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FLIGHT INVESTIGATION OF THE LANDING TASK IN A JET TRAINER WITH RESTRICTED FIELDS OF VIEW

by John J. Perry, William H. Dana, and Donald C. Bacon, Jr.

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SUMMARY

A total of 155 landings were made in a T-33A jet aircraft in order to determine the relationship between the pilot's field of view and his performance of the landing maneuver. The field of view was reduced from unrestricted to a minimum of 0.10 radian (5.7°) horizontal and 0.52 radian (30°) vertical. The pilot's task was to fly a 180° power-on pattern and final approach and land the aircraft on a predetermined point on the runway. Also, power-off 360° overhead and straight-in approaches were performed by one of the pilots. The quality of the performance of the power-on task was measured by recording touchdown error. Pilot comments were obtained for all flights.

Performance of the power-on landing task, as measured by touchdown error, was not appreciably affected by the reduction of the field of view. However, pilot comments indicate that even the smallest restrictions of the field of view adversely affected the performance of the task.

INTRODUCTION

A flight program was conducted at the NASA Flight Research Center to gather data on the effects of field of view on the pilot's ability to perform the landing maneuver. A single restricted field of view had been evaluated in flight previously as part of the study of reference 1. In that investigation, the task was to land a transport aircraft from a straight-in approach with the runway almost always in the field of view. The results indicated no significant degradation of performance as a result of the restricted field of view.

In the Flight Research Center investigation, a 180° pattern was chosen so that the effects of field of view on pattern control, as well as on approach and landing, could be investigated. A series of power-on landings was made in a T-33A jet trainer with the canopy masked in varying degrees. Touchdown error was used to measure the quality of the pilots' performance of the landing maneuver, and pilot comments on the total task were recorded. In addition, 360° overhead and straight-in approaches were performed with power off and were evaluated qualitatively. The results of all the landings made by four research pilots during the investigation are summarized in this paper.

SYMBOLS

The units used for the physical quantities in this paper are given, where applicable, in both the International System of Units (SI) and U.S. Customary Units. Factors relating the two systems are presented in reference 2.

H hypothesis

n number of trials

S standard deviation

$$t' = \frac{\mu_i - \mu_j}{\sqrt{\frac{S_i^2}{n_i} + \frac{S_j^2}{n_j}}}$$

$t_{\alpha/2;d}$ statistical-table variable, where α = confidence level and d = degrees of freedom

X touchdown error (+ denotes long, - denotes short of desired touchdown point), meters (feet)

$\overline{X}$ average touchdown error, meters (feet)

$\overline{|X|}$ average of the absolute values of touchdown error, meters (feet)

μ hypothesis test parameter

Subscripts:

i, j, k integral indices

EQUIPMENT

A T-33A jet aircraft (fig. 1) was used as the test vehicle for this program. The aircraft was flown with tip tanks installed. The weight at touchdown varied between 6130 kilograms (13,500 pounds) and 4540 kilograms (10,000 pounds). The indicated airspeed at touchdown varied between 57 meters per second (110 knots) and 49 meters per second (95 knots).

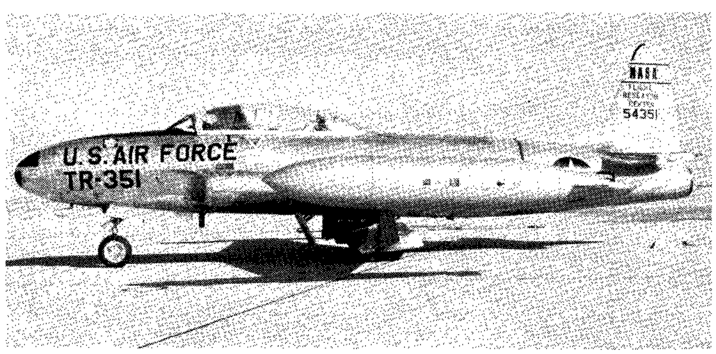
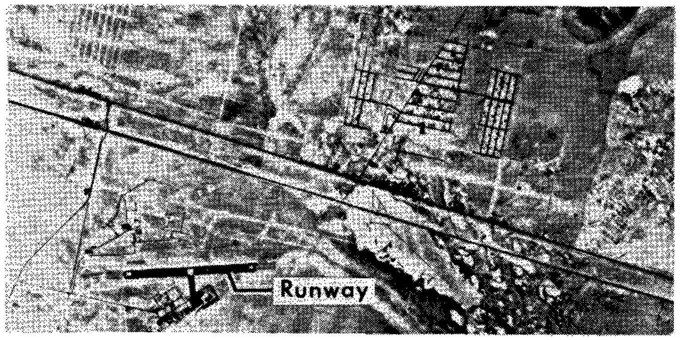
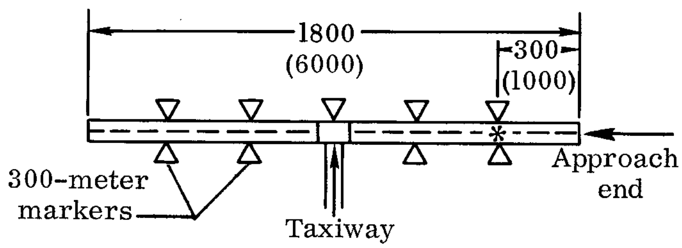


Figure 1.– Test vehicle (T-33A jet trainer).

The asphalt runway used was 1800 meters (6000 feet) long with markers on both sides at 300-meter (1000-foot) intervals (figs. 2(a) and 2(b)). The predetermined touchdown point was the marker nearest the runway threshold.



(a) Aerial photo of area in vicinity of runway.



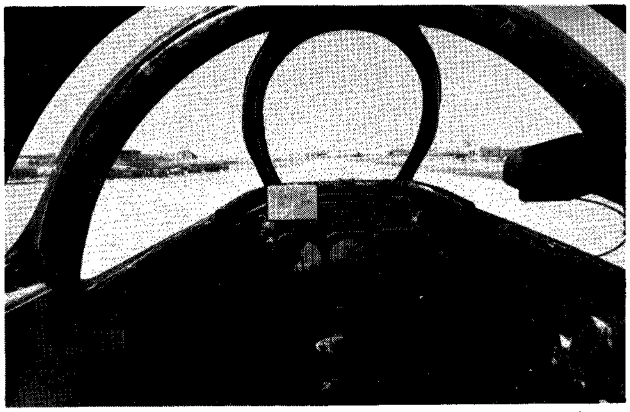
(b) Sketch of runway and desired touchdown point (*). Dimensions in meters (feet).

Figure 2.— Ground features of pattern area and runway.

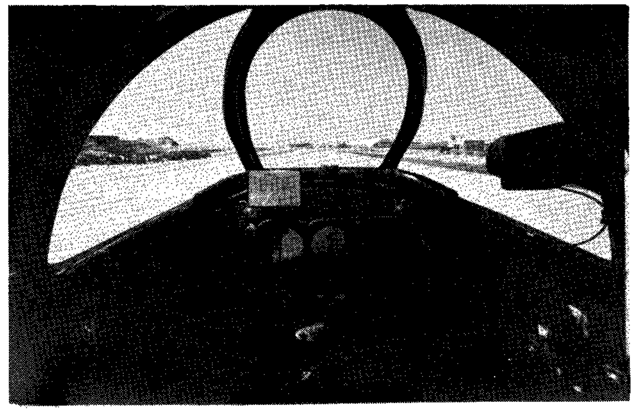
The field of view was restricted by using amber cellulose acetate to partially cover the inside of the canopy and windshield (figs. 3(a) to 3(g)) and by requiring the subject pilot to wear a blue visor. This particular blue-amber combination produced

(a) Closeup side view of T-33A showing cockpit masking and subject pilot.

