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USAARL REPORT NO. 75-11

AVIATOR VISUAL PERFORMANCE IN THE UH-1

STUDY II

By

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March 1975

U. S. ARMY AEROMEDICAL RESEARCH LABORATORY

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This study monitored, via the corneal reflection technique, visual performance of Army aviators while flying incline maneuvers in a UH-1 helicopter. Visual performance, to include time and transition information, was gathered over 13 sectors. In addition to visual data, performance measurements were recorded simultaneously on an incremental digital recorder. Results acquired by both techniques are provided.

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SUMMARY

This study monitored, via the corneal reflection technique, visual performance of Army aviators while flying incline maneuvers in a UH-1 helicopter. Visual performance, to include time and transition information, was gathered over 13 sectors. In addition to visual data, performance measurements were recorded simultaneously on an incremental digital recorder. Results acquired by both techniques are provided.

APPROVED ______________________

ROBERT W. BAILEY
Colonel, MSC
Commanding

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INTRODUCTION

There is little question that helicopters have become an integral part of the Army's tactical structure. Also, there is little question that mission accomplishment and safe flight of the helicopter is dependent in large measure on visual information received by aircrew personnel. Evidence that minimum adequate visual information is currently afforded Army aviators is substantiated by the very fact they can, and do, fly the machines. However, little is known with regard to what areas of the windscreen aviators most often use, how long they dwell in these areas, what dynamic response patterns they utilize to transition from area to area, where and what they view external to the aircraft, or how these parameters change as a function of variables, such as aircraft flown, maneuvers flown, level of training, or physiological state.

Though the visual sensory modality is considered, almost without exception, to be highly critical to helicopter flying, few research studies measuring where the pilot looks during actual rotary wing flight have been carried out. Two of these studies, [1,2] done some fifteen years ago, were primarily concerned with establishing minimal accepted visual envelopes for helicopters. These studies examined visual performance, in several aircraft over a number of maneuvers, in terms of the frequency with which aviators utilized certain visual areas. While attempting to establish these visual envelopes, the investigators did study visual performance of aviators while flying helicopters. It might be added, these particular studies appear to have been overlooked when one views the military standards concerning visual envelopes for helicopters and some current research in this area. Since these studies, a number of new helicopters have been added to the Army inventory, the function and flight envelopes of helicopters have expanded, and the technology for recording visual performance has advanced, providing more measures with greater accuracy.

Much more recently two other studies [3,4] investigated where helicopter pilots look to gain information when flying a UH-1. These studies investigated a number of maneuvers, gaining data by way of interview techniques, as well as in-flight recording of visual performance. The in-flight visual data was examined by using three lateral areas referenced to the windscreen and four vertical categories referenced to the earth's surface. The major emphasis of the inflight visual performance, however, was directed at measuring performance in maneuvers flown IFR (instrument flight rules). This provided much needed information as to what instruments are used, how long they are used, and provided information on order of usage.

With regard to VFR (visual flight rules) rotary wing flight several studies have just been conducted concerning visual performance.[5,6] Though much information has been added to visual performance data, much yet remains to be established for this sensory modality which is so critical to safe flight.

Additionally, quantitative data concerning aviator performance is another area in which increased information is required. Though studies have investigated pilot performance in a given aircraft for a limited number of maneuvers, they often lack data relating the measured performance to resultant aircraft performance.[7,8] A small number of studies have quantified both but, for the most part, have been concerned with performance differences in a modified aircraft for some limited number of maneuvers,[9] or the assessment of flight capabilities and limitation of aircraft performing a given maneuver.[10,11,12,13]

The purpose of this investigation was to measure visual and psychomotor performance during incline or slope landings. Such maneuvers are common to helicopter operations and are taught to every pilot. Incline operations require the pilot to maintain extremely close coordination of all available flight controls in order to successfully execute the maneuver. Additionally, many small control inputs based on sensory feedback in addition to vision are required because in some cases precise visual cues are not available.

METHOD

Subjects

Subjects were seven Army aviators. Demographic information concerning these individuals is presented in Table 1.

Table 1

Age	Total Flt Hrs	Flt Hrs in UH-1	Acft Currently Flown Most
S_1 - 25	2400	2200	UH-1
S_2 - 32	2100	1000	UH-1
S_3 - 25	1000	800	UH-1
S_4 - 25	3100	2700	UH-1
S_5 - 25	2400	2300	UH-1
S_6 - 30	2300	1600	UH-1
S_7 - 25	2400	2300	UH-1

Apparatus

Visual performance was measured with a modified EYE NAC Mark Recorder used in conjunction with an onboard video recording system. A detailed description of the visual apparatus and scoring techniques can be found in USAARL Report No 74-7.

Control movement data was recorded in real time via an Incremented digital recorder which is part of an onboard Helicopter Inflight Monitoring System (HIMS). Additional information regarding this system and scoring techniques can be found in USAARL Report No's 72-11 and 74-7.

Procedure

Visual data information concerned thirteen visual sectors. These areas were as follows:

8 windscreen sectors - *Surface Area = 260 square inches
2 chin bubble sectors - *Surface Area = 634 square inches each
2 side door sectors - *Surface Area = 560 square inches each
1 inside cockpit sector -

*Note that sectors within each group are of equal surface area but not necessarily equal viewing area. Figure 1 shows a sketch of the thirteen visual areas that were available. The numbering of the sectors served only as guides for data reduction.

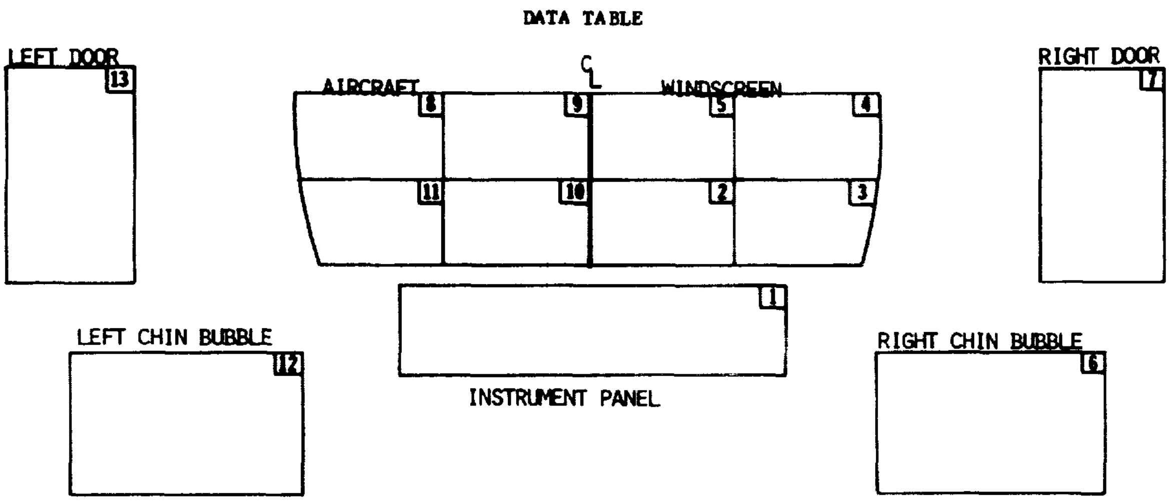


Figure 1

Each subject, prior to piloting the helicopter, was fitted with the NAC recorder in the laboratory where accuracy of alignment was checked. He then proceeded to the aircraft for interface with the video recorder and additional calibrations. Each subject flew in the right seat adjusted to his own comfort. Upon completion of testing, calibrations were again checked to insure that no movement had occurred to the NAC recorder. Throughout testing, no movement was found to exist.

