EFFECT OF FIELD OF VIEW ON PERFORMING A LOW ALTITUDE MANEUVERING TASK

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ABSTRACT

Visual systems with a single window display are often utilized in ground based simulators used to study helicopter flying qualities during visual low altitude maneuvering tasks. The effects of this limited field of view (FOV) on pilot assessments of flying qualities are uncertain. A study was conducted using a variable stability UH-1H helicopter to compare restricted and unrestricted FOV for a range of flying qualities. With the restricted FOV, the pilots reported reduced ground track precision owing to loss of visual contact with the course markers. However, the predictable ground track of the repeated S-turn task with no obstacles made it easy for them to anticipate their maneuvers, and resulted in only a slight degradation of pilot ratings. This degradation was not sensitive to large changes in helicopter flying qualities.

INTRODUCTION

Factors that can affect the fidelity of ground based simulation include the mathematical model, visual system, motion system, aural cueing, cockpit layout, and environmental conditions. Visual systems with a single window display are often utilized in the ground based simulators used to study helicopter flying qualities. The purpose of this experiment was to evaluate the effects of FOV restrictions on the pilot's perception of flying qualities for a low altitude maneuvering task. The study was conducted using a variable stability helicopter, with the evaluation pilot's FOV restricted to that of a single window simulator display. The procedures described in (1) and (2) were used to restrict the field of view. To determine the sensitivity of FOV effects to large changes in handling qualities, modified helicopter flying qualities configurations were selected from those used in the experiment reported in (3); they are summarized in Table 1. The four FOV configurations used in this experiment are defined in Table 2.

EXPERIMENTAL APPROACH

FOV Setup Procedures

The simulator FOV with respect to pilot design eyepoint was measured using the specially adapted transit shown in Figure 1. This FOV was then mapped onto the test helicopter windscreen, as shown in Figure 2. Orange masking film was installed on the inside of the aircraft windscreen, except for the mapped area. When viewed through the blue visor (Fig. 3) all sections of the aircraft windscreen covered by the orange masking film become opaque. Objects viewed through the mapped window appeared to the pilot as different shades of gray. The light transmission characteristics of the orange masking film and blue visor are presented in Figure 4. In the right seat, the safety pilot had only a small loss of visual acuity looking through the orange masking film. On bright, sunny days, the safety pilot used the sun visor on his helmet to reduce the glare from the orange masking film. No flying was conducted under IMC or at night because of safety considerations.

Evaluation Task

The FOV flight experiment was conducted at Ames Research Center's flight research facility at Crow's Landing in conjunction with the flying qualities experiment described in (3). The task consisted of low altitude maneuvering around a series of markers, set up along an 8,000 ft runway (Fig. 5). The pilots were instructed to traverse the course while using the 1,000 ft runway markers as points around which to turn the helicopter fuselage without considering rotor blade clearance. The pilots were also instructed to maintain an airspeed of 60 knots and, for safety, an altitude of 100 ft.

Data Acquisition

Quantitative flight data were recorded by an on board analog magnetic tape recorder and were also telemetered to a ground station for real time monitoring and postflight analysis. Variables recorded included control positions, attitudes, rates, accelerations, airspeed, and altitude. A tracking radar produced ground track data for real time x-y plots. For each FOV configuration, the pilots provided an overall Cooper-Harper handling qualities rating and specific commentary on the precision of control through the course. A Cooper-Harper rating scale is shown in Figure 6.

RESULTS AND DISCUSSION

The results of this experiment are presented in the form of qualitative pilot opinion ratings and comments (Table 3) and quantitative flight data (Table 4 and Figures 8 and 9).

