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AVIATION VISUAL PERFORMANCE IN THE UH-1H. STUDY I.(U)
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USAARL REPORT NO. 74-7

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STUDY I

By

Thomas L. Frezell
Mark A. Hofmann
Richard E. Oliver

October 1973

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The authors wish to express their sincere thanks to all those aviators who gave of their personal time to participate in this project.

ABSTRACT

This study monitored, via the corneal reflection technique, visual performance of Army aviators while flying a number of maneuvers in a UH-1H. Visual performance, to include time and transition information, was gathered over 13 cockpit areas. In addition to the objective recordings, subjective assessments by the aviators with regard to their visual performance was also attained. Results acquired by both techniques are provided.

APPROVED: ROBERT W. BAILEY
COL, 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 with his eyes 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. 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. While attempting to establish these visual envelopes, the investigators did study visual performance of aviators while flying helicopters. They studied this performance in several aircraft over a number of maneuvers with visual performance measures in terms of the frequency with which aviators utilize certain visual areas. 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 more accuracy.

Much more recently two other studies[3,4] investigated where helicopter pilots look to gain information when flying a UH-1. These studies explored 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 referenced by using three lateral areas referenced to the windscreen and four vertical categories referenced to the earth's surface. The major emphasis of the in-flight 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.

In light of the limited knowledge concerning visual performance in VFR (visual flight rules) rotary wing flight and its criticality for mission accomplishment and safe flight, it seems most desirable this sensory modality be further investigated to achieve a fuller understanding of how it is used as well as how certain variables affect its use. The object of this investigation is to provide information concerning areas of the windscreen most often used by the aviator, while flying a number of maneuvers under VFR conditions, in a UH-1 helicopter. Additionally, it is to provide information regarding the amount of movement the eyes engage in during these maneuvers and the amount of time spent in various areas of the windscreen. Lastly, it will provide comparative data between questionnaires and objective in-flight measurements with regard to what visual areas were utilized.

METHOD

Subjects

The subjects were 6 Army aviators. Demographic information concerning these individuals can be seen in Table 1.

TABLE 1

SUBJ	AERO DESIG	INSTRUMENT RATING	TOTAL HRS FLT	FLT HRS UH-1	A/C FLYING MOST
S_1	Army Aviator	Standard RW	1628	1300	UH-1H
S_2	Army Aviator	Standard RW	300	90	UH-1H
S_3	Sr Army Aviator	Standard RW	2500	2000	UH-1H
S_4	Army Aviator	Standard RW	900	700	UH-1H
S_5	Sr Army Aviator	Standard RW	2400	200	UH-1
S_6	Army Aviator	Expired RW Standard FW	2000	1200	T41B

Apparatus and Procedures

Visual performance was measured via a modified NAC Eye Mark Recorder used in conjunction with a video recording system. Figure 1 shows an aviator wearing the modified NAC recorder. Mounting modifications were required to assure accuracy during in-flight measurement. The net weight of this apparatus to the head was approximately 18 ounces.

Figure 2 shows the Eye Mark with modification. The field of view of the camera was 60° horizontal and 43.5° vertical.