Control movement and roll input data were analyzed with respect to the absolute value of each control. These absolute values are as follows:

	Control Movement Limits
Cyclic Fore, Aft (CYCFA)	± 6 inches
Cyclic Left, Right (CYCLR)	± 6 inches
Collective (COLL)	0-10 inches
Pedals (PED)	± 3.7 inches
Roll (ROLL)	*No absolute value

Physiological measures were also obtained and included EMG's of the forearm muscle complex as well as EKG's: These data appear in a separate report.

All subjects were briefed twice prior to the test period concerning the series of maneuvers to be performed. During the test profile each pilot was briefed concerning the next maneuver he would perform immediately prior to performing that maneuver.

RESULTS & DISCUSSION

The results and discussion of this investigation are presented in two parts. The first part will deal with the in-flight data gathered by way of the EYE NAC Recorder, and the second part will deal with the control and aircraft movement data.

PART 1

The results and discussion of the visual performance data cover seven areas. These are as follows:

1. Touchdown - Left (TDL) (Aircraft at Hover to Touchdown) - Slope on Left Side of A/C - Pilot Right Side

2. Take Off - Left (T/OL) (Touchdown to Aircraft at Hover)

3. Touchdown - Right (TDR) (Aircraft at Hover to Touchdown) - Slope on Right Side of A/C - Pilot Right Side

4. Take Off - Right (T/OR) (Touchdown to Aircraft at Hover)

5. Summation of 1 & 3

6. Summation of 2 & 4

7. Summation of 5 & 6

The visual data collected are summarized in Tables 1A through 7A and 1B through 7B. The lower portion of the A Tables are divided into two parts. The Left Side entitled "Totals" represents the total time in seconds, total number of sectors used, the number of sector transitions (permutations), percent of time spent outside the aircraft and the percent of time spent inside the aircraft.

The Right Side of the A Tables contain subject means, standard deviations and ranges of the same parameters. Notice that values for time out and time inside the aircraft are presented in seconds rather than percentages.

The last two lower measures provided are Mean Sector Transitions per minute and Mean Dwell Time (seconds). The sector transition measure was derived by taking the total number of sector transitions recorded for the subjects, dividing it by the time it took for them to complete the maneuvers and multiplying by 60. These values were then used to establish the means, standard deviations, and ranges. The dwell measure was handled in a similar manner, except the time spent for completing the maneuver was divided by the number of transitions.

The upper portion of the A Tables is a schematic representing the thirteen visual areas used in the investigation. The sectors are represented as follows:

Sector 1 = Inside the aircraft

Sector 2 & 3 = Lower front windscreen (right half)

Sector 4 & 5 = Upper front windscreen (right half)

Sector 10 & 11 = Lower front windscreen (left half)

Sector 8 & 9 = Upper front windscreen (left half)

Sector 7 = Right Door Window

Sector 13 = Left Door Window

Sector 6 = Right Chin Bubble

Sector 12 = Left Chin Bubble

Within each sector are five values. These values, in order, are: Total time in seconds, percent of total time, total number of times sector exited, dwell time and standard deviation. Dwell time was established by dividing the total time spent in the sector by the number of exits for that sector. This general format holds for all A Tables. However, the data presented in Tables 5,6 and 7 represent the summation of data for the maneuvers which they encompass.

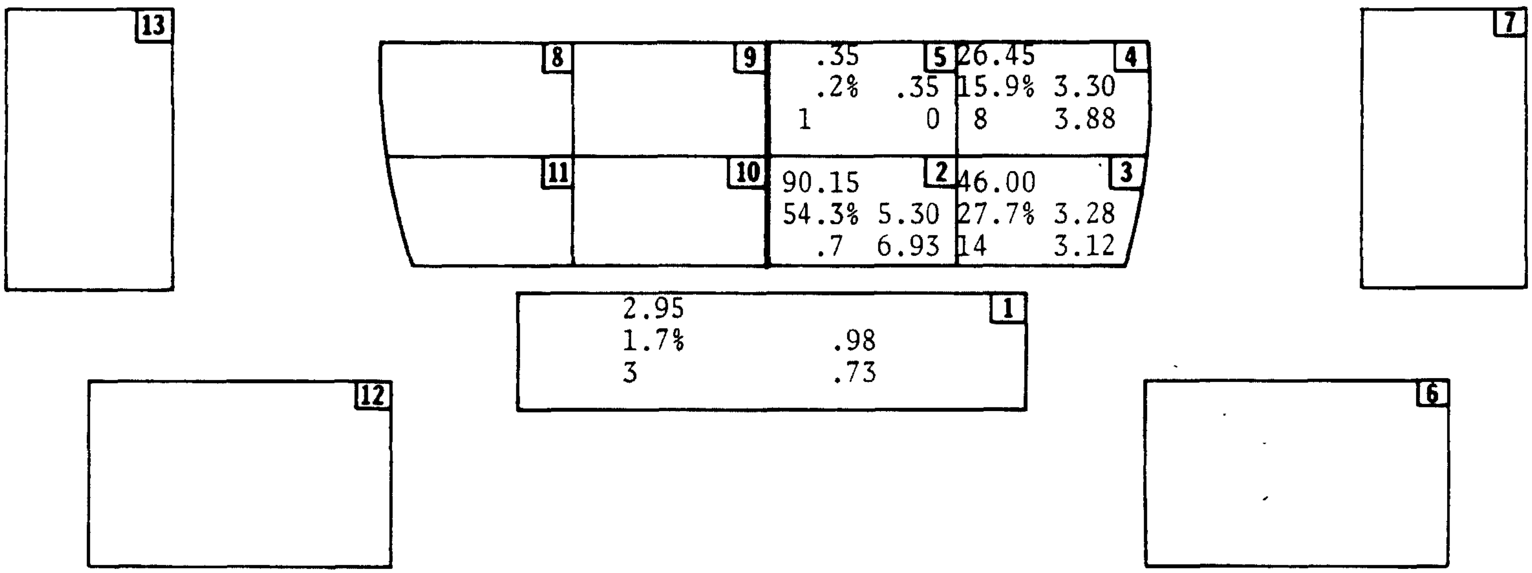
The B Tables provide data concerning the frequency with which each transition permutation occurred. To read the Tables, one need only read down or across, e.g., Table 1B, the subjects went from Sector 1 to Sector 2 twice and Sector 3 once; they went from Sector 2 to Sector 1 two times, Sector 3 nine times, Sector 4 two times; etc.

1. Aircraft at Hover to Touchdown (Left Side of A/C upslope)

Starting with the aircraft at a stabilized hover above the touchdown point and ending when the aircraft was fully on the ground and the controls neutralized.

Tables 1A and 1B indicate this maneuver took, on the average, 24 seconds to complete. The range was 8.6 seconds to 46.9 seconds. The sector transition scores indicate moderate eye movement activity from sector to sector. Sectors 2 and 3 were most often frequented and accounted for 82 percent of total vision time. During this portion of the maneuver 98.3 percent of the pilots' visual time was spent outside of the cockpit with only 1.7% spent inside. This visual performance is not unlike that found in forward hover.