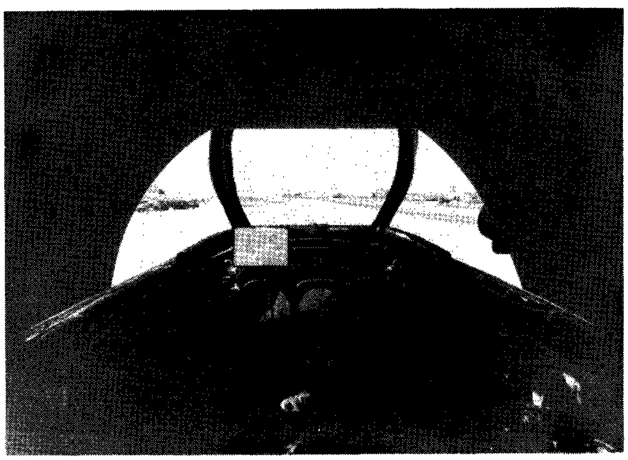
Figure 3.— Test configuration.



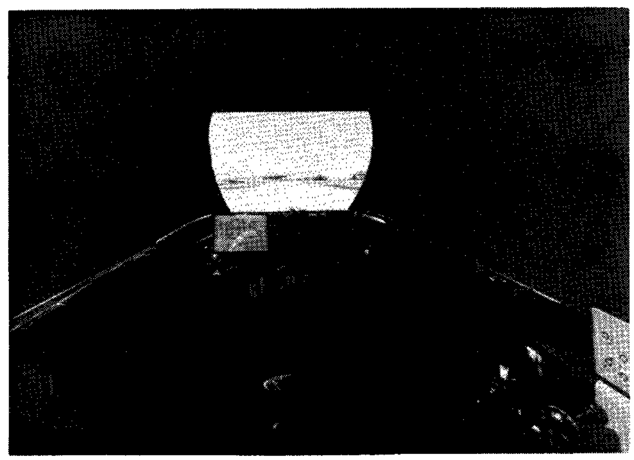
(b) Field of view A.



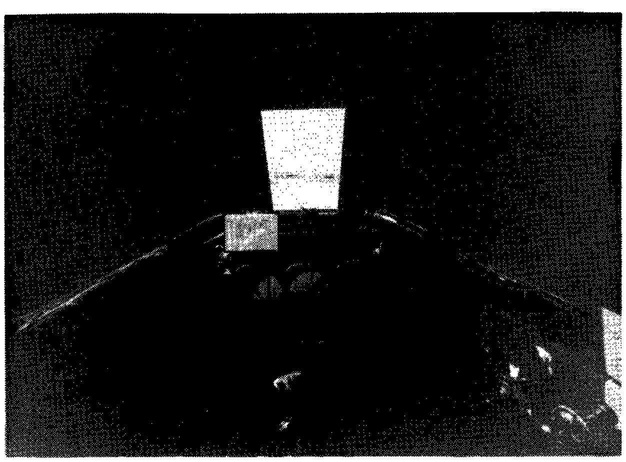
(c) Field of view B.



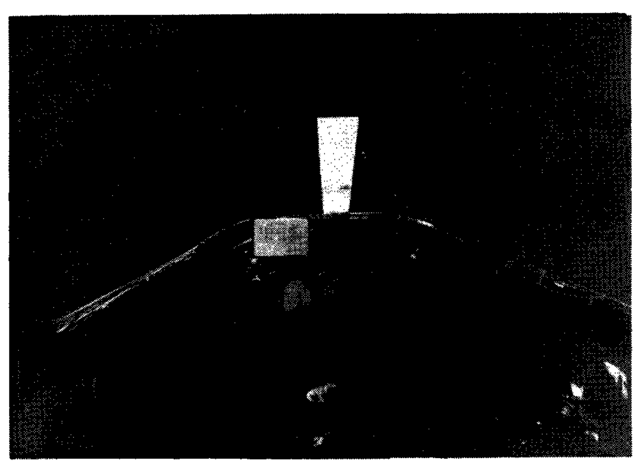
(d) Field of view C.



(e) Field of view D.



(f) Field of view E.



(g) Field of view F.

Figure 3.— Concluded.

a near-perfect mask. This technique was used instead of a single opaque mask in order to provide vision for the safety pilot in the rear cockpit while masking the subject pilot's view. The dimensions of the restricted fields of view, A to F, are presented in table I.

TABLE I.– DIMENSIONS FOR EACH RESTRICTED FIELD OF VIEW INVESTIGATED

Field of view	Horizontal dimensions, radians (degrees)	Vertical dimensions, radians (degrees)
A	2.44 (140)	1.29 (74)
B	1.69 (97)	.72 (41)
C	1.17 (67)	.52 (30)
D	.63 (36)	.52 (30)
E	.32 (18.3)	.52 (30)
F	.10 (5.7)	.52 (30)

TESTS AND PROCEDURES

Four experienced research pilots performed landings at unrestricted and six different restricted fields of view. A total of 155 landings were performed. The sequence of flights for each pilot is shown in table II. All flights except one were made under visual-flight conditions with a surface wind velocity less than 5 meters per second (10 knots); during one flight, the wind velocity increased to 9 meters per second (18 knots).

TABLE II.– SEQUENCE OF RESTRICTED AND UNRESTRICTED FIELDS OF VIEW EVALUATED BY EACH SUBJECT PILOT

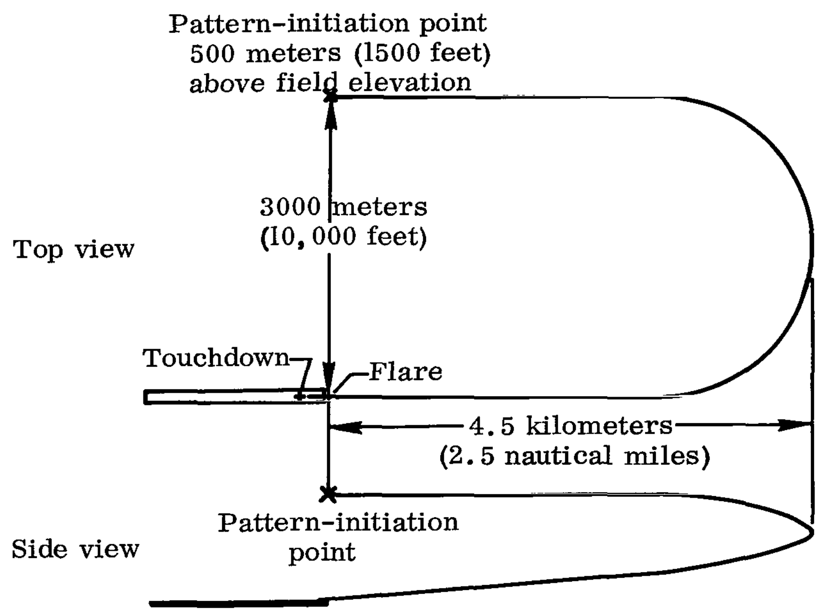
Flight	Pilot 1	Pilot 2	Pilot 3	Pilot 4
1	[1]U(1)	U(1)	U(1)	U(1)
2	A	B	B	B
3	B	C	C	C
4	C	A	D	E
5	D	D	A	D
6	E	E	E	A
7	F	U(2)	U(2)	U(2)
8	[2]U(2)	----	F	F

[1]U(1) denotes initial flight with unrestricted field of view.