Figure 1

Aviator Wearing Modified NAC Recorder

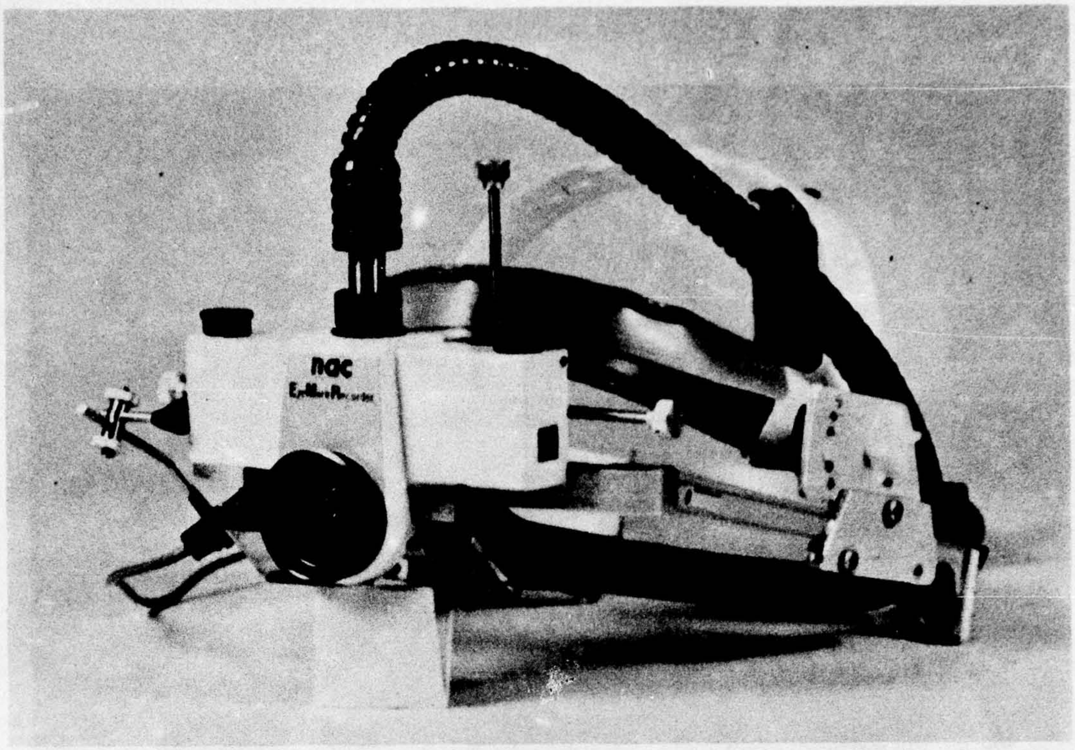


Figure 2

Modified NAC Recorder

Previous literature has stated that pilot head movements must be considered any time eye movement is greater than 15°[1] in any direction from the centrofoveal position. Therefore, the accuracy with which the Eye Nac could track the eye at visual angles of 15° and less was determined. This was accomplished by using a Bausch and Lomb Projection Perimeter Mark IV Model 4520A. The visual angles utilized were 5°, 10°, and 15°. The directions used were 90° up-down relative to the horizontal plane, and 90° right-left relative to the vertical plane. Error in any direction at 5° was zero for all subjects. At 10° three subjects had a 1° error when going right, and one had a 5° error when going down. At plus or minus 15° relative to the horizontal plane two subjects could not be tracked with loss of the eyemark occurring at approximately 13°. Using this as a 2° error, the average for all subjects in the up as well as the down position was approximately 2.5°, with a range from 0-3°. Going left at the 15° position, average error was .66°, with a range of 0-4°. Going right, the average error was 2°, with a range from 0-4°. These errors come from two primary sources. One source is the axis angle of the light source, the other is the shape of the subject cornea.

Due to these errors and their potential impact on the data, it was decided that some effort should be made to ascertain when the head would rotate. The perimeter was modified to afford this rotation information. The angle at which the pilots would start head rotation was found to be highly variable between subjects as well as within subjects, but in most cases, fairly extensive angles were required to elicit head rotation. Subsequently, it was decided to check the accuracy of the NAC system in the helicopter. Pilots were seated in the helicopter and asked to look at a large number of points representing a number of visual angles throughout the visual areas of interest. Error, in terms of the eye mark not coinciding with the points was negligible, indicating these pilots moved their heads much more readily in the operational environment than was expected from their laboratory performance. Head movements were observed when the point of displacement in terms of visual angle was quite small. Further studies will deal more in depth with these findings, but nonetheless the efforts did indicate that the laboratory performance, in terms of head rotation, was quite different from that found in the operational environment. These findings gave the authors every confidence that the data presented in this study are quite accurate.

Figure 3 shows a picture of what was recorded on video tape.