DATA TABLE 1A
Touchdown (Left)



TOTAL		SUBJECT MEAN	SUBJECT STD DEVIATION	SUBJECT RANGE
Time (secs.)	165.9	23.70	12.13	8.65-46.9
Sectors Used	15	2.14	1.12	1-4
Sector Transitions (Permutations)	36	5.14	5.36	0-15
% Time In	1.7%	Time In (secs) .98	.733	.47-2.0
% Time Out	98.3%	Time Out (secs.) 3.79	5.52	.35-21.0
Mean Sector Transition/min.		15.58	11.58	2.85-29.7
Mean Dwell Time (secs.)		3.85	5.18	2.02-21.0

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TABLE 1B
Touchdown (Slope Left)

DATA TABLE

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		2	1											3
Q2	2		9	2										13
Q3	1	7		4										12
Q4		3	3		1									7
Q5				1										1
Q6														
Q7														
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	3	12	13	7	1									36

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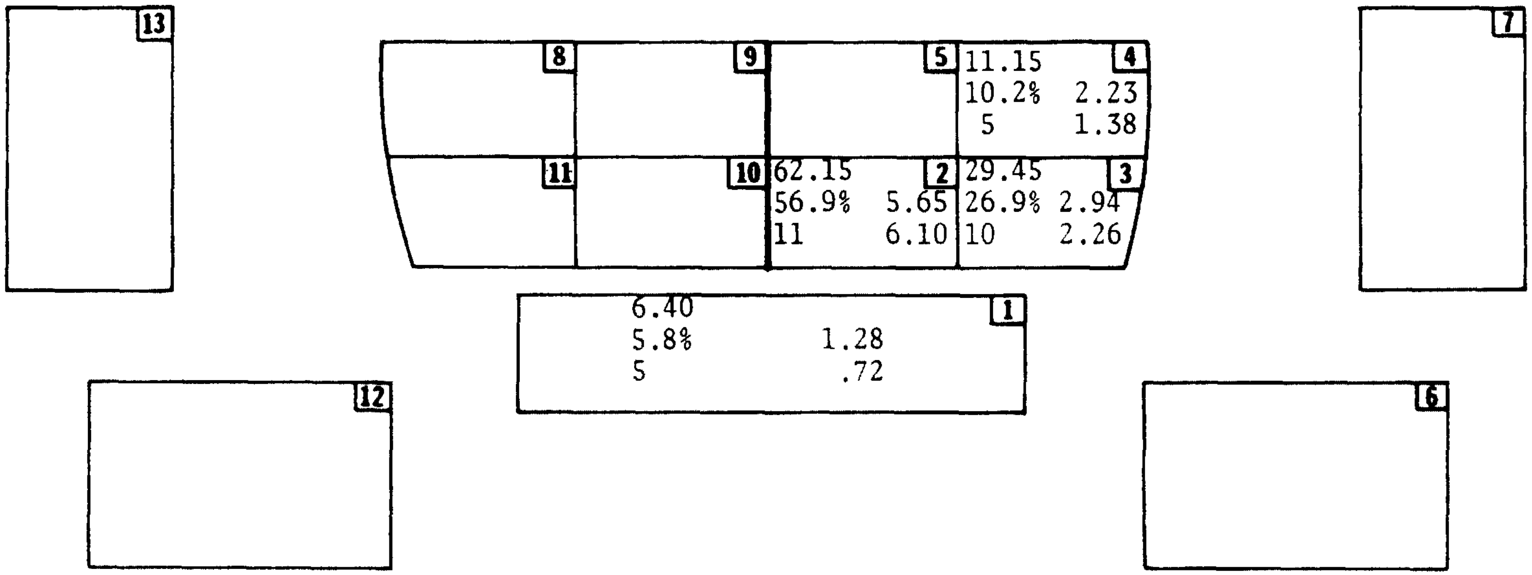
2. Touchdown to Aircraft at Hover

Starting with the aircraft on the incline the pilots' first control input began this maneuver segment. The end point was when the aircraft was at a three foot stabilized hover above the touchdown point.

Data provided on Tables 2A and 2B indicate that the mean time to complete this maneuver decreased. The percent of time spent inside of the aircraft increased approximately 4%. This would seem to indicate that a quick glance at the instruments was completed as a before take-off check. Mean sector transitions per minute increased slightly while dwell time decreased slightly. Sectors 2 & 3 accounted for 83.0 of the time. Sector transition data verify that more transitions were made to the instrument panel (Sector 1). This particular visual pattern of performance had not been recorded on any other maneuver thus far investigated.

DATA TABLE
Take Off (Left)



	TOTAL	SUBJECT MEAN	SUBJECT STD DEVIATION	SUBJECT RANGE
Time (secs.)	109.15	15.59	4.61	9.85-22.85
Sectors Used	15	2.14	.64	1-3
Sector Transitions (Permutations)	24	3.43	2.97	0-8
% Time In	5.8%	Time In (secs) 1.28	.72	.55-1.46
% Time Out	94.2%	Time Out (secs.) 3.95	4.50	.20-13.40
Mean Sector Transition/min.		17.05	14.15	4.47-28.84
Mean Dwell Time (secs.)		3.52	4.24	2.08-13.40

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TABLE 2B
Take Off (Slope Left)

DATA TABLE

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		2	2											4
Q2	1		4	2										7
Q3	4	3		2										9
Q4		2	2											4
Q5														
Q6														
Q7														
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	5	7	8	4										24

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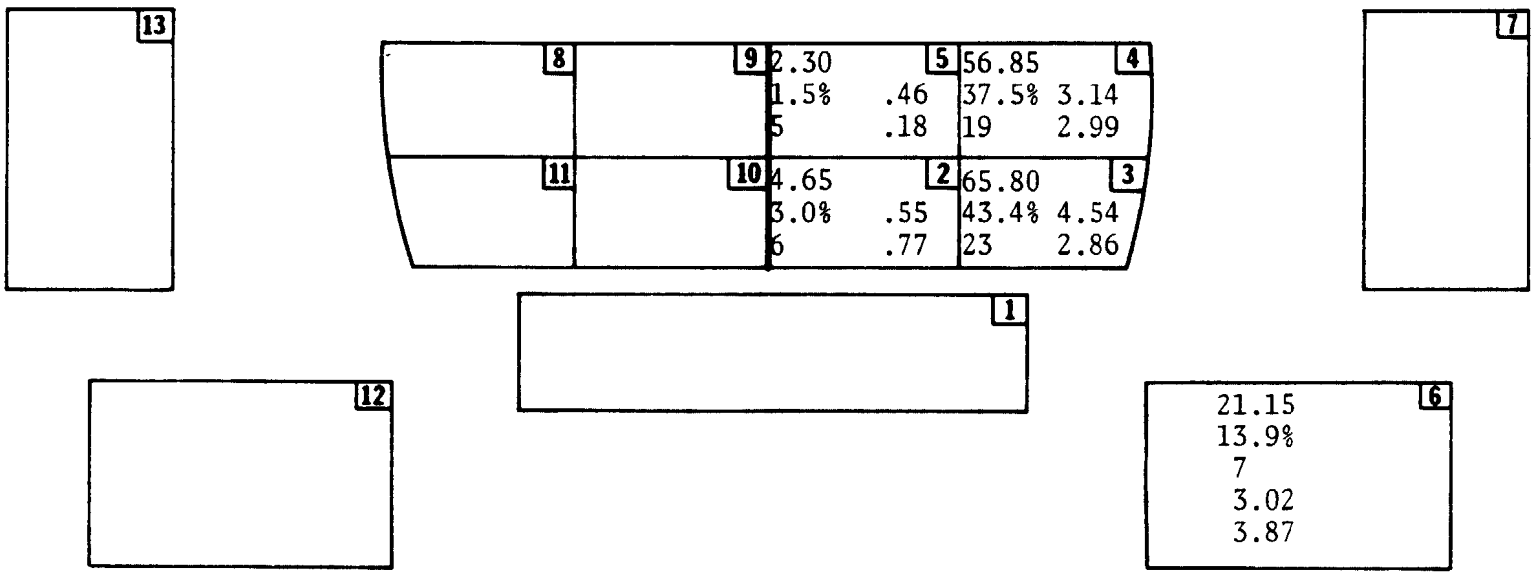
3. Aircraft at Hover to Touchdown (Right Side of Aircraft upslope)

This maneuver is basically the same as the first maneuver except the right side of the aircraft is upslope.