[2]U(2) denotes final flight with unrestricted field of view.

The safety pilot set up the following conditions at the start of each pattern: 3000 meters (10,000 feet) abeam and 500 meters (1500 feet) above the desired touchdown point, on the downwind leg of the pattern, at an airspeed of 72 meters per second (140 knots). On the early flights, in addition to this task and his safety role, the safety pilot also recorded airspeed at touchdown and estimated touchdown error.

At the desired pattern-initiation point (fig. 4(a)), with airspeed, trim, and aircraft configuration set, the subject pilot was given control of the aircraft. He was in complete control for the remainder of the flight, which included downwind leg, 180° final turn, final approach, landing, and takeoff. At each field of view, the pilot flew three power-on approaches and landings for practice and five to obtain data. The first and last, or next to last, flights by each pilot were performed with an unrestricted field of view.

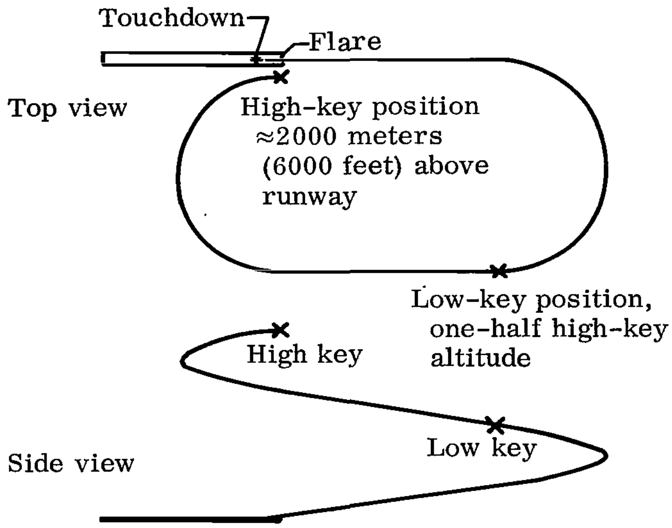


(a) 180° approach.

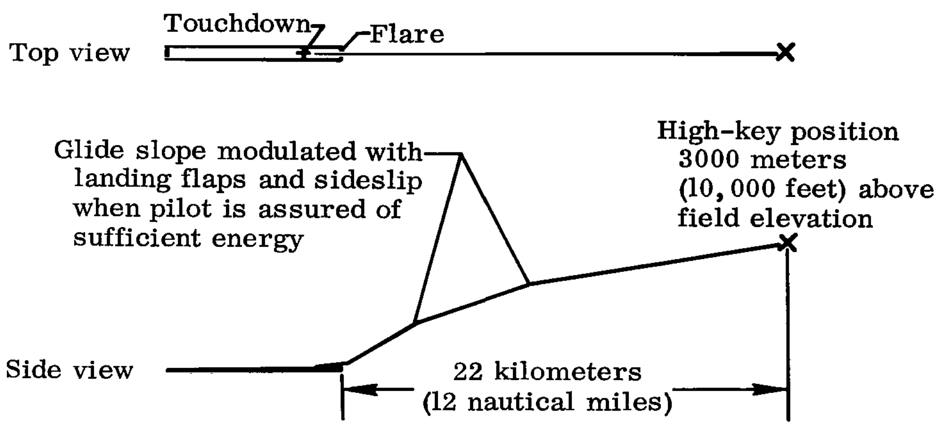
Figure 4.— Illustration of approaches.

In addition to the power-on approaches performed for data, one pilot performed power-off, 360° overhead and straight-in approaches at several fields of view (figs. 4(b) and 4(c)). Pattern control within an area with which the pilot was familiar was evaluated qualitatively by the pilot at each field of view.

Touchdown errors were measured by ground observers to within 1.5 meters (5 feet) of the actual touchdown point by reference to a particular quarter of the 6-meter (20-foot) runway centerline segments.



(b) 360° overhead approach.



(c) Straight-in approach.

Figure 4.— Concluded.

RESULTS AND DISCUSSION

The landing task was evaluated through the use of observed touchdown error data and comments from the subject pilots. Touchdown error data from the landings, which were performed from a 180° power-on approach, are presented in table III and figure 5. All the pilots commented on these landings, and one pilot commented on landings made from 360° and straight-in power-off approaches (figs. 4(b) and 4(c)).

There are two sets of data points for which unforeseen influences might have increased the error. The first of these is the flight at field of view D for pilot 3. The pilot elected to complete this flight even though a crosswind developed that was greater (9 meters per second (18 knots)) than the experiment limit (5 meters per second (10 knots)). Secondly, the touchdown error data for the flight at field of view U(1) for pilot 1 were estimated by the safety pilot. A check of the previous estimates by this safety pilot showed that he was within 2.75 meters (9 feet) of the average values calculated from ground-observer records.

It is recognized that the T-33 airplane has very satisfactory landing characteristics that enable approaches to be made from shallow angles even with power off. The ability to perform landings at restricted fields of view may change if an aircraft with different landing characteristics is used or if the task is performed with different experimental guidelines.

