of a standard aircraft cockpit simulator permits both the pilot and the copilot to simultaneously view the three-dimensional presentation. Proper design of the complete system permits the depth and viewpoint of the visual displays to be accurately presented.

How it's done:

The visual flight simulator consists of three groups of components: (1) an instrumented, fixed cockpit cabin, complete with an engine-sound system, wheel noise, and a control system which reacts realistically to the pilots' movements; (2) a pair of projection and collimated monitor viewing systems which present the "outside" view to the pilots; and (3) a color TV camera and an optical probe which scans a scale model of a runway and generates for the TV monitor a view corresponding to the flight attitude of the cockpit simulator as selected by the pilots.

The projection system is the conventional Schmidt type, with unity picture perspective magnification, color and black-and-white viewing capability, and a screen brightness gain of 2.5. The pilot's eye position for this system is located 10 ft from the screen, with a field of view of about 48° horizontal and 36° vertical and a maximum resolution of 7 min of arc. The collimated virtual image display system for each pilot consists of a 21 in. monitor, two 25 in. diameter plano-convex acrylic lenses (50 in. focal length), with a unity picture perspective field of view of 40.6° horizontal and 30.4° vertical. The collimated monitor display has a maximum resolution of 5 min of arc. Since the resolution of the human eye is about 1 min of arc, the TV scene lacks some of the detail available to a pilot in real situations. It was found that the collimated monitor scene is more acceptable to color TV viewing than to black and white TV.

The design of the optimum virtual-image lens system for visual simulation displays is based on the relationships among image distance, angular magnification, field of view, and exit-window diameter. Because of some undesirable characteristics of refractive lens systems, a compromise had to be made in order to maintain height-and-depth visual cues. This was accomplished by minimizing observations without disturbing the image area at sharp focus. Usually, the distance from the pilot's eye to the projection screen should be on the order of 10 ft. Calculations for the collimated monitor showed the best position of the image plane to be about 10.9 ft from the pilot's eye; therefore, 3 1/2 in. thick convex lenses were selected for location in the windscreen area, about 27 in. from the pilot's eye. Also, since the TV camera's photosensitive system is normally adjusted for a field of view of about 48°, the

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lens diameter was matched with the 21 in. monitor and selected to subtend the same field of view, thus preserving the linear perspective as seen by the pilot.

The system allows pilots the freedom to move their heads without receiving the impression that the field of view has shifted grossly. Moreover, since sufficient collimation has been achieved, visual transition from the instrument panel to the displayed outside scene is accomplished with normal eye accomodation, and the altitude-range perspective of the display approaches that of actual flight conditions.

An analog computer was programmed to represent a 6-degrees-of-freedom simulation of a DC-8 aircraft. The system includes longitudinal responses (both phugoid and short-period modes), lateral responses (including the spiral, roll subsidence, and Dutch-roll modes), and ground-effect characteristics. Several hundred experimental simulated flights were conducted for comparison of the TV virtual-image system with conventional TV projection systems, for both color and black-and-white viewing. Based upon the performance measures of the system and on comments of commercial airline pilots, it was concluded that color displays were far more satisfactory than black-and-white displays. Various flight maneuvers were more accurately performed and better picture quality and depth perception were provided with the color monitor display.

Note:

Requests for further information may be directed to:

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No patent action is contemplated by NASA.

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