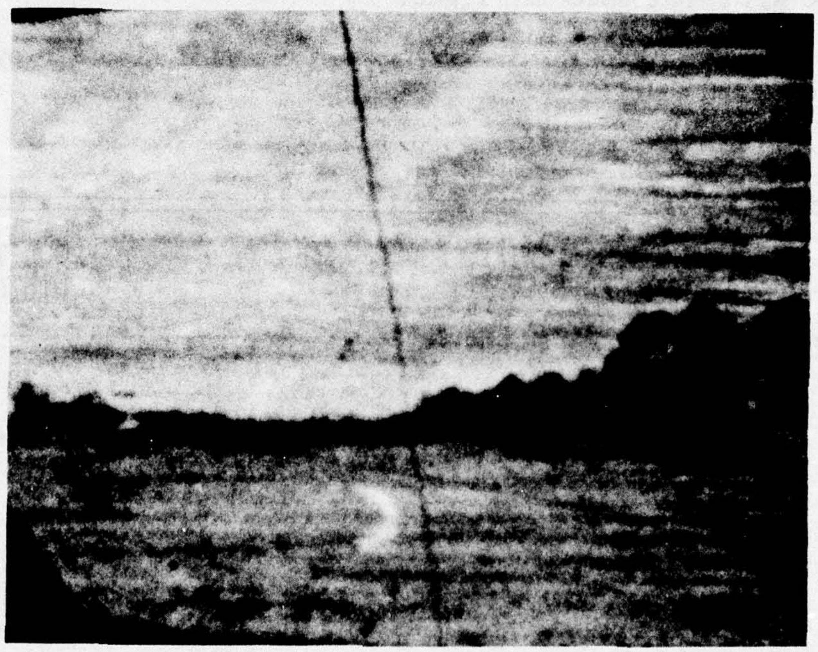


Figure 3

Eye-mark Video Tape Recording

Recording was done in real time at a rate of 30 frames per second. As can be partially seen in Figure 3, the aircraft was divided into various sectors of interest. Thirteen such sectors were utilized and were as follows:

8 windscreen sectors (area of each = 260 square inches.)
2 chin bubble sectors (each sector area = 634 square inches.)
2 side door sectors (each sector = 560 square inches.)
1 inside cockpit sector.

It should be noted that the windscreen sectors were of equal surface area, not equal viewing area.

Figure 4 shows a visual plot of the viewing area of the UH-1H model helicopter. This plot provided by The Bell Helicopter Company, Fort Worth, Texas, was generated using water line 64.05 and station 470.90. The black vertical and horizontal superimposed lines on this plot represent the divisions of the various windscreen sectors used in this investigation. A triangle depicts the area inclosing the center points for all subjects. These points are referenced to the right eye (the eye from which measurements were taken) and were determined on the ground after the pilot had adjusted the seat to his comfort and assumed a posture commensurate with that used in flight.

Table 2 shows the eye-to-windscreen distance and floor-to-eye height for each subject.

TABLE 2

SUBJ	EYE-TO-WINDSCREEN DISTANCE	FLOOR-TO-EYE DISTANCE
Subj 1	19.5"	38.25"
Subj 2	19.5"	44"
Subj 3	22.5"	40.5"
Subj 4	22"	39.5"
Subj 5	20.75"	40.75"
Subj 6	21"	40.75"