Pilot Ratings and Commentary

For the task used in this experiment, the pilot ratings were not, in general, sensitive to restrictions in FOV. This was true for large changes in aircraft flying qualities. The best flying qualities configuration, UH-1H manual mode (MAN), with no FOV restrictions was given a handling qualities rating (HQR) of 3, and the worst flying qualities configuration (R8.5, defined as sluggish and highly coupled) was rated about 7.5. With these same flying qualities configurations, the restricted FOV did not produce degradations greater than 1 HQR for pilots familiar with the task. Only pilot R, who initially was not familiar with the task, rated the good (MAN) configuration at 5 on his initial run with a restricted FOV. The rating was lowered to 4.5 and 4 for the second and third runs, respectively. However, these ratings, which reflect pilot learning, did not converge to the 3 rating that the pilot gave the nonrestricted FOV case. Pilot D reported a maximum degradation of 1 HQR with the restricted FOV on the initial qualitative checkout flight. Subsequent flights by pilots D, G, M, and T failed to produce greater than a one-half HQR degradation, as shown in Figure 7. On his first flight, pilot M actually rated the restricted FOV case better than the unrestricted case for the highly damped, highly coupled R8.5 configuration, as shown in Figure 7 and Table 3. However, on his second flight, he rated both restricted and unrestricted FOV the same for configuration R8.5. The fact that all pilots except pilot R were familiar with the task from the experiment reported in reference 3, and that the flight course was predictable, may have influenced these evaluations. Pilot T noted that it required only one pass through the course to be able to guess where the next marker was located, and that a more difficult course, tighter turns, or a less predictable flightpath might have shown a greater effect due to limiting the field of view.

Control Activity Statistics

A statistical summary of lateral and longitudinal control positions, series-servo positions, aircraft rates, and attitudes for selected data runs is presented in Table 4. For the good handling qualities configuration (SBO*) the data show very little difference between the restricted and unrestricted FOV cases. For the poor handling qualities configuration (R8.5), the restricted FOV resulted in a small reduction in standard deviations, especially for the longitudinal parameters.

Aircraft Flightpath Control

The moderately high altitude (100 ft) at which the task was flown meant that precise aircraft flightpath cues were not available. In addition, the pilots reported losing ground track precision because of loss of visual contact with the course markers during runs with the restricted FOV. However, most portions of the radar derived ground track plots shown in Figures 8 and 9 indicate a relatively close correlation in ground track between restricted and unrestricted FOV runs. This may imply that the predictable course layout of repeated S-turns with no obstacles made it easy for the pilots to anticipate their maneuvers.

The pilots also experienced difficulty in judging aircraft height above the ground with the restricted FOV without referring to the radar altimeter. This was attributed to the lack of peripheral cues with the restricted FOV and the high reference altitude above ground level.

Related Flight Program

Previous unpublished restricted FOV flight tests performed at Ames Research Center in December 1973 using a UH-1B helicopter produced similar qualitative results for low level day flying. Those tests consisted of performing a number of basic low level helicopter maneuvers, including takeoff, landing, precision hover, pedal turns, and air taxi tasks; the maneuvers were performed over a runway with no obstacles or traffic to monitor. Maneuvers were performed with no FOV restrictions, with a helmet fitted with a visor that restricted the pilot's FOV to 48° × 34°, and also with opaque material used to mask off the windscreen to produce a 48° × 34° FOV. A slight degradation in performance was reported for the case with the visor. This was attributed to the fact that inadvertent head movement could be interpreted as an attitude change of the aircraft causing the pilot to make undesirable control inputs. With the masked windscreen, the pilot was able to maintain a performance level comparable with the unrestricted FOV case.

FOV Requirements for Nap-of-the-Earth Flight

The FOV effects on flying qualities ratings for the task used in this experiment may not apply to a course requiring the pilot to fly around real obstacles or to actual Nap-of-the-Earth (NOE) flight. With the restricted FOV, the pilot would be unable to monitor rotor blade clearance in confined areas or monitor flightpath during sideward or rearward flight. Reference 4 reported the operational suitability evaluation of the UH-60A helicopter in an advanced attack helicopter role which involved low level, contour flight and NOE flight. The most critical reduction in visibility in the utility helicopter compared with that in the attack helicopter was the pilots' inability to see the main rotor at the 90° point. During the evaluation, this accounted for six blade strikes by the utility helicopter crew; there were no blade strikes by the attack helicopter crew. Other limitations of the utility helicopter that were noted included limitations in overhead visibility and downward visibility both to the left and right.

Attempts to establish a realistic NOE task for the experiment reported in (3) and the experiment reported herein were not successful. Safety precautions required that a minimum altitude of 100 ft be used. The necessity to monitor both the aircraft and real time telemetered data required that the experiment be conducted in the immediate vicinity of the Crow's Landing data station. Installation of high obstacles to fly around was precluded because they would have interfered with other air traffic at Crow's landing.