Tables 3A and 3B indicate that this maneuver took an average of 21.6 seconds to complete. We also see that 100% of the pilots' visual time was spent outside the aircraft cockpit. The most interesting fact is the large percent of time (13.9%) spent in the right chin bubble (Sector 6). Previous research showed this sector was very infrequently used. As can be seen in Table 3B the transitions to and from Sector 6 were from and to Sector 3. Another change in landing from the right is the increased sector transition data. This maneuver produced 53 permutations as compared to 36 permutations for the same maneuver from the other direction. This increased activity led to the decreased dwell times recorded for this maneuver.

DATA TABLE 3A
Touchdown (Right)



	TOTAL	SUBJECT MEAN	SUBJECT STD DEVIATION	SUBJECT RANGE
Time (secs.)	151.50	21.64	8.17	11.85-38.5
Sectors Used	16	2.28	.88	1-4
Sector Transitions (Permutations)	53	7.57	6.25	0-21
% Time In	0%	Time In (secs) 0	0	--
% Time Out	100%	Time Out (secs.) 2.48	3.67	.75-11.85
Mean Sector Transition/min.		24.19	16.35	5.06-34.68
Mean Dwell Time (secs.)		2.48	3.67	.75-11.85

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TABLE 3B
Touchdown (Slope Right)

DATA TABLE

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Total
Q1														
Q2			4	1	1									6
Q3		5		10		5								20
Q4		1	9		4								1	15
Q5				5										5
Q6			6											6
Q7														
Q8														
Q9														
Q10														
Q11														
Q12														
Q13				1										1
		6	19	17	5	5							1	53

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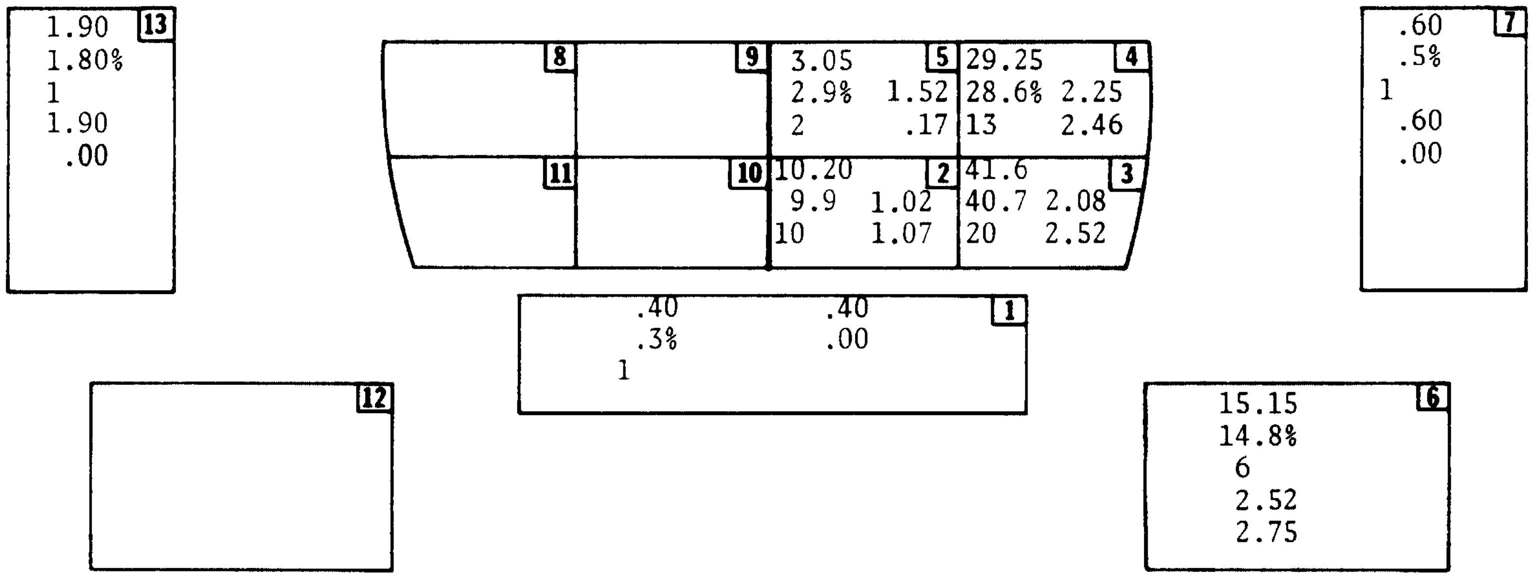
4. Touchdown to Aircraft at Hover

Again this maneuver is basically the same as the second maneuver with the only exception being that the right side of the aircraft is upslope.

Again Tables 4A and 4B show a large percentage of pilot visual time was spent in Sector 6. The mean subject times to complete the maneuver were within 1 second of the counterpart but as with the previous maneuver there is increased eye activity which is reflected in the greatly increased mean sector transitions/minute scores: 31.7 versus 17.0. For this maneuver visual times are recorded in the two side door window areas, (Sectors 7 & 13), which for the previous maneuvers had gone unused. Also increased activity was measured in the number of sector transitions. Transitions increased from 24 in maneuver number two to 47 in this maneuver.

DATA TABLE 4A
Take Off (Right)



TOTAL		SUBJECT MEAN	STD DEVIATION	RANGE
Time (secs.)	102.15	14.59	4.99	7.55-21.65
Sectors Used	19	2.71	1.05	1-5
Sector Transitions (Permutations)	47	6.71	3.73	0-12
% Time In	.3%	Time In (secs) .40	00	---
% Time Out	99.7%	Time Out (secs.) 1.92	2.29	.26-7.55
Mean Sector Transition/min.		31.75	26.31	7.95-63.16
Mean Dwell Time (secs.)		1.89	2.28	.95-7.55

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TABLE 4B
Take Off (Slope Right)

DATA TABLE

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1				1										1
Q2			7											7
Q3		6		7		5								18
Q4	1	3	6		1									11
Q5				1			1						1	3
Q6			5											5
Q7				1										1
Q8														
Q9														
Q10														
Q11														
Q12														
Q13					1									1
	1	9	18	10	2	5	1						1	47