TABLE III.– TOUCHDOWN ERRORS FOR ALL LANDINGS

Pilot	Touchdown error, meters (feet)[1]							
	Field of view							
	[2]U(1)	A	B	C	D	E	F	[3]U(2)
1	+61 (+200)	-57 (-187)	-9 (-30)	+9 (+31)	+13 (+42)	+16 (+54)	+61 (+200)	-37 (-120)
	-21 (-70)	-12 (-39)	-39 (-127)	-18 (-58)	-17 (-56)	-11 (-36)	+9 (+30)	-28 (-91)
	+15 (+50)	-26 (-86)	-15 (-49)	-20 (-66)	-11 (-37)	+10 (+32)	0 (0)	-51 (-166)
	-61 (-200)	-14 (-45)	-18 (-58)	-54 (-178)	-33 (-108)	-30 (-99)	-9 (-29)	+7 (+23)
	+46 (+150)	-6 (-20)	+13 (+42)	-28 (-93)	+2 (+8)	-9 (-30)	+22 (+71)	-40 (-132)
2	+38 (+126)	0 (+1)	-18 (-58)	-48 (-158)	-9 (-31)	-31 (-103)	--- -----	-33 (-108)
	-38 (-123)	-26 (-87)	-8 (-27)	-10 (-34)	-48 (-158)	-11 (-37)	--- -----	-9 (-28)
	-14 (-46)	+4 (+13)	-38 (-125)	-21 (-70)	-11 (-36)	+12 (+40)	--- -----	-42 (-139)
	+8 (+25)	+28 (+92)	0 (0)	-4 (-13)	-41 (-134)	-6 (-20)	--- -----	-12 (-39)
	-10 (-32)	-10 (-32)	-4 (-13)	-5 (-18)	-13 (-42)	-20 (-66)	--- -----	-8 (-27)
3	+28 (+92)	+7 (+22)	-1 (-3)	-33 (-108)	+7 (+23)	-16 (-53)	+7 (+24)	+6 (+21)
	-6 (-21)	+8 (+26)	-1 (-3)	+1 (+2)	-33 (-108)	-6 (-19)	+6 (+19)	+6 (+21)
	-18 (-58)	+8 (+27)	-26 (-85)	-30 (-97)	-6 (-19)	-12 (-39)	+1 (+2)	0 (+1)
	+13 (+42)	-2 (-8)	0 (0)	+13 (+42)	+8 (+27)	-9 (-31)	-46 (-151)	+7 (+22)
	+14 (+47)	+10 (+33)	-1 (-2)	-52 (-171)	-28 (-92)	-26 (-86)	-42 (-138)	+13 (+42)
4	+17 (+56)	-9 (-31)	+5 (+16)	-1 (-3)	+18 (+59)	+2 (+6)	-4 (-13)	+5 (+17)
	+5 (+17)	-11 (-36)	-6 (-19)	0 (+1)	+19 (+62)	-39 (-128)	-3 (-11)	+5 (+17)
	-25 (-82)	-1 (-2)	-14 (-46)	+10 (+33)	+18 (+59)	+28 (+92)	-10 (-32)	-7 (-24)
	-33 (-108)	0 (-1)	-48 (-158)	-9 (-28)	+13 (+42)	+2 (+7)	-20 (-66)	-5 (-18)
	+1 (+2)	-9 (-29)	-14 (-45)	+19 (+61)	+2 (+5)	-9 (-29)	-10 (-34)	+4 (+12)

[1] + denotes long, - denotes short of desired mark; measured in feet.

[2] U(1) denotes initial flight with unrestricted field of view.

[3] U(2) denotes final flight with unrestricted field of view.

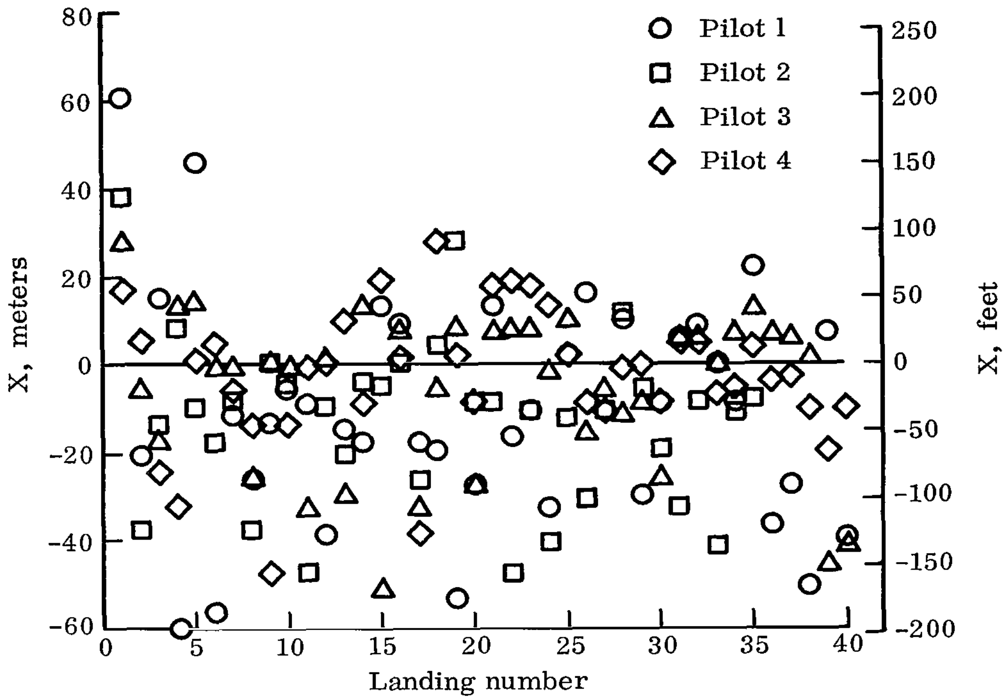


Figure 5.– All touchdown errors as a function of landing number for each pilot. $\bar{X}$ = -7.3 meters (24 feet).

Pilot Comments

Other than touchdown error, which was measured quantitatively, effects of reduced field of view were evaluated qualitatively by the subject pilots. Their comments are included in the following two sections. Comments on the circling approaches (180° power on and 360° power off) are combined because of the similarity of the observations for all circling approaches.

180° and 360° approaches.– Even the least restrictive field of view, A, compromised collision-avoidance capability. It also caused the runway to be out of sight for some portion of the circling (180° and 360°) approaches, which forced the pilot to fly this portion of the pattern by reference to geographic landmarks (fig. 2(a)) and the aircraft altimeter.

At field of view B and other more restricted fields of view during the 180° approach, the references defining the touchdown point (a runway marker on one side of the runway and a vehicle parked on the other side) disappeared from sight during the final approach appreciably before touchdown. Thus, the pilot had to acquire another target for touchdown. Three of the pilots determined which dash of the dashed runway centerline was at the touchdown point and aimed for it after the prescribed touchdown references had disappeared from sight. Pilot 1 did not develop this technique and ascribed a portion of his touchdown error at the lower fields of view to loss of sight of the touchdown targets.

At field of view B the first difficulty arose in establishing a high-key position for the 360° approach. High key is normally established by flying toward the runway until it disappears under the nose of the aircraft, at which time short periods of banked flight are used to obtain visual contact with the runway through the side canopy. As side vision was restricted, the use of banked flight for maintaining sight of the runway became ineffective farther from the overhead position. The distance from the high key at which banked flight was rendered ineffective became significant at field of view B. From this point, the pilot had to estimate the time required to fly to high key and begin his approach at this estimated position.

As the experiment progressed, various piloting techniques for reducing touchdown error at the expense of other parameters were observed. All the pilots eventually resorted to long, exaggeratedly shallow approaches which allowed them to arrive over the runway threshold at the minimum safe altitude. This altitude of 1 to 2 feet was then maintained, to the best of the pilot's ability under the experiment conditions, until the aircraft was over the desired touchdown point. At this point, most pilots "dumped" the aircraft onto the runway by releasing back pressure on the stick, knowing that the rate of sink incurred would not be disastrous. One pilot used a variation of the "dumping" technique in which he cycled the ailerons rather violently, thus killing lift and increasing drag to accomplish touchdown at the desired spot without regard for rate of sink.

It was at field of view C that shallowing of the approach and "dumping" the aircraft when over the desired touchdown point became obvious. Smoothness of longitudinal control also began to deteriorate as a result of the loss of perception of deviation from the desired glide path until large errors existed. Large corrections were then made, and smoothness of control diminished. Also at field of view C, banked flight for high-key determination during the 360° approach was useless. Once the landing runway disappeared from sight under the nose of the aircraft, it was not reacquired until the last few degrees of the final turn. Successful overhead approaches were performed, but the pilot acknowledged that a certain amount of luck was involved in properly estimating the time required to fly from the point at which visual contact with the runway was lost to the high-key position. Some loss of perception of glide-path angle occurred on the final approach, similar to that experienced during 180° power-on approaches.