CONCLUSIONS

The flight experiment described in this paper was conducted to determine the effects of field of view (FOV) on helicopter flying qualities when a low altitude maneuvering task was performed. The task consisted of flying "S-turns" over a series of runway markers, separated 1,000 ft longitudinally and 250 ft laterally, at an airspeed of 60 knots and at an altitude of 100 ft. Qualitative and quantitative results were obtained for the nominal FOV of a UH-1H helicopter and with the FOV restricted to that of a simulator with a single window visual system. FOV effects were evaluated on the basic test helicopter and on a variety of configurations with degraded flying qualities. From the limited data obtained during this experiment and from related data discussed in this paper, the following trends and conclusions are noted:

1. The results showed only a minimal variation in pilot flying qualities ratings and statistical data while performing this task with restricted and unrestricted FOV. Restricting the FOV resulted in a maximum degradation of one pilot rating even for configurations with widely differing flying qualities.

2. The predictable ground track of the repeated S-turn course, the relatively high altitude, and lack of obstacles, made it easy for the pilots to anticipate their maneuvers and did not

demand high precision. These factors appeared to lessen the effect of reduced field of view.

3. The restricted FOV made height control difficult and required a frequent scan of the radar altimeter to maintain the reference altitude.

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TABLE 1. EXPERIMENT FLYING QUALITIES CONFIGURATIONS

Configuration	Description
MAN	Manual mode or basic UH-1H helicopter
SBO*	Manual mode using the series servos in the automatic flight control system. Approximately same characteristics as basic helicopter with increased yaw damping, $N_r = -3.5\ sec^{-1}$
R4	Roll damping (L_p) = $-4\ sec^{-1}$ Cross coupling (L_q/L_p), (M_p/M_q) = 0
R4.5	Roll damping (L_p) = $-4\ sec^{-1}$ Cross coupling (L_q/L_p), (M_p/M_q) = 0.5
R8	Roll damping (L_p) = $-8\ sec^{-1}$ Cross coupling (L_q/L_p), (M_p/M_q) = 0
R8.5	Roll damping (L_p) = $-8\ sec^{-1}$ Cross coupling (L_q/L_p), (M_p/M_q) = 0.5

Note: During the experiment, the lateral control sensitivity (L_δ) was held at 0.55 rad/sec^2/in., and the longitudinal control sensitivity (M_δ) was held at 0.14 rad/sec^2/in.

TABLE 2. EXPERIMENT FIELD OF VIEW CONFIGURATIONS

Configuration	Description
1	No FOV restrictions
2	Pilot wearing blue visor, no orange masking film on windscreen
3	Helicopter windscreen covered by orange masking film except for a clear 48° × 36° area in front of the evaluation pilot; no blue visor
4	Pilot wearing blue visor, orange masking film on windscreen

TABLE 3. SUMMARY OF PILOT HANDLING QUALITIES RATINGS

Configurations: Helicopter	Configurations: Visual	Pilot	Pilot rating	Pilot Comments
MAN	1	D	3	
	2	D	3	Acuity reduced, but workload still the same
	3	D	3	Orange glare in bright sunlight
	4	D	4	Like simulator with restricted FOV; height perception poor; turns no problems, but cannot see what you are turning towards
MAN	1	G	3†	
	4	G	3-3.5	Feels slow; cannot see pylon as you go by it; would be a problem in real NOE flight; gray appearance from blue visor no problem
	4	G	3-3.5	
MAN	1	R	3	
	4	R	5	Pilot not familiar with task; excursions in yaw exaggerated (especially turbulence); airspeed seems slower; difficult to judge height with limited FOV, tended to get low; more comfortable after learning period
	4	R	4.5	
	4	R	4	
MAN	1	G	3†	
	3	G	3.5	Helicopter handles well
	3	G	3.5	
	4	G	4	
R8	1	G	5.5†	
	4	G	5	
R8.5	1	G	6.5†	
	4	G	6	Poor altitude control, poor airspeed control because of helicopter configuration
SBO*	1	M	3.5†	
	3	M	3	Used sun visor to reduce annoyance from orange masking film glare (sun visor not lifted until R8.5 configuration; made seeing airspeed indicator difficult for pilot for runs with blue visor)
	4	M	3.5	Difficult to see airspeed indicator for instrument cross-check; would use next marker as guide on when to turn after losing sight of marker being passed over
R4	1	M	4†	
	3	M	3.5	A little more control activity required
	4	M	4	
R4.5	1	M	5†	
	3	M	4.5	Significant increase in control activity; no real problem with FOV, but think lack of peripheral cues makes difference on accuracy in flying course
	4	M	5	
R8	1	M	5†	
	3	M	4.5	Sluggish, large inputs required; lack of peripheral vision caused pilot to let deviations build up larger than with full FOV
	4	M	5	
R8.5	1	M	7†	
	3	M	6	Configuration very uncomfortable, jerky; required almost full lateral control coming out of the turns
	4	M	4.5	Felt more comfortable with restrictive FOV, seemed more accurate with task and in better control