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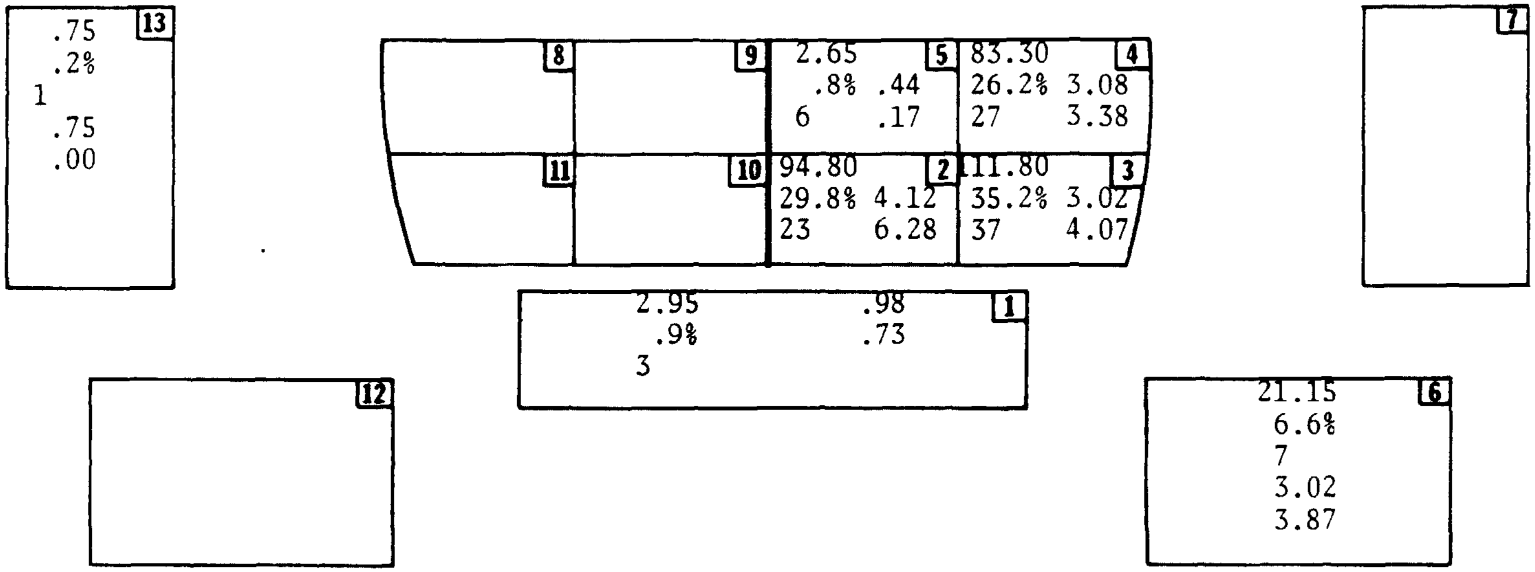
5. Summary of Aircraft at Hover to Touchdown (Left & Right Combined)

This is summary data of Tables 1A & B and 5A & B.

Data from Summary Tables 5A and 5B indicate that 99.1% of all visual time was spent outside of the aircraft cockpit and that 91.2 percent of this time was spent in Sectors 2,3, and 4. The range data indicates that it took some pilots more than five times as long to complete this maneuver than it did others.

DATA TABLE 5A
Summary of Tables 1A & 3A



	TOTAL	SUBJECT MEAN	SUBJECT STD DEVIATION	SUBJECT RANGE
Time (secs.)	317.4	22.67	10.39	8.65-46.90
Sectors Used	31	2.21	.94	1-4
Sector Transitions (Permutations)	89	6.36	5.95	0-21
% Time In (Time In (secs))	.9%	.98	.73	.47-2.00
% Time Out (Time Out (secs.))	99.1%	3.11	4.46	.35-21.00
Mean Sector Transition/min.		19.67	13.60	2.85-34.68
Mean Dwell Time (secs.)		3.05	4.41	.75-21.00

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TABLE 5B
Summary of Tables 1 & 3B

DATA TABLE

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		2	1											3
Q2	2		13	3	1									19
Q3	1	12		14		5								32
Q4		4	12		5								1	22
Q5			6											6
Q6														
Q7														
Q8														
Q9														
Q10														
Q11														
Q12														
Q13				1										1
	3	18	32	24	6	5							1	89

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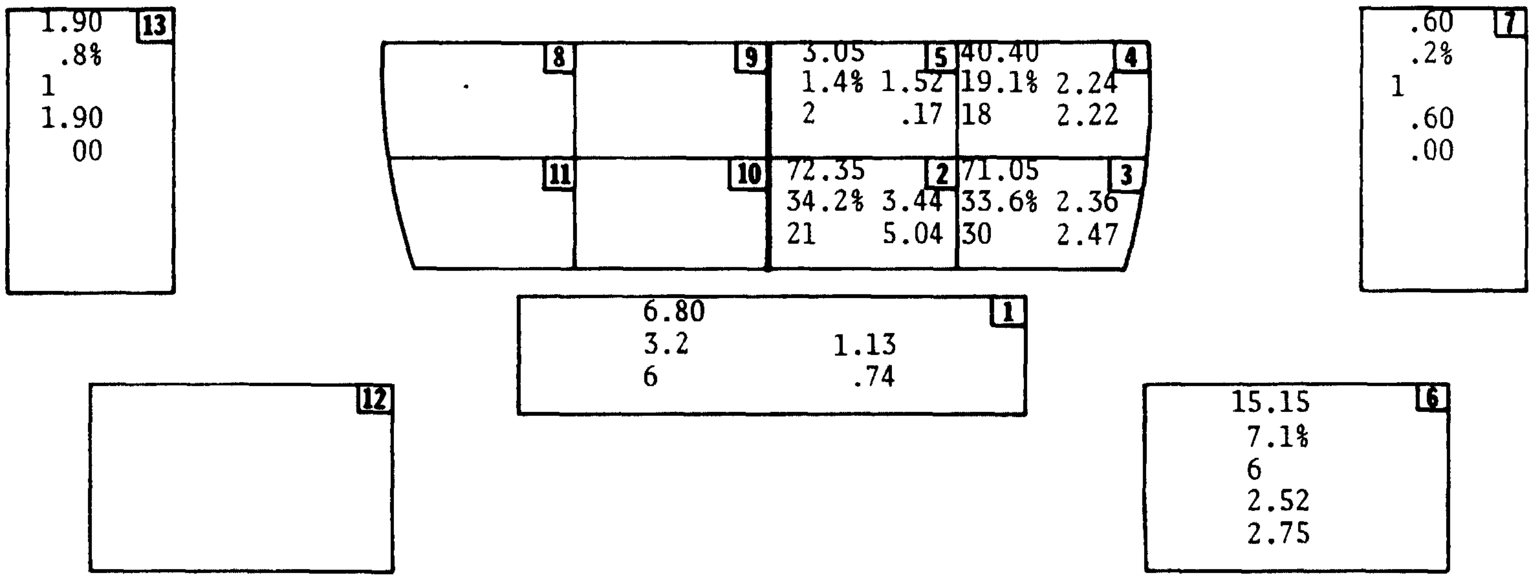
6. Summary of Touchdown to Aircraft at Hover

Presented here is summary data from Tables 2A & B and 4A & B.

Summary Tables 6A & B show that the percentage of time spent inside the cockpit increased almost four fold over the time spent inside for the aircraft to land from a hover. Mean subject time to complete this maneuver decreased on the average approximately 7 seconds over the other maneuver. Mean sector transition/min increased while dwell time decreased significantly. The times spent in Sector 6 in this summary as well as Summary 5 is attributed only to those maneuvers where the slope area was to the right of the aircraft.