At field of view D, it was no longer possible to acquire sight of the runway during the final turn of the 180° approach. Therefore, the first glimpse of the runway was on final approach, which caused the runway centerline to be consistently overshot or undershot. Loss of glide-path and sink-rate perception became more acute than with field of view C.

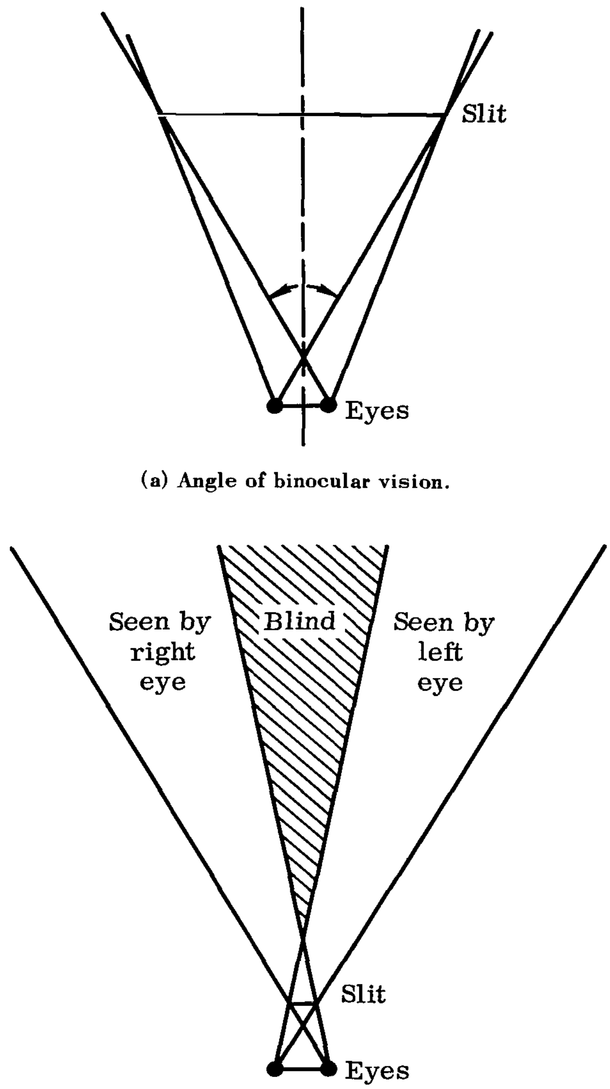
A successful 360° overhead approach was accomplished at field of view D by the pilot who had performed the overhead approaches at field of view C. No further loss of visual contact with the landing runway during the approach was incurred by this reduction of the field of view, except for a slightly later reacquisition of the runway at the end of the final turn. Since it was obvious that further reduction of field of view would not have resulted in appreciable further loss of sight of the runway during overhead approaches, none were performed at fields of view smaller than D. Some further loss of perception of glide-path angle on the final approach occurred at field of view D. This inadequacy undoubtedly would have been amplified had power-off approaches been performed at smaller fields of view.

At field of view E, the runway disappeared from sight on the final leg of the 180° approach during small heading corrections. This was annoying to the pilots, but they did not consider it to be a serious problem. Loss of glide-path and sink-rate perception became more acute than with field of view D.

At field of view F, the width of the opening in the windshield was narrower than the pilots' interpupillary distance, which caused the loss of binocular vision illustrated in figures 6(a) and 6(b). The right eye and the left eye saw different parts of the outside world, with a blank area between. Three pilots reported that they ignored the information gathered by one eye and effectively flew with the use of the other eye. One pilot reported that he closed his left eye and used only his right eye.

Although the smoothness of longitudinal control deteriorated progressively with fields of view below C, there was no loss of precision in the control of bank angle, heading, or position over the runway centerline. Also, at no time was the safety pilot required to take control of the aircraft or to abort a landing.

Straight-in approaches.– Successful straight-in power-off approaches were performed at fields of view A, B, C, and D. Pilot performance was not adversely affected by the restriction of field of view except for slight loss of perception of proper glide-path angle at the smaller fields of view similar to that experienced on final approach during 180° power-on and 360° overhead approaches.



(a) Angle of binocular vision.

(b) Effect of slit narrower than interpupillary distance. Not drawn to scale.

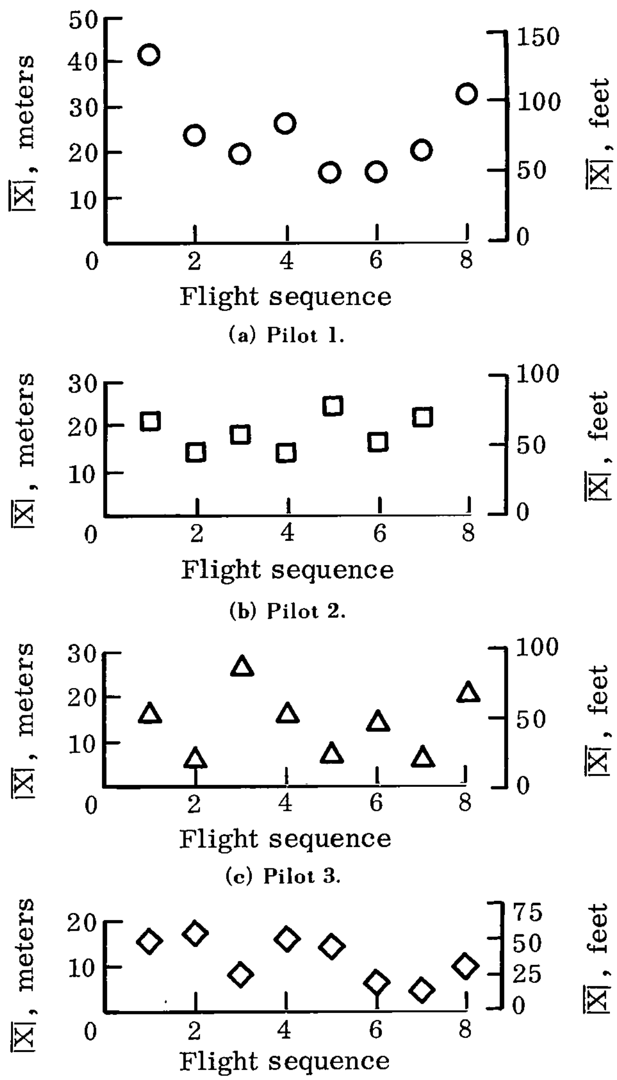
Figure 6.– Field of vision.

Analysis of Touchdown Error Data

Inasmuch as touchdown error X was used to measure the quality of the performance of the task, a statistical analysis was conducted on mean touchdown error $\overline{X}$ and then mean absolute touchdown error $|\overline{X}|$. The hypothesis that all values of $\overline{X}$ and all values of $|\overline{X}|$ were equal, regardless of field of view, was tested with a t-test, with the level of significance at 0.05 (see appendix). These data were analyzed individually for each pilot.