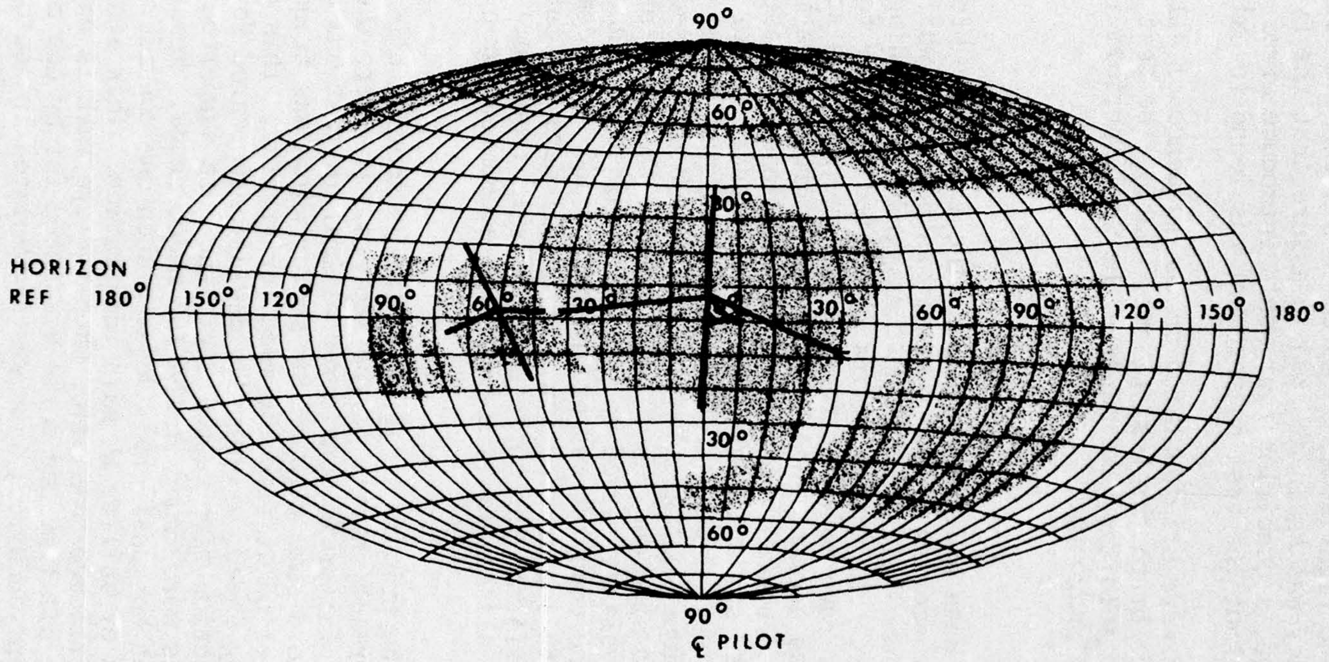


Figure 4

Visual Plot, UH-1H

Each subject, prior to flying the helicopter, was fitted with a NAC recorder in the laboratory and checked for accuracy. He then proceeded to the aircraft for final hookup and additional accuracy calibrations. He flew from the right seat, adjusted to his own comfort. After each flight, accuracy was again checked to assure that the Eye Nac recorder had not shifted, a condition that would introduce error into the measurements. Throughout the test no movement was found to exist.

All pilots were briefed twice on the sequence of all maneuvers to be performed prior to the test flight. During the test profile, each pilot was also told the next maneuver he would perform just prior to performing that maneuver.

Data Analysis

After all data had been recorded, the tapes were brought back to the laboratory for scoring. Time scoring was performed while playing the tapes back at one-half speed, and consisted of recording the time spent in each sector. The timing system permitted accuracy to 50 msec. Time per sector for each maneuver for the six subjects was scored by two persons and was accomplished by pressing microswitches mounted on specifically designed boards to accommodate the fingers of each hand. Each board contained six switches with the thirteenth sector being represented by a foot switch. Each switch closure performed three functions. It provided a unique voltage to a digital voltmeter, caused a counter (time base) to stop and reset, and signaled the computer to accept both values. The voltage served to provide a unique core address for each sector, and the computer was programmed to add the incoming values to the appropriate sector location. After all data was entered, the computer then performed the subsequent analysis required. All timing was forced, i.e., all flight time had to be accounted for by one of the sectors.

Perhaps the primary limiting factor of scoring time in this manner involves the reaction time of the scorers. However, the error introduced by this factor is considered minimal in that one can reasonably expect to record some time in any sector which was frequented by the eye for any period of time 100 msec. or greater. This exists because, at the scoring speed, a 100 msec. deviation appeared for 200 msec., which is within reaction time capability. The data supported this contention because scores were found in the 100 msec. range. Measurement to this resolution can be considered adequate when one considers the response time in terms of ability to gain information. This scoring method will, of course, introduce some error when the eye mark is not visible to the scorer, since all time had to be accounted for by one of the sectors. When this event occurred, time was accumulated in sector one or time spent inside. However, error introduced by this situation was negligible since the scorers did not often lose sight of the eye mark. Eyeblinks, for example, which could cause loss of the eyemark and cause time to be accumulated in sector one were not considered a problem inasmuch as they were in most cases below the scorer's response threshold. Eyeblinks, as recorded during helicopter flight, have been reported to occur with average frequencies ranging from 18 to 24 per minute.[5] Durations of these blinks have ranged from under 20 msec. to over 114 msec. with 89% occurring below 56 msec.[6] With regard to saccadic movements influencing the data to any extent, this again, in the opinion of the authors, was minimal because saccadic movements for the visual angles involved would be of very short duration.