DATA TABLE 6A
Summary of Maneuvers 2A & 4A



	TOTAL	SUBJECT MEAN	SUBJECT STD DEVIATION	SUBJECT RANGE
Time (secs.)	211.30	15.09	4.83	7.55-22.85
Sectors Used	34	2.43	1.05	1-5
Sector Transitions (Permutations)	71	5.07	3.75	0-12
% Time In	3.2%	Time In (secs) 1.13	.74	.55-1.46
% Time Out	96.8%	Time Out (secs.) 2.58	3.33	.2-13.40
Mean Sector Transition/min.		24.19	18.52	4.47-63.16
Mean Dwell Time (secs.)		2.48	3.24	.95-13.4

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TABLE 6B
Summary of Tables 2 & 4B

DATA TABLE

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		2	2	1										5
Q2	1		11	2										14
Q3	4	9		9		5								27
Q4	1	5	8		1		1							16
Q5				1									1	2
Q6			5											5
Q7				1										1
Q8														
Q9														
Q10														
Q11														
Q12														
Q13					1									1
	6	16	26	14	2	5	1						1	71

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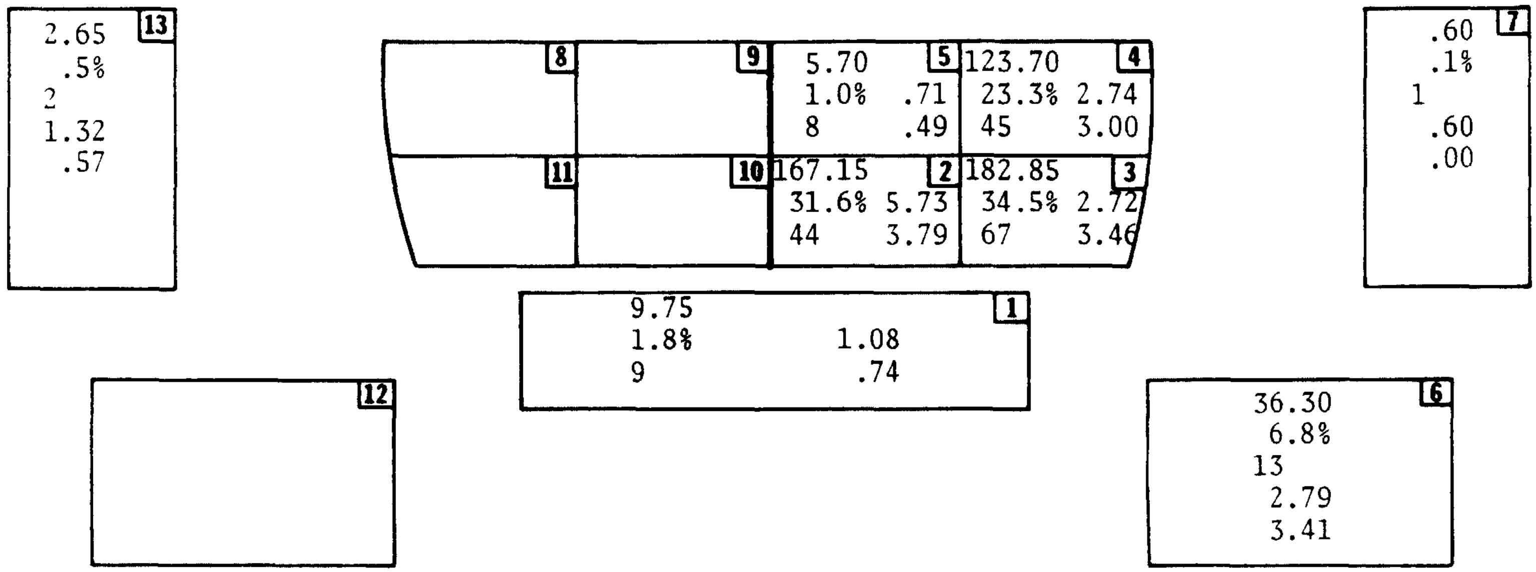
7. Summary of All Maneuvers

This data represents summary information from the first four Tables (A & B).

The point of interest in Tables 7A & B is that there exists no visual time in Sectors 8,9,10, and 11 even though they are available for pilot usage. Also we note that 98.2 percent of visual time is spent outside the cockpit area during visual incline operations. Mean sector dwell times are 2.0 seconds and the subject pilots averaged 21.5 sector transitions per minute. Visual Sectors 2 & 3 account for 66.1 percent of pilots visual time. This would support the assumption that visual cue information is provided at fairly close ranges when performing incline operations.

DATA TABLE 7A
Summary of all Maneuvers



	TOTAL	SUBJECT MEAN	SUBJECT STD DEVIATION	SUBJECT RANGE
Time (secs.)	528.70	18.88	8.95	7.55-46.9
Sectors Used	65	2.32	1.00	1-5
Sector Transitions (Permutations)	160	5.71	5.01	0-21
% Time In	1.8%	Time In (secs) 1.08	.74	.47-2.00
% Time Out	98.2%	Time Out (secs.) 2.88	4.01	.2-21.00
Mean Sector Transition/min.		21.50	15.26	2.85-34.68
Mean Dwell Time (secs.)		2.76	3.93	.75-21.00

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TABLE 7B
Summary of all Maneuvers

DATA TABLE

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		4	3	1										8
Q2	3		24	5	1	10								43
Q3	5	21		23										49
Q4	1	9	20		6		1						1	38
Q5				7									1	8
Q6			11											11
Q7				1										1
Q8														
Q9														
Q10														
Q11														
Q12														
Q13				1	1									2
	9	34	58	38	8	10	1						2	158

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Part II

The results of the pilots' in-flight control movement data are presented in graphic and tabular form. The HIMS system measures aircraft position in all six degrees of freedom while simultaneously recording Cyclic, Collective, and Pedal inputs as well as aircraft status values. All the data are recorded in real time on an incremental digital recorder.

Control movement data are presented for the four main pilot controls (Cyclic fore, aft; Cyclic, left, right; Collective and Pedals). Roll rate data are presented for the Roll Axis of the aircraft. These data are presented for the seven maneuver sets discussed in Part I:

1. TDL (Aircraft at Hover to Touchdown) - Slope on Left Side of A/C - Pilot Right

2. T/OL (Touchdown to Aircraft at Hover)

3. TDR (Aircraft at Hover to Touchdown) - Slope on Right Side of A/C - Pilot Right

4. T/OR (Touchdown to Aircraft at Hover)

5. Summation of 1 & 3

6. Summation of 2 & 4

7. Summation of 5 & 6

The first control comparison examined was the number of Steady State occurrences compared to the number of Control Movement occurrences. Steady State occurrences are recorded when a control has not exceeded an empirically defined distance in a specified time. Secondly, a Control Movement is defined as any movement starting from steady state or a control reversal and ending with a steady state or control reversal.

Figure 2 is a histogram depicting the number of Steady State occurrences for the first four maneuver sets for each of the control parameters.