The mean absolute values were not significantly different for any combination of restricted cases for each pilot; however, there were a few combinations for which the mean values were significantly different. For each subject, the mean for each restricted case was not significantly different from the mean of the first unrestricted case. Also, for each subject the means for the first and the last unrestricted cases were not significantly different.

Figure 7 shows mean absolute touchdown error at each field of view by the sequence in which flown, and table II gives the fields of view in the order flown by each pilot.



(a) Pilot 1.

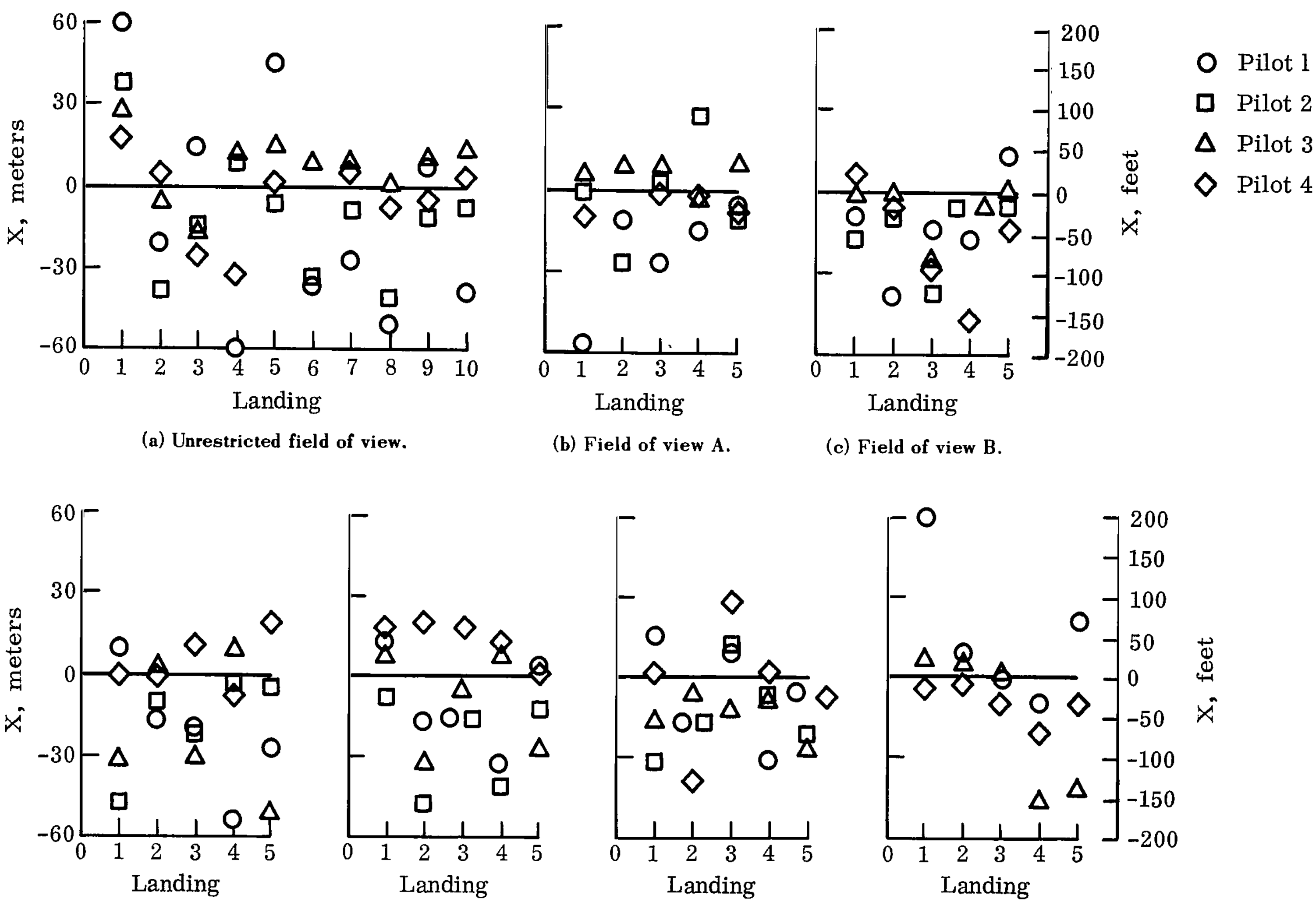
(b) Pilot 2.

(c) Pilot 3.

(d) Pilot 4.

Figure 7.— Mean absolute touchdown error by flight sequence.

Figure 7 shows that there was no general trend toward lower mean absolute errors that might be a result of "learning." The touchdown errors of all landings for each pilot were shown in figure 5. Had there been appreciable "learning," an overall convergence in the errors from the first to the fortieth landing would have been expected. Figures 8(a) to 8(g) show touchdown errors versus landing number for each field of view.



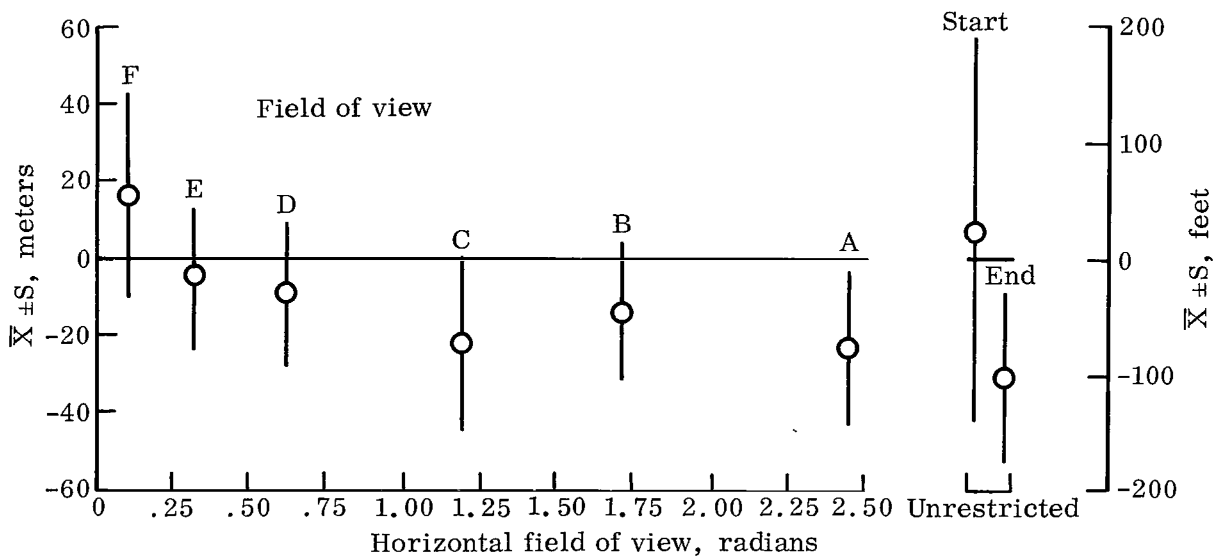
(a) Unrestricted field of view. (b) Field of view A. (c) Field of view B.

