

FLIGHT TEST OF A VISION DEVICE

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ABSTRACT

This paper describes flight test of a research external viewing device (REVD). The REVD was designed and flown as a substitute for forward vision through a wind screen, constructed of optical lenses and mirrors, and evaluated during approaches and landings. A NASA F-104 aircraft hosted the experiment to enable 25° glide slope approaches. Additionally, conventional 3° glide slope approaches were flown to evaluate the REVD for a hypothetical high-speed civil transport. The REVD was satisfactory for all approaches.

BACKGROUND

During December 1993 and January 1994, the NASA Dryden Flight Research Center (DFRC), Edwards Air Force Base, California, flight tested a vision display. The REVD was intended for pilots to use as their primary forward field of view (FOV) for landing aircraft. Forward field of view is very costly to provide for high-speed aircraft. The REVD was offered as an experimental alternative to conventional windows where the performance cost might be significant.

PHYSICAL DESCRIPTION

The REVD was an optical path composed of several lenses and mirrors. The display provided one-to-one registration, instantaneous FOV of approximately 30° by 30°, and resolution equal to or better than 3 mrad. The entry pupil was a mirror mounted at 45° under the aircraft fuselage (fig. 1). The exit pupil was collimated on a lens in the aft cockpit of the test aircraft (fig. 2). The entire optical column with housing weighed approximately 120 kg. The optics were effectively isolated from all aircraft vibrations.

A two-seat F-104 aircraft hosted the experiment. This aircraft was selected because its ability to fly steep approaches, ease of modification, and availability. The REVD was incorporated into the aft cockpit. The aft canopy was taped sufficiently to prevent observation of any

useful landing environment information from sources other than the REVD (fig. 3).

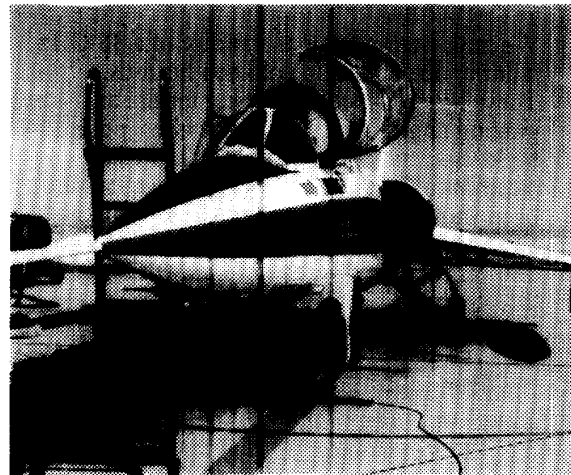


Figure 1. Entry pupil.

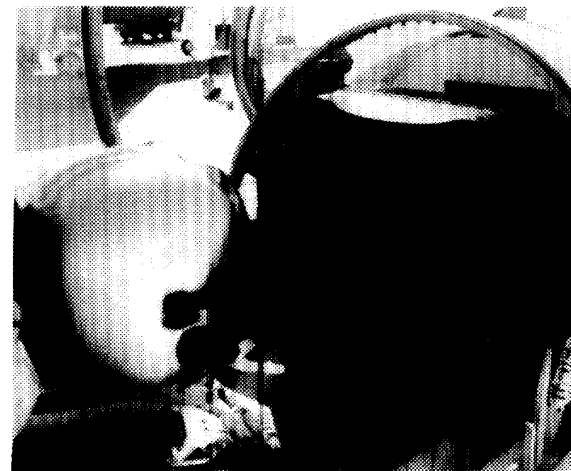


Figure 2. Exit pupil.



Figure 3. Taped aft canopy of the F-104 cockpit.

CONCEPT DEVELOPMENT AND FABRICATION

Inclusion of the REVD into the F-104 aircraft was the last step in a long history. The concept was proposed by engineers from General Dynamics, Fort Worth, Texas. They suggested that the concept be considered for the proposed X-30 National Aerospace Plane (NASP). Next, General Dynamics contracted with Kaiser Electro-Optics, Carlsbad, California, to provide the optics. Then, the NASP office completed fabrication with a contract to Systems Technology Incorporated (STI), Mountain View, California. Finally, DFRC modified the test aircraft and installed the REVD.

TEST PROGRAM

Installation of the REVD permitted the initiation of flight testing to qualitatively evaluate the utility of this device as

the sole source of visual information for landing the aircraft. A secondary objective of collecting enough data to enable analysis of certain pilot models at STI was desired. Because of aircraft failures, the flight test program ended before the second objective could be achieved.