†Averaged data from (3).

TABLE 3. CONCLUDED

Configurations		Pilot	Pilot rating	Pilot Comments
Helicopter	Visual			
SBO*	3	T	3	
	4	T	3.5	Visual acuity good, everything clear; only takes one pass through course even when you cannot see markers to guess where next one will be; a more difficult course or tighter turns or a less predictable flightpath might show up in worst ratings
R4	3	T	3.5	
	4	T	3.5	Very little difference in running course with restricted FOV
R4.5	3	T	4.5	
	4	T	4.5	Airspeed control more difficult; cannot tell airspeed by looking outside
R8	3	T	4	
	4	T	4	
R8.5	3	T	7	
	4	T	6	
SBO*	1	D	3†	
	3	D	3.5	
	4	D	3.5	Can see enough going out of a turn or into a turn to complete course
R8	1	D	5†	
	3	D	5	Definite degradation in flying qualities
	4	D	5	
R8.5	1	D	7†	
	3	D	7	
	4	D	7	Do not think FOV degrades this configuration much; biggest problem is the almost sustained oscillation of airframe
SBO*	1	M	3.5†	
	1	M	4	Roll sensitivity felt high; gained 40 ft but was able to correct; airspeed control was good
SBO*	3	M	4	Used the clear area of windscreen mostly; problem with airspeed not FOV
SBO*	4	M	4	Had to use airspeed indicator due to lack of peripheral cues
R8.5	1	M	7†	
	1	M	7.5-8	Configuration has loping motion; cannot establish precise bank angle, altitude or airspeed
R8.5	1	M	7.5	Large control inputs required; problems with airspeed, altitude, roll sensitivity, and damping
R8.5	3	M	7.5	
R8.5	4	M	7.5-8	Very uncomfortable

†Averaged data from (3).

TABLE 4. STANDARD DEVIATION SUMMARY FOR SELECTED LATERAL AND LONGITUDINAL PARAMETERS

Pilot Pilot rating Helicopter configuration Visual configuration	M† 3.5 SBO* 1	M 3 SBO* 3	M 3 SBO* 4	D† 3 SBO* 1	D 3.5 SBO* 3	D 3.5 SBO* 4	M 6 R8.5 3	M 4.5 R8.5 4	D 7 R8.5 3	D 7 R8.5 4
Standard deviations										
Lateral cyclic, in.	0.61	0.60	0.60	0.86	0.75	0.74	0.81	0.73	1.41	1.15
Lateral series servo, deg swashplate	0.99	0.77	0.76	1.36	0.96	0.94	0.83	0.80	1.07	1.00
Roll rate, deg/sec	5.66	5.38	5.15	8.70	7.16	6.78	5.08	4.78	7.99	6.90
Roll attitude, deg	16.62	16.47	14.60	21.38	19.51	19.70	14.88	14.37	21.24	18.39
Longitudinal cyclic, in.	0.23	0.28	0.22	0.42	0.32	0.32	1.17	0.54	1.12	0.82
Longitudinal series servo, deg swashplate	0.43	0.44	0.34	0.76	0.50	0.45	0.54	0.46	0.71	0.71
Pitch rate, deg/sec	1.73	1.92	1.54	3.60	2.34	1.95	2.07	1.49	3.57	2.77
Pitch attitude, deg	1.41	1.72	1.41	2.35	1.83	1.56	3.15	1.54	2.41	1.59

†Data from (3).