The sector transition data was scored by one person. Based on a rater intercorrelation coefficient of .97 for the time data derived from a random sample of ten maneuvers from the six subjects, it was considered unnecessary to have more than one scorer for this measurement.

The sector transition measure consisted of a frequency count for transitions from one sector to another. Since there were 13 sectors, this yielded 156 permutations, e.g., sector one to sector three, sector three to sector one, sector one to sector five, sector five to sector eight, etc. As with the timing scores, the switch closures provided voltages that the computer manipulated such that each permutation was assigned a unique core address and a simple counter was set up to provide the frequency of occurrence. After all data was entered, the computer then performed the subsequent analysis required. For this measurement score reaction time was not critical in that frequency was all that was important, thus permitting the scorer to lag if necessary to record.

After a period of approximately three weeks, the aviators were called back to complete the questionnaire portion of the investigation. The questionnaire listed the maneuvers in the sequence in which they were previously flown and contained a diagram of the 13 scoring sectors. They were asked to estimate the percentage of time they used each sector for each maneuver performed.

Approximately three weeks after completing the first questionnaire the pilots were again asked to return. It was explained that they would again fly all maneuvers previously flown, after which they would be asked to indicate on a questionnaire, identical to the one administered three weeks previous, the percentage of time they spent in each sector for each maneuver. This questionnaire was administered immediately following their completion of the flight.

The questionnaire data is presented in Tables 1C through 12C, with the results and discussion in Part II.

RESULTS AND DISCUSSION

The results and discussion of this investigation will be 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 questionnaire data.

PART I

The results of the in-flight data are summarized in pairs of Tables 1A through 22A and 1B through 22B. The A tables summarize time and transition data. The B tables provide data concerning the frequency with which each transition permutation occurred. The lower portions of the A tables are divided into two parts. The left part entitled "Totals" represents for each maneuver the total time utilized in seconds, the total number of sectors used, percent of time spent outside the aircraft, and the percent of time spent inside the aircraft for the six subjects across all visual sectors.

The right part of the A tables merely contain the subject means, standard deviations, and ranges for the same parameters. As can be seen, time out and time in scores are provided in seconds rather than in percentages. Two additional measures are also provided and these are - Mean Sector Transition per minute and Mean Dwell Time (seconds). The sector transition measure was derived by taking the total number of sector transitions made by the eyes of each subject, dividing it by the time it took for him to complete the maneuver in seconds, 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 part of the A tables contain a schematic representing the various sectors used in the investigation. The sectors are represented as follows:

Sector 1 = Inside the aircraft
Sector 2 & 3 = Lower windscreen (right half)
Sector 4 & 5 = Upper windscreen (right half)
Sector 10,11 = Lower windscreen (left half)
Sector 8 & 9 = Upper 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 there are four values. These values, in order, are - total time in seconds, percent of total time, total number of times exited, and dwell time (placed to the right). 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 20, 21, and 22 represent the summation of data for the maneuvers which they encompass. That is to say, the statistics are derived from summing across maneuvers.

It can be seen in the upper part of A Tables 3, 9, 11, 14, and 19, there exists time in sectors which have no transition value. This condition occurred when one or more aviators frequented this sector and terminated the maneuver there. This meant they did not exit the sector, thus no exit transition score was obtained. The B tables contain data concerning the frequency with which each sector transition permutation was used. It can be seen that entrance and exit frequencies to a sector are not always equal. This condition arose from the pilots terminating each maneuver in a sector, plus starting each maneuver in a sector. The B tables will not be discussed in that they are self-explanatory. To read the tables, one need only read down or across, e.g., Table 1B, the subjects went from sector 1 to sector 3 five times; they went from sector 2 to sector 3 three times; sector 3 to sector 1 three times; sector 3 to sector 2 three times; and sector 3 to sector 4 four times; etc.