(d) Field of view C. (e) Field of view D. (f) Field of view E. (g) Field of view F.

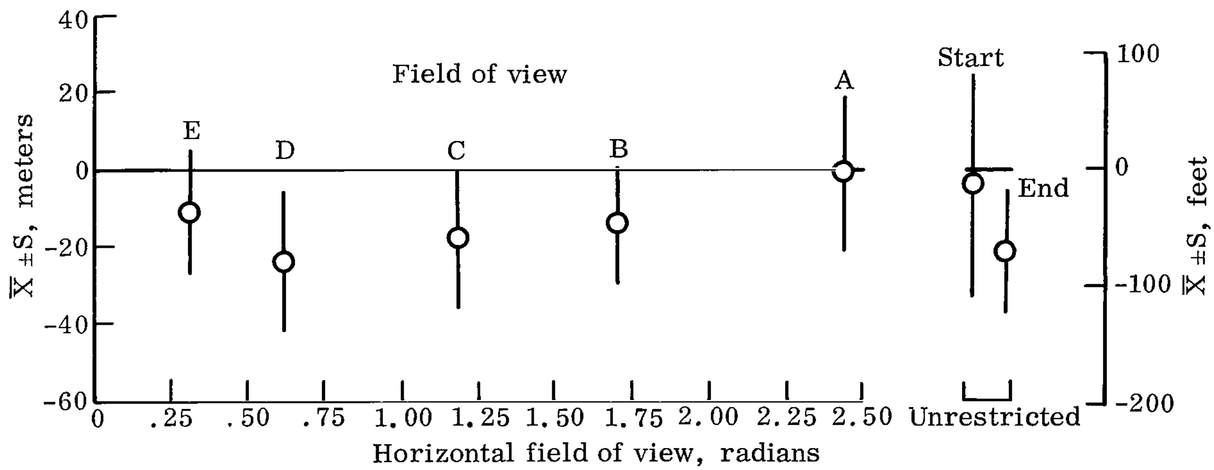
Figure 8.– Touchdown error as a function of landing number for all pilots at each field of view.

The absence of a convergence from the first to the fifth landing within the restricted fields of view and from the first to the tenth landing within the unrestricted field of view indicates that there was no appreciable "learning" within any particular field of view.

The subject pilots flew without restriction of the field of view both before and after the sequence of restricted field of view flights. The mean touchdown error ±1 standard deviation for each pilot is shown in figures 9(a) to 9(d). The band, $\overline{X} \pm S$, is wider at the start than at the end of the sequence. There was also a reduction in mean absolute error as well as scatter in the second unrestricted flight for each pilot (figs. 7 and 8). The statistical analysis performed indicated that these differences are not significant.

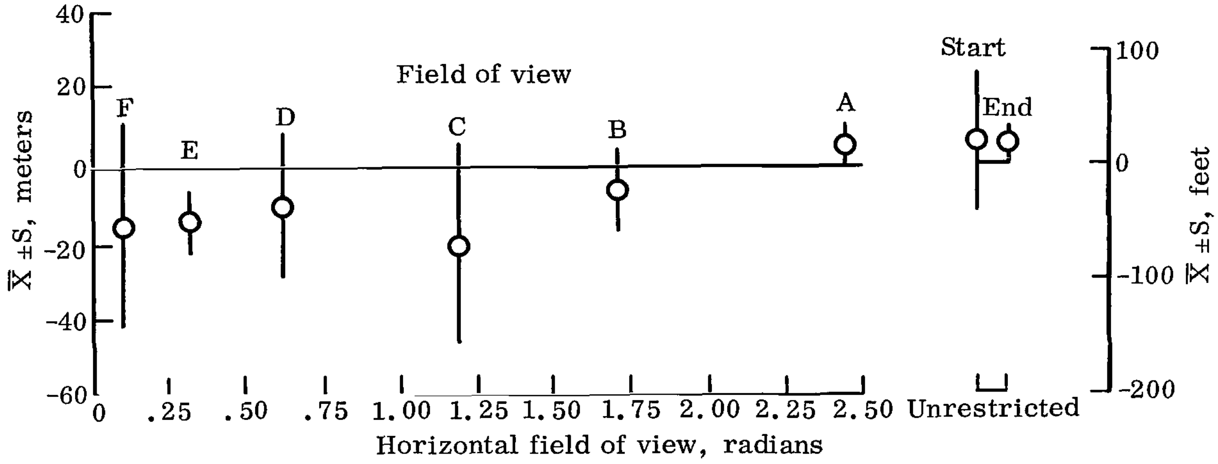


(a) Pilot 1.

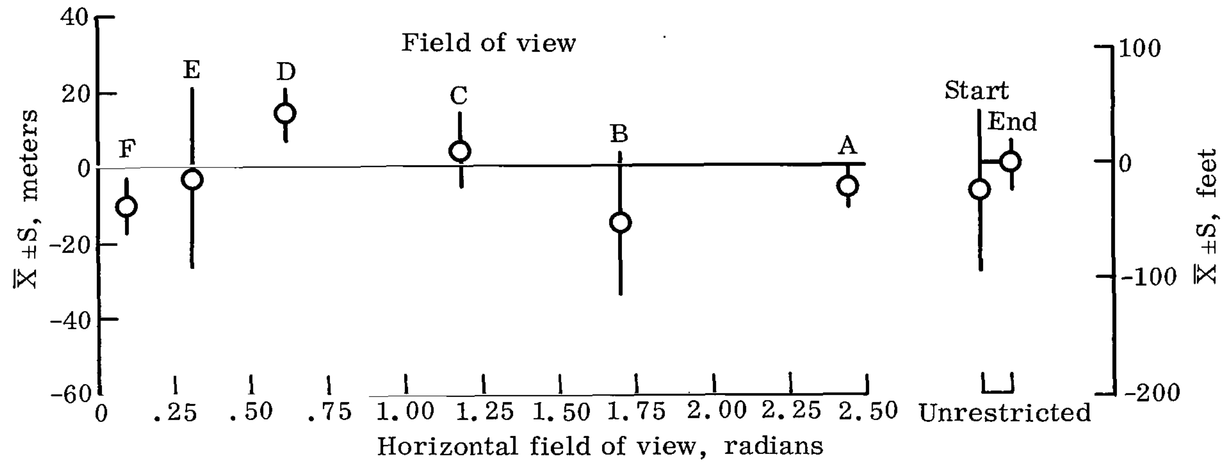


(b) Pilot 2.

Figure 9.— Mean touchdown error ±1 standard deviation as a function of field of view for each pilot.



(c) Pilot 3.



(d) Pilot 4.

Figure 9.– Concluded.

Suggestions for Future Research

An evaluation of this experiment by the authors, subject pilots, and other cognizant persons indicates that it may be possible to improve future experiments of this type by considering the following suggestions:

1. The ground rules for the subject pilots should be as strict as feasible, and the pilots should be instructed to follow these rules very closely. A more controlled experiment would thereby be realized.

2. Rate of sink at touchdown, along with touchdown error, may be a more useful measure of a pilot's performance of the task than touchdown error alone. Qualitative ratings of overall performance by a nonsubject pilot may also be useful.