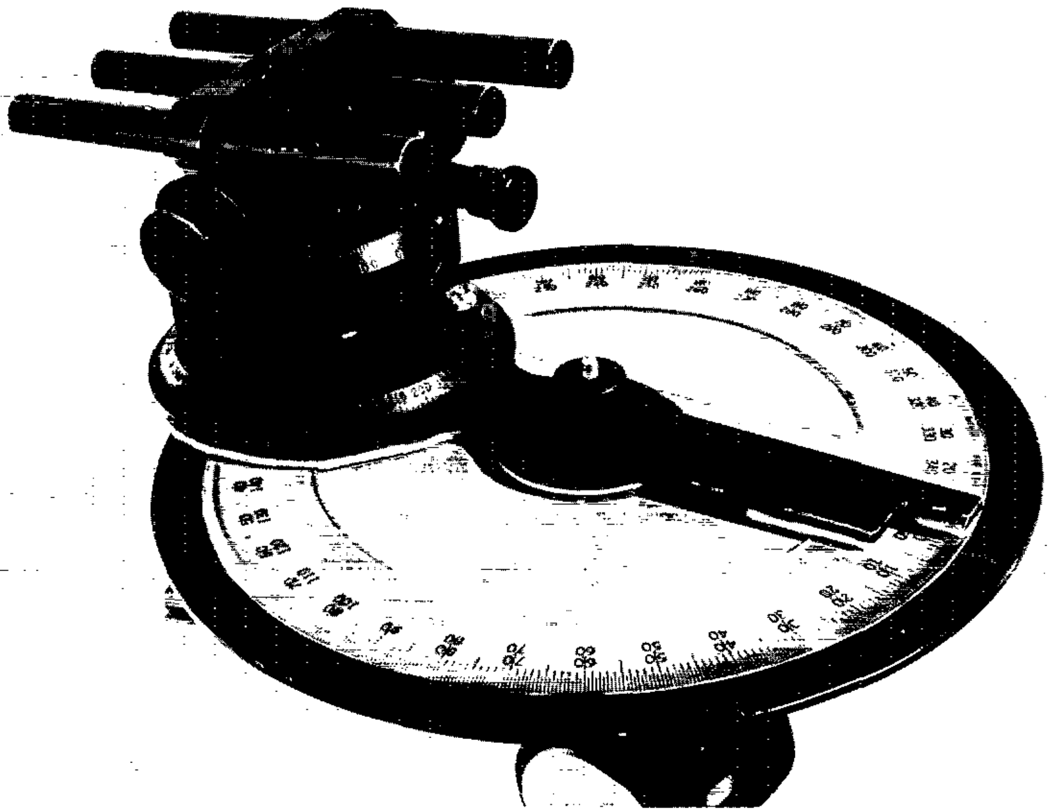


Figure 1. Field of View Transit

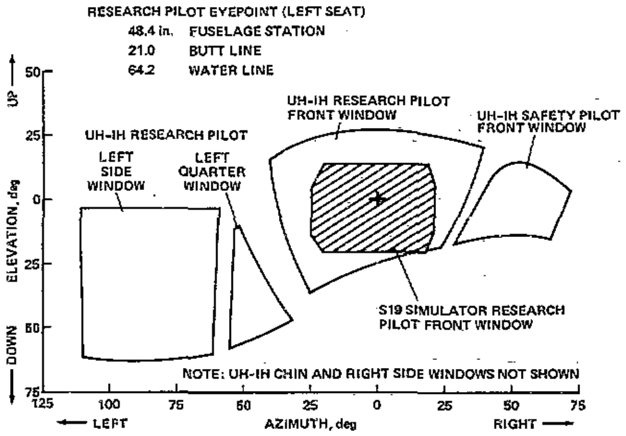


Figure 2. UH-IH Helicopter and S19 Simulator Vision Plot

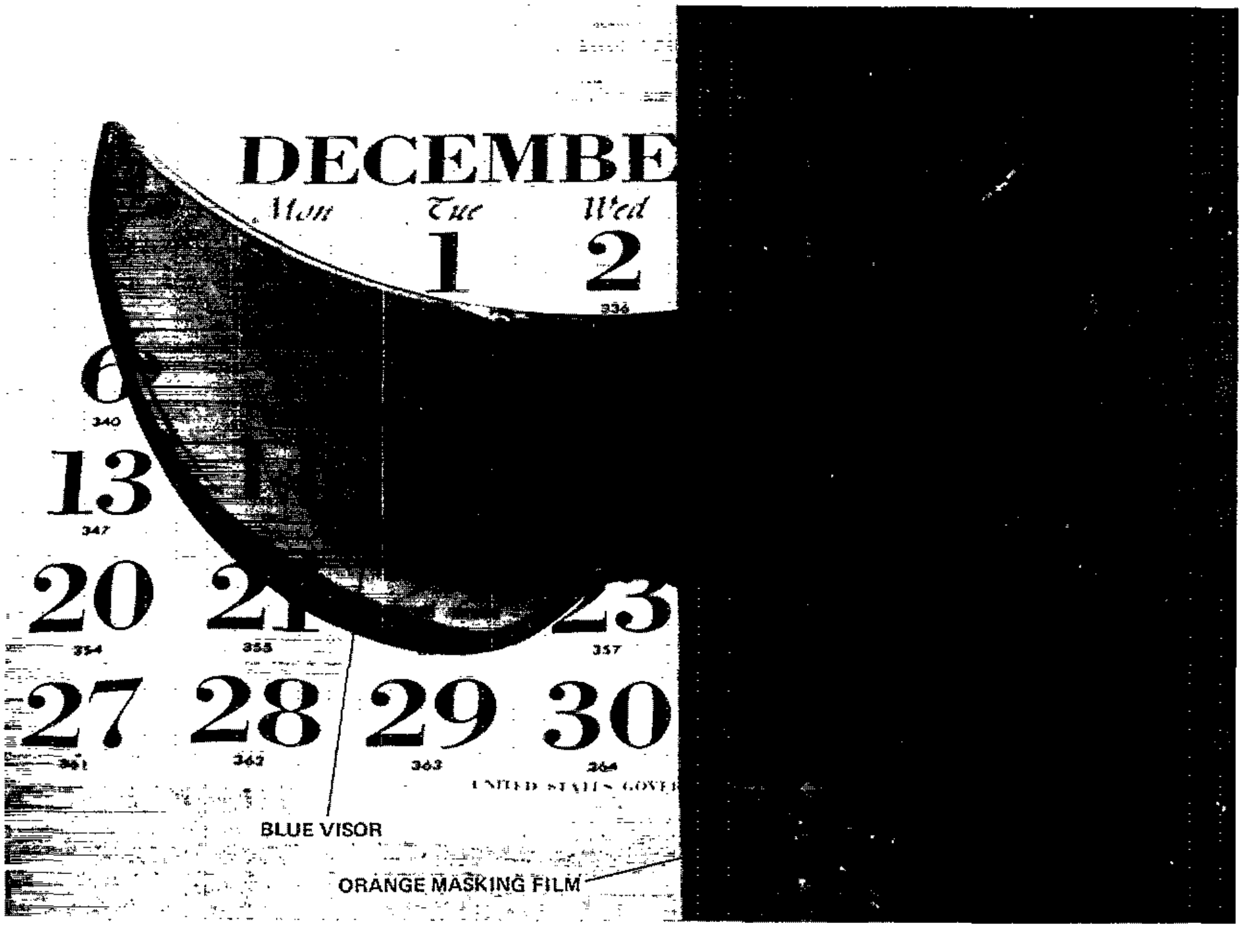