The face validity of the data thus far discussed would seem to support the proposition that error introduced into the recording and scoring methods was indeed minimal. This proposition is perhaps further supported by the percent of time in and percent of time out values found in Table 22A, which are in general agreement with those reported by Sunkes, Pizzaro, and Howell,[2] for the H-34 when using a passive recording device and a different measurement technique for a similar set of maneuvers.

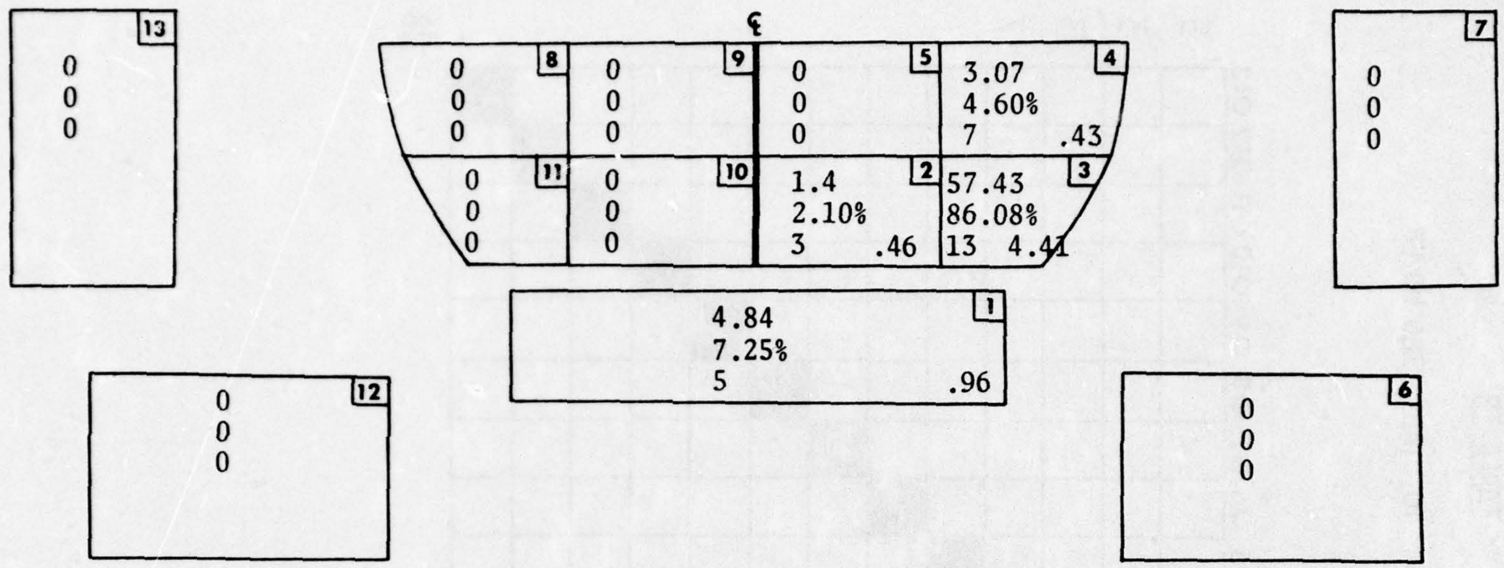
1. Liftoff to stabilized hover:

Starting with the skids on the runway, the aviator lifted the helicopter to a stabilized three foot hover aligned with the runway. The recorded period began with the pilot being instructed to "begin now" and ended when stabilized hover was acquired.

Tables 1A and 1B indicate this maneuver took, on the average, approximately 11 secs. to execute. As the range data shows, the shortest time was approximately 4 secs., while the longest time was approximately 15 secs. The pilots' sector transition scores indicate a fairly low level of eye activity, i.e., going from sector to sector. The range transition data shows that one individual remained in one sector for the complete maneuver. As a consequence of the low amount of activity, the mean dwell time is relatively long. The sector which was utilized most heavily was sector 3. This sector accounted for approximately 86% of the time. Total time spent outside the cockpit while performing this maneuver was approximately 93%, while the inside time was approximately 7%.

TABLE 1A

Lift Off to Stabilized Hover



	TOTAL		SUBJECT MEAN	SUBJECT STD DEVIATION	SUBJECT RANGE
Time (secs.)	66.74		11.12	4.04	4.94 - 14.70
Sectors Used	14		2.33	.75	1 - 3
Sector Transitions (Permutations)	28		4.67	3.15	0 - 9
Mean Sector Transition/min.			26.76	15.55	0 - 48.58
Mean Dwell Time (secs.)			3.87	3.98	1.63 - 12.64
% Time Out	92.8	Time Out (secs.)	10.31	3.80	4.23 - 14.09
% Time In	7.2	Time In (secs.)	.81	1.24	0 - 3.52

TABLE 1B

LIFT OFF TO STABILIZED HOVER

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1			5											5
Q2			3											3
Q3	3	3		7										13
Q4	1		6											7
Q5														
Q6														
Q7														
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	4	3	14	7										28

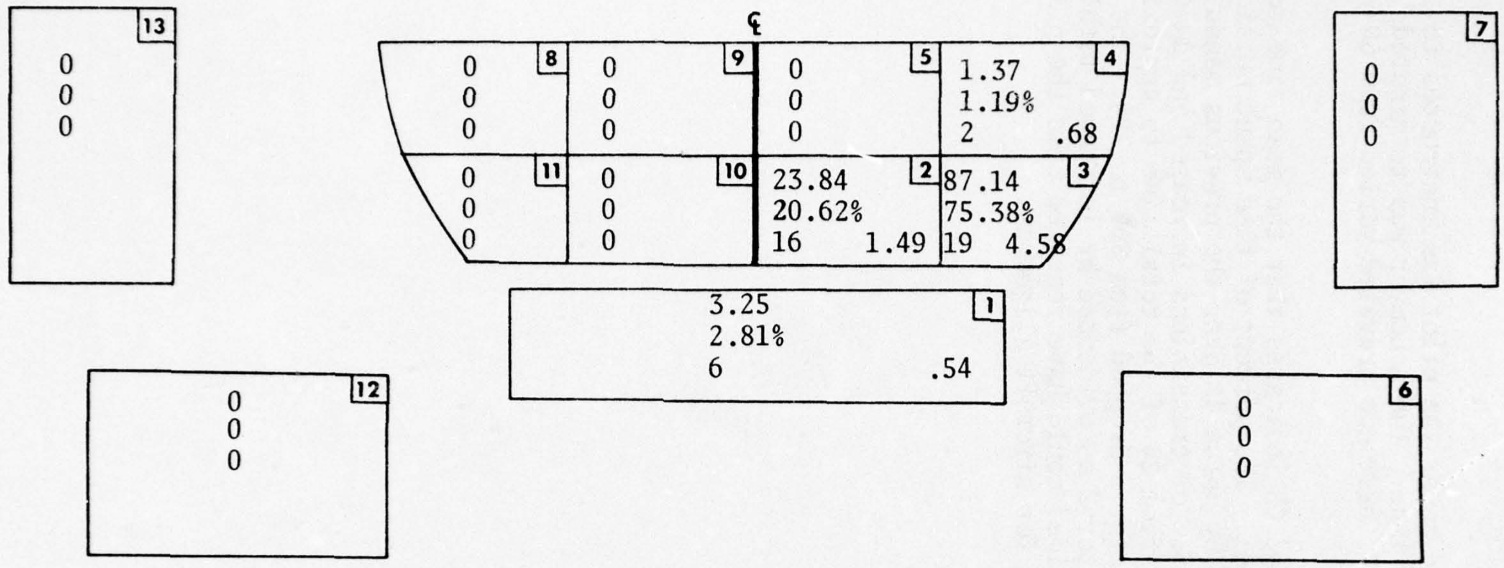
2. Forward hover:

After reaching a stabilized hover the pilot was instructed to hover forward along the center line. The maneuver was terminated with the instruction to "stop." Distance traveled varied from 60 to 70 feet.