The evaluation consisted of 3° and 25° glide slope approaches which were initiated from a 20° to 40° bank turn onto final approach without the runway in sight. Some of the low-angle approaches were corrected from about a 400-ft lateral offset at 300 ft above the ground. Similarly, some of the steep approaches were corrected from about a 500-ft offset at 1500 to 1700 ft above the ground. All approaches were flown to touch down.

The flight test matrix consisted of 7 flights, 30 steep approaches, and 14 shallow approaches (table 1). The seven flights were flown from the back cockpit. Full stop landings were included. The canopy cover was included for all flights except flight 1884.

RESULTS AND DISCUSSION

This section summarizes qualitative observations regarding the REVD. The REVD provided landing scene information equivalent to traditional aircraft forward wind screens. Although the REVD had a slightly different color and provided only about 30° FOV, no information required for landing an F-104 aircraft from steep and shallow approaches was lost.

Resolution was equal to or greater than that of human vision. The REVD initially experienced substantial airframe vibration. This vibration was accommodated by isolation mounting such that no image movement was visible.

The REVD provided sufficient FOV for landing. Sensitivity to this parameter was exposed by landing with about 20° FOV. Although adequate landings could be effected with the smaller FOV, my anxiety and dependence on prior experience with the landing environment increased. If the wider FOV were decreased or increased by 5 or 10 percent, I would have been ambivalent. If the smaller FOV were

Table 1. Flight test matrix.

Flight	Date	Approaches			Comments
		Steep	Shallow	Total	
1884	23 Dec 93	6	1	7	Canopy uncovered
1885	7 Jan 94	6	1	7	Canopy covered
1886	10 Jan 94	0	1	1	Tail hook came down
1887	11 Jan 94	0	5	5	Gear doors would not close
1888	11 Jan 94	5	1	6	
1889	19 Jan 94	6	2	8	Small field of view
1890	24 Jan 94	7	3	10	One approach to lakebed 15

decreased by similar amounts, I would have been much more anxious about safely completing the landing. Similarly, if it were increased by 5 or 10 percent, I would have anticipated less compensation to complete the landing. The wider FOV appeared to be insensitive to small changes. Meanwhile, the smaller FOV appeared to be very sensitive to small changes.

Safety pilots noted repeated lateral drifts during the final seconds of flare. I attribute such drifts to three decreasingly important characteristics. First, minimum sink rate at touch down is the primary objective as long as lateral drift is small. Because no rudder pedals exist in the aft cockpit, I could only correct lateral drift with lateral stick. I was more sensitive to sink rate than to small lateral drift and reluctant to mix lateral with pitch stick inputs. Second, the 8 or 10 in. above the ground at the REVD entry pupil made it difficult to detect lateral drift at elevations of 1 or 2 ft above the runway. Finally, the reduced FOV may not have provided adequate information. Smaller FOV systems which were mounted 6 or 8 ft higher evidenced no lateral drift. I, therefore, conclude that extremely low-entry pupil and lack of yaw control were the primary causes of uncorrected lateral drift.

During several steep approaches, the runway could not be seen until preflare. These approaches were unsatisfactory because of anxiety associated with an inability to judge aircraft position relative to the runway. Including the approach end of the runway in the FOV is very important once the aircraft is established on nominal high final approach. Most

approaches were initiated with the evaluation pilot acquiring the runway from a 20° to 40° bank turn onto final. No difficulty was evident in acquiring centerline or in correcting to centerline as deviations were recognized. Late corrections to centerline were examined, but no change in this conclusion resulted.

RECOMMENDATIONS

The qualitative observations noted in the Results and Discussion section infer two immediate recommendations for future efforts. Approaches to landings should be evaluated using television or other imaging devices. These results should be compared with those obtained using a pure optical display, such as the REVD. Preferably, the comparison would involve flying an approach to landing with one system followed by a repeat of the same procedures using the other system. Pilot work load, anxiety, and compensation parameters should be extensively measured. Landing performance measurements should also be taken.

An interesting consequence of such instruments as the REVD is that they decouple crew station locations from places where windows are conveniently accommodated. Aircraft may exist in which the crew would be highly useful but not easily accommodated, for example, by the payload which tends to be near the center of gravity. Evaluating landing an aircraft with the crew station installed in different locations could prove interesting and useful.