Figure 3. Blue Visor and Orange Masking Film

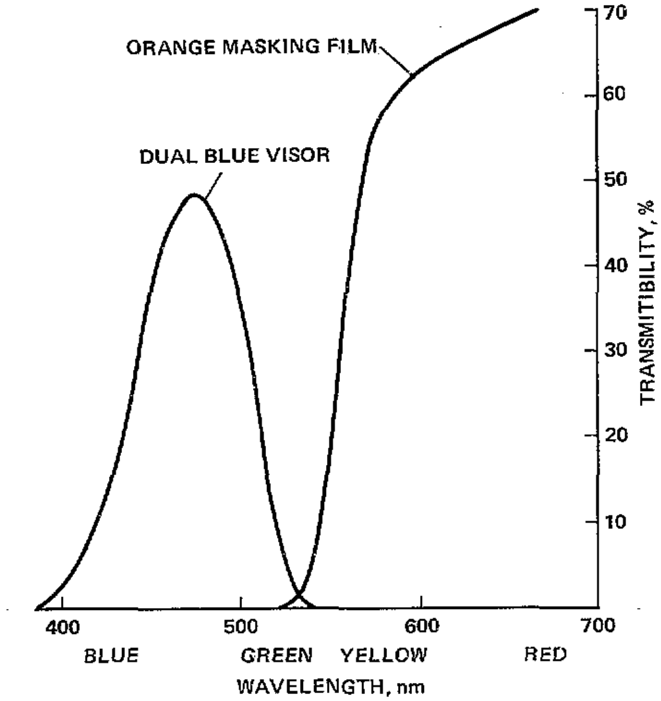


Figure 4. Light Transmission Characteristics

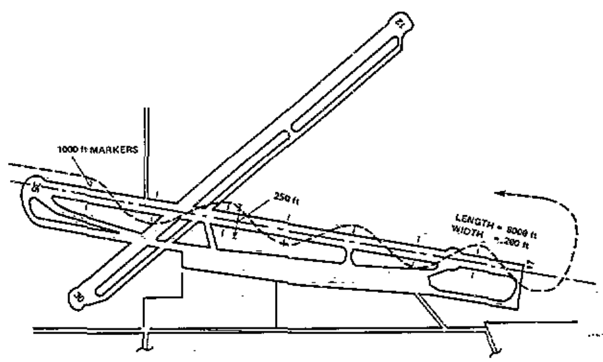
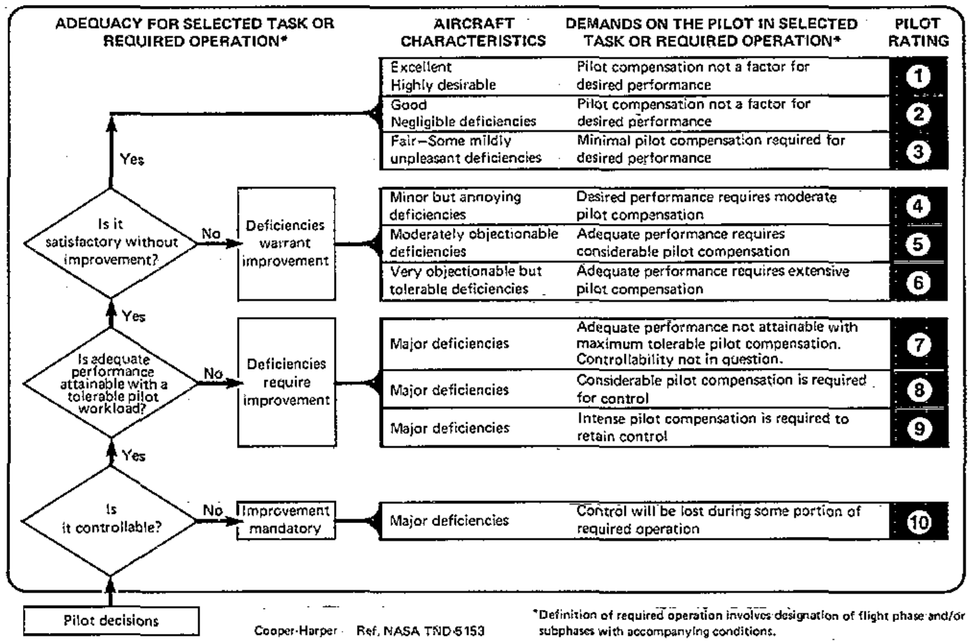


Figure 5. Low Altitude Maneuvering Course Task



DEFINITIONS FROM TN-D-5153

COMPENSATION

The measure of additional pilot effort and attention required to maintain a given level of performance in the face of deficient vehicle characteristics.

HANDLING QUALITIES

Those qualities or characteristics of an aircraft that govern the ease and precision with which a pilot is able to perform the tasks required in support of an aircraft role.

MISSION

The composite of pilot-vehicle functions that must be performed to fulfill operational requirements. May be specified for a role, complete flight, flight phase, or flight subphase.

PERFORMANCE

The precision of control with respect to aircraft movement that a pilot is able to achieve in performing a task. (Pilot-vehicle performance is a measure of handling performance. Pilot performance is a measure of the manner or efficiency with which a pilot moves the principal controls in performing a task.)

ROLE

The function or purpose that defines the primary use of an aircraft.

TASK

The actual work assigned a pilot to be performed in completion of or as representative of a designated flight segment.

WORKLOAD

The integrated physical and mental effort required to perform a specified piloting task.

Figure 6. Handling Qualities Rating Scale

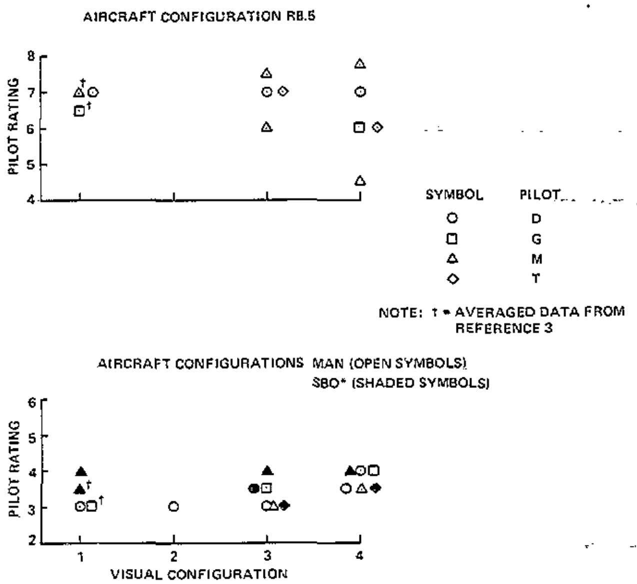


Figure 7. Effect of Visual Configuration on Pilot Ratings for Selected Aircraft Configurations

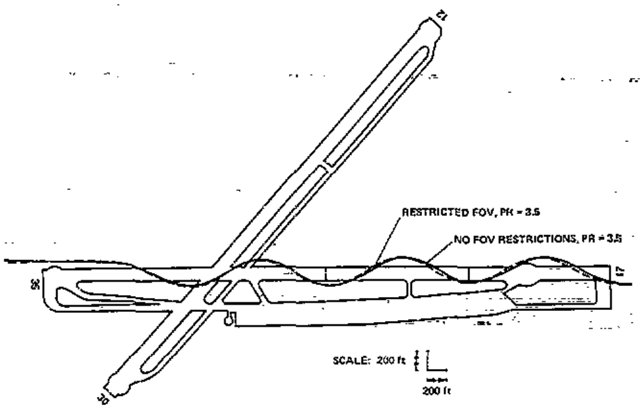


Figure 8. Ground Track Plot Showing Effects of FOV for Configuration SBO*: Pilot D

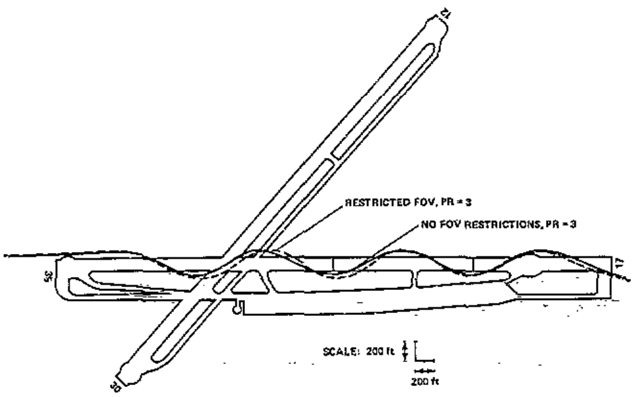


Figure 9. Ground Track Plot Showing Effects of FOV for Configuration SBO*: Pilot M

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