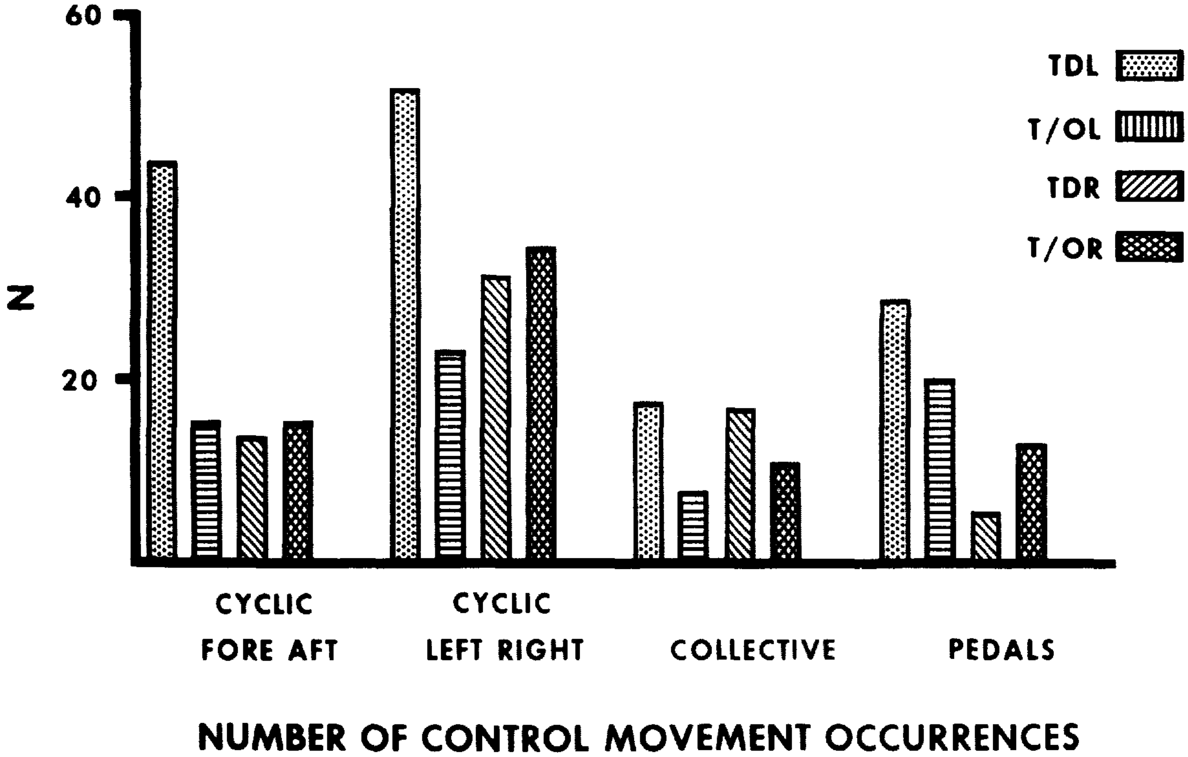


Figure 2

Figure 3 is a histogram depicting the number of control movements across the same control and maneuver sets as those in Figure 2.

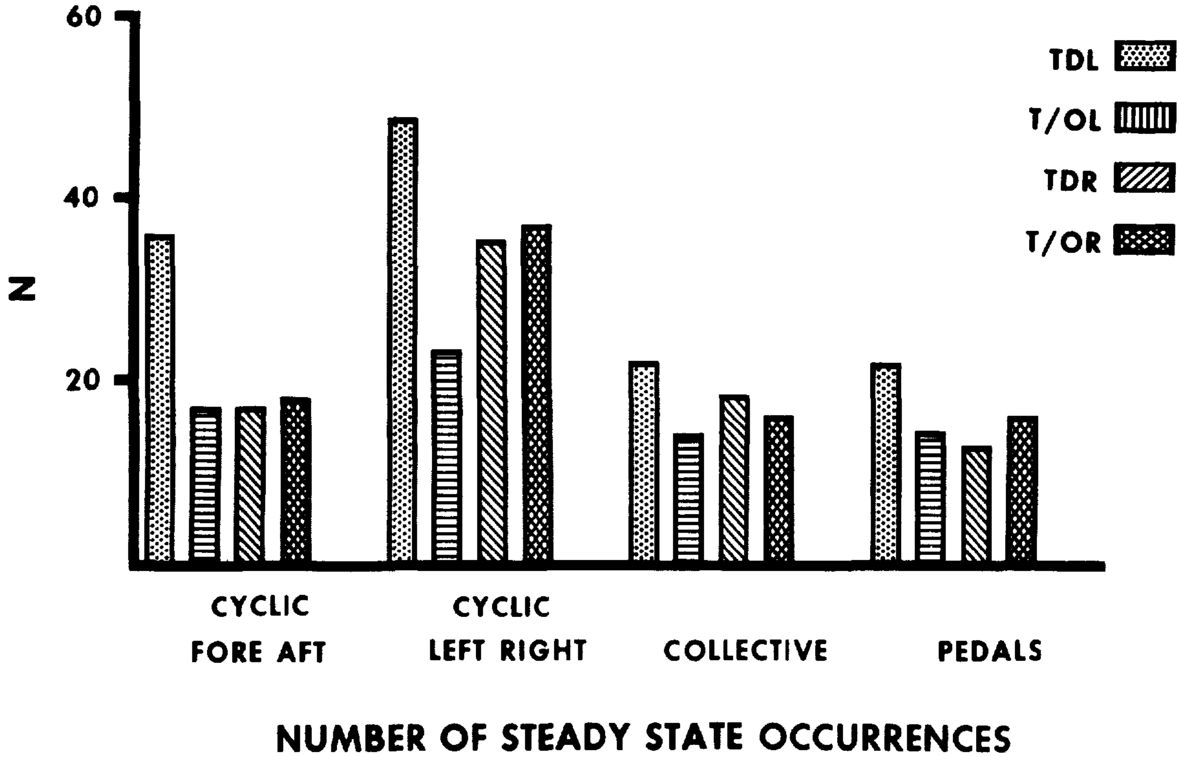


Figure 3

These graphic presentations illustrate that the number of Steady State and Control Movement occurrences follow the same general pattern across the pilots' control parameters as well as within the particular maneuver set.

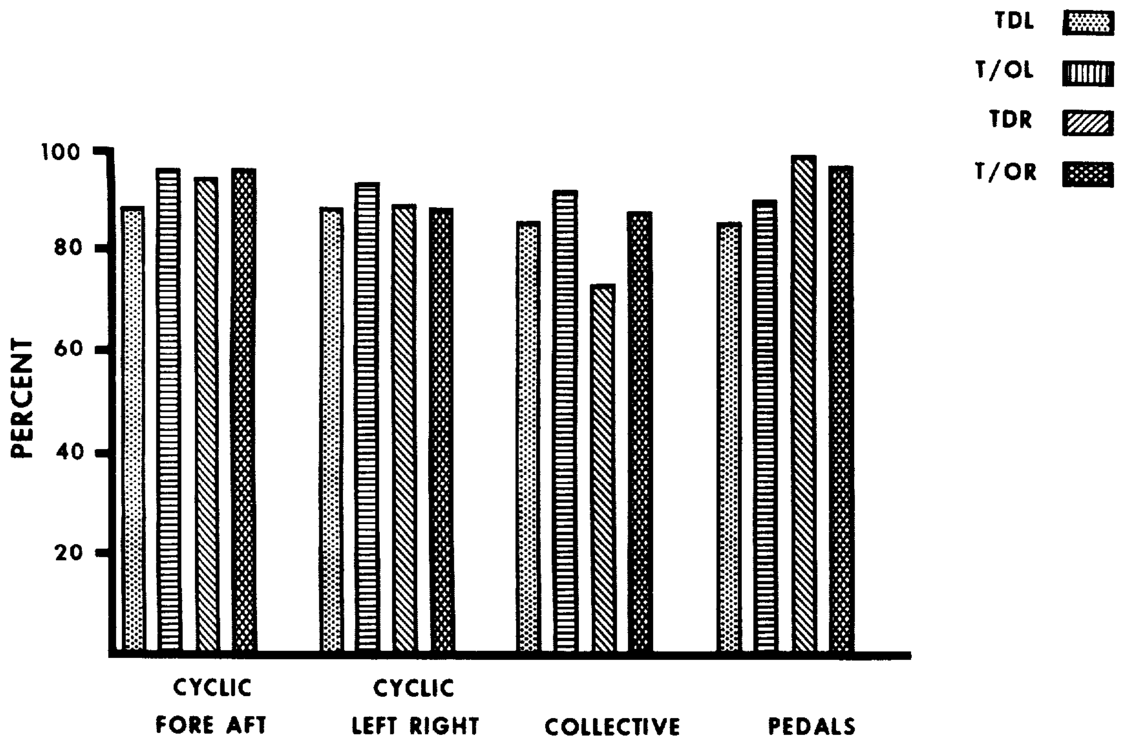
However, when we inspect Figures 4 and 5 it can be noted that the percentage of total flight time in which these conditions occur is highly variable. Thus, one can see that even though the number of occurrences remains fairly constant, the percentage of total time in which they are performed is unequal. This means that Control Movement occurrences are confined to a small percentage of total time, while the number of Steady States occur over a much greater period of time. It might be added that the average times to complete the maneuver segments were: TDL, 1.87; T/OL, 1.69 min; TDR, 1.12 min; T/OR, 1.97 min. This result is further amplified when one views the mean duration times of Steady State and Control Movement occurrences as seen in Table 1C and Table 2C.

Table 1C lists the Steady State mean duration times for the first four previously discussed maneuver sets. While Table 2C lists the Control Movement mean duration times for these same maneuver sets.

TABLE 1C

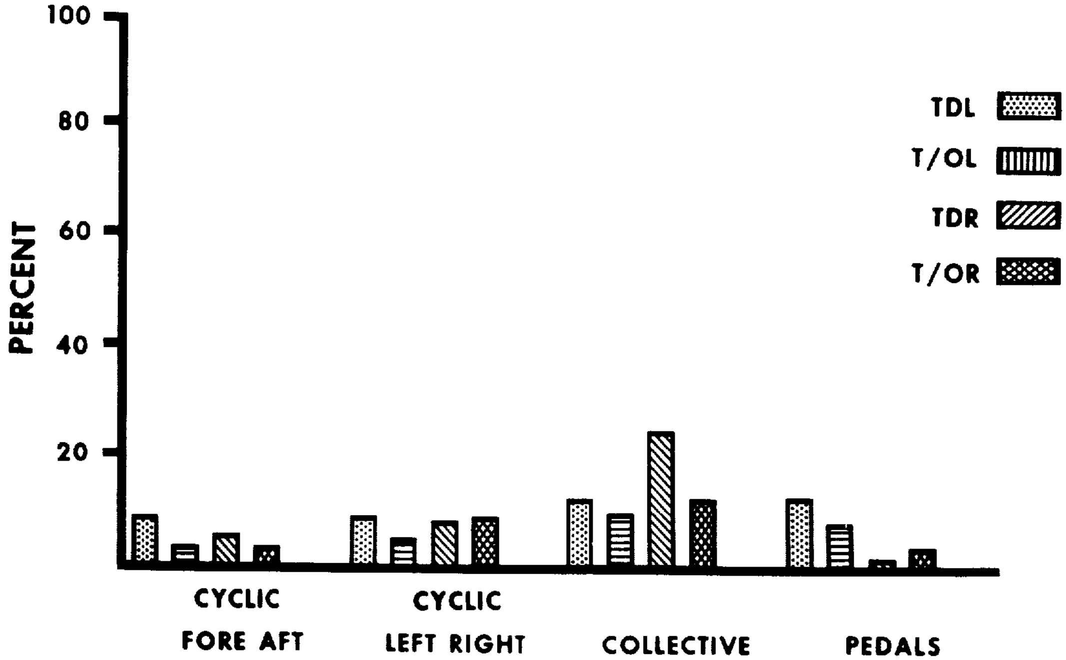
STEADY STATE MEAN DURATION TIME

Cyclic Fore Aft	Cyclic Left Right	Collective	Pedal
(1) 2.89	2.11	4.53	4.50
(2) 6.11	3.97	6.30	6.65
(3) 4.00	1.75	2.69	5.69
(4) 5.68	2.68	6.90	6.90



PERCENT OF TOTAL FLIGHT TIME FOR STEADY STATE OCCURRENCES

Figure 4



PERCENT OF TOTAL FLIGHT TIME FOR CONTROL MOVEMENTS

Figure 5

TABLE 2C

CONTROL MOVEMENT MEAN DURATION TIME

Cyclic Fore Aft	Cyclic Left Right	Collective	Pedals
(1) .26	.26	.74	.52
(2) .25	.22	1.02	.49
(3) .27	.17	1.03	.15
(4) .29	.26	1.23	.35

It can be seen that Steady State mean duration times are significantly larger than the Control Movement mean duration times.

Other control data of interest is that of control position. Summation data, in inches, are listed in Table 3C for pilots' Control Movements.

TABLE 3C

CONTROL MOVEMENT IN INCHES

	Cyclic Fore Aft	Cyclic Left Right	Collective	Pedals
Mean	.956	-.971	2.979	-.682
Standard Deviation	.967	2.923	1.348	.500
Maximum	3.100	5.100	5.000	.800
Minimum	-2.700	-5.900	.000	-2.600

Though (*) ± 6 inches of Cyclic Control Movement is available in both the Fore-Aft and Left-Right Axis, it can be seen that the maximum forward Cyclic recorded in any phase of the maneuver sequence is +3.1 inches. However, the range of Left-Right Cyclic varied from +5.1 to -5.9 inches thereby indicating that at some point a situation existed in which the control was within .1 inch of its limit. Further analysis indicated that a -5.9 inch Control Movement was required to successfully negotiate the incline area and produced an aircraft roll value of 8.2 degrees.

Since no quantitative data about the performance of the aviator and helicopter was available for this type of maneuver, this effort was devoted to gaining some baseline data in this regard. It is apparent that new information was gained from this investigation in that the visual performance reported was different from that found in previously studied maneuvers. There was for example a total lack of time spent in the left side of the windscreen as well as in the left chin bubble. Additionally, only 1.8% of the total maneuver time for the six subjects was spent inside the cockpit. With regard to the right chin bubble, approximately 14% of the total time was spent in this area when the slope was on the right. This is compared to a maximum of 3.2% found in a previous study for a hover sideward maneuver. This increased percentage of time, for the most part, was contributed by one subject and the overall time spent in this chin bubble across some thirteen maneuvers was only .3 of a percent.

With regard to the psychomotor performance and aircraft state variables additional information was also made available. The inputs to the controls per unit time for the touchdown were on the order of that found earlier in a most demanding NOE (nap-of-the-earth) riverbed course.[14] They were far in excess of those found during local area and low level flying. Additionally, it was shown that for the successful negotiation of the indicated 8.2 degree slope, Cyclic Left-Right Control Movement was within .1 inch of limit.

(*) Negative values are for Aft Cyclic, Left Cyclic and Left Pedal. Collective values would be the highest at a hover and the lowest upon touchdown when the control is lowered to its full down position. Pedal control values indicate the amount of left or right pedal necessary to align the aircraft with the intended incline landing area.

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