Examination of Tables 2A and 2B indicates that the mean time to complete this maneuver increased. The percent of time spent outside the cockpit was also increased by about 4% over the previous maneuver, while time inside decreased. Sector transitions increased and dwell time decreased. Sector 2 went from 2% of the total time to approximately 21% of the total time while sector 3 dropped from 86% to 75%. The shift in visual pattern to sector 2 as evidenced by increased total time there, as well as dwell time, could have resulted from the pilots using the center line as a cue for aircraft alignment.

TABLE 2A

Forward Hover



	TOTAL		SUBJECT MEAN	STD DEVIATION	RANGE
Time (secs.)	115.60		19.27	6.41	9.20 - 29.00
Sectors Used	16		2.68	.47	2 - 3
Sector Transitions (Permutations)	43		7.17	5.87	1 - 17
Mean Sector Transition/min.			21.57	18.01	5.39 - 58.55
Mean Dwell Time (secs.)			5.18	3.69	1.03 - 11.13
% Time Out	97.2	Time Out (secs.)	18.73	6.38	9.17 - 29.00
% Time In	2.8	Time In (secs.)	.54	.49	.0 - 1.32

TABLE 2B

FORWARD HOVER

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		1	5											6
Q2	2		14											16
Q3	4	14		1										19
Q4			2											2
Q5														
Q6														
Q7														
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	6	15	21	1										43

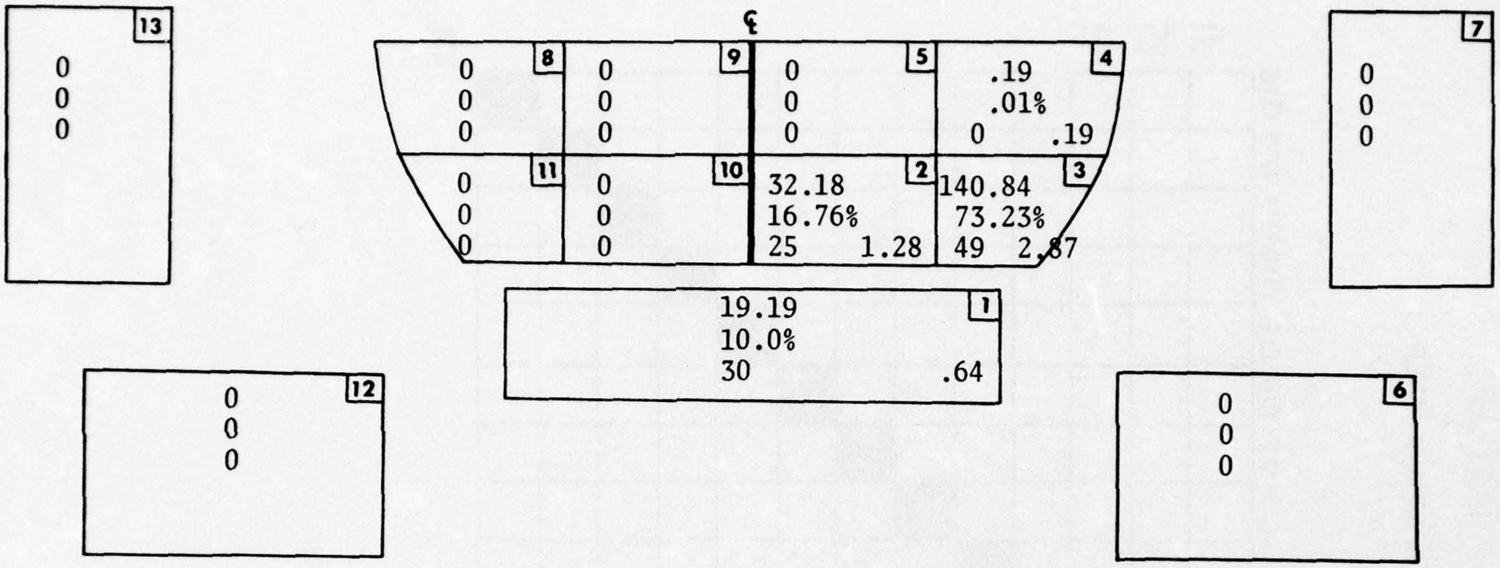
3. Rearward hover:

After reaching a stabilized hover from a forward hover, the pilot was instructed to hover rearward. The instruction to "stop