3. One pilot commented that split fields of view should be evaluated. He believes that 0.785 radian (45°) of forward vision and the same amount of side vision would be more useful than a single 1.57 radian (90°) field, regardless of the orientation of the latter field. It was also suggested that the experiment be repeated in a visual simulator in order to determine if field of view has the same effect in a simulator as in flight.

A similar study performed in an aircraft with more stringent landing characteristics would amplify the findings of this program. Also, a similar study using an aircraft with a low lift-drag ratio could provide design information for lifting reentry vehicles, a category of aircraft likely to have a restricted field of view.

CONCLUSIONS

A flight investigation performed with a T-33 jet aircraft to investigate the effects of restricted fields of view on performance of the approach and landing maneuver by four research pilots led to the following conclusions:

1. Pilots were able to complete a 180° power-on pattern and make successful landings in this aircraft with a restricted field of view down to and including 0.10 radian (5.7°) horizontal and 0.52 radian (30°) vertical.

2. Touchdown error or standard deviation did not vary significantly with field of view; however, pilot comments indicated that the task became increasingly difficult with decreasing field of view.

3. Smoothness of longitudinal control decreased with decreasing field of view, but lateral and directional control were unaffected.

Flight Research Center,
National Aeronautics and Space Administration,
Edwards, Calif., January 20, 1967.
125-19-06-03-24

APPENDIX

ANALYSIS OF TOUCHDOWN-ERROR DATA

The average touchdown error $\overline{X}$ was calculated by using the expression

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n}$$

The average absolute touchdown error $\overline{|X|}$ was calculated by using the expression

$$\overline{|X|} = \frac{\sum_{i=1}^{n} |X_i|}{n}$$

Standard deviation S was calculated as follows:

$$S = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \overline{X})^2}{n - 1}}$$

where

$$\sum_{i=1}^{n} (X_i - \overline{X})^2 = \sum_{i=1}^{n} X_i^2 - \frac{\left(\sum_{i=1}^{n} X_i\right)^2}{n}$$

The latter expression was used in order to avoid squaring and adding small numbers.

In a normal distribution, standard deviation S and average of absolute data $\overline{|X|}$ are proportional; therefore, only $\overline{X}$ and $\overline{|X|}$ were tested for significance.

The data for each pilot, when considered as eight samples (seven for pilot 2) taken from the same distribution, satisfied a 99-percent confidence interval test. Thus the data are from the same population and can be represented by a normal distribution.

A test of $H : \mu_i = \mu_j$ for $i = 1, \cdot \cdot \cdot, 7$ and $j = 2, \cdot \cdot \cdot, 8$ was made for each pilot at all combinations of i and j for which $j > i$. Thus, each field of view was compared with every other field of view. It was assumed that the five landings at a particular field of view were unbiased, random samples from normal distributions and that the standard deviations were unknown and not necessarily equal. The test applied is described in reference 3.

The criterion for rejection of $H : \mu_i = \mu_j$ was that $|t'| \geq t_{0.05/2;d}$, where

$t' = \frac{\mu_i - \mu_j}{\sqrt{\frac{S_i^2}{n_i} + \frac{S_j^2}{n_j}}}$, with degrees of freedom d calculated by using the expression

$$d = \frac{\left(\frac{S_i^2}{n_i} + \frac{S_j^2}{n_j}\right)^2}{\frac{\left(\frac{S_i^2}{n_i}\right)^2}{n_i + 1} + \frac{\left(\frac{S_j^2}{n_j}\right)^2}{n_j + 1}} - 2$$

The quantity S_i^2 was calculated as follows:

$$S_i^2 = \frac{\sum_{k=1}^{n_i} X_k^2 - n_i(\overline{X}_i)^2}{n_i - 1}$$

The test was applied to determine significant differences at the 0.05 level between the means of all combinations of fields of view for the pilot. The absolute means were similarly checked. If there was no significant difference (H accepted) between the means of two fields of view, an = notation was entered on table IV. If there was a significant difference (H rejected), a ≠ notation was entered. The entry was made at the intersection of row i and column j headed by the fields of view compared.

TABLE IV.– RESULTS OF TESTS FOR INDICATED HYPOTHESES[1]

		$H: \overline{X}_i = \overline{X}_j$									$H: \overline{\lvert X_i \rvert} = \overline{\lvert X_j \rvert}$									
Pilot	i	j = 1	2	3	4	5	6	7	8	Field of view	j = 1	2	3	4	5	6	7	8	i	Pilot
1	1		=	=	=	=	=	=	=	[2] U(1)		=	=	=	=	=	=	=	1	1
	2			=	=	=	=	≠	=	A			=	=	=	=	=	=	2	
	3				=	=	=	=	=	B				=	=	=	=	=	3	
	4					=	=	≠	=	C					=	=	=	=	4	
	5						=	=	=	D						=	=	=	5	
	6							=	=	E							=	=	6	
	7								≠	F								=	7	
	8									[3] U(2)									8	
2	1		=	=	=	=	=	=		U(1)		=	=	=	=	=	=		1	2
	2			=	=	=	=	=		A			=	=	=	=	=		2	
	3				=	=	=	=		B				=	=	=	=		3	
	4					=	=	=		C					=	=	=		4	
	5						=	=		D						=	=		5	
	6							=		E							=		6	
	7									U(2)									7	
3	1		=	=	=	=	=	=	=	U(1)		=	=	=	=	=	=	=	1	3
	2			=	=	=	≠	=	=	A			=	=	=	=	=	=	2	
	3				=	=	=	=	=	B				=	=	=	=	=	3	
	4					=	=	=	=	C					=	=	=	=	4	
	5						=	=	=	D						=	=	=	5	
	6							=	≠	E							=	=	6	
	7								=	F								=	7	
	8									U(2)									8	
4	1		=	=	=	=	=	=	=	U(1)		=	=	=	=	=	=	=	1	4
	2			=	=	≠	=	=	=	A			=	=	=	=	=	=	2	
	3				=	≠	=	=	=	B				=	=	=	=	=	3	
	4					=	=	≠	=	C					=	=	=	=	4	
	5						=	≠	≠	D						=	=	=	5	
	6							=	=	E							=	=	6	
	7								≠	F								=	7	
	8									U(2)									8	

[1] = denotes hypothesis accepted; ≠ denotes hypothesis rejected.

[2] U(1) denotes initial flight with unrestricted field of view.

[3] U(2) denotes final flight with unrestricted field of view.

Because all entries in the table for absolute means are = notations, it was concluded that there was no significant difference between the fields of view when the amount of error is considered without regard to whether the subject pilot was long or short of the desired touchdown point.

For means of touchdown error there are some ≠ signs in the table, but the following conclusions are based on the locations of the = notations. For each subject pilot, there was no significant difference between the mean touchdown error of any restricted field of view and the mean touchdown error of the unrestricted field of view (U(1)) at the start of the program. The mean touchdown error at the start of the program was not significantly different from the mean touchdown error of the unrestricted case at the end of the program (U(2)). For example, for subject pilot 1, the mean of the distribution of landings at field of view B is not significantly different from the mean of the distribution of landings at field of view F at the 0.05 level of significance. This is evidenced by the placement of an = notation at the intersection of row 3 and column 7, indicating that H: $\mu_3 = \mu_7$ was accepted at the 0.05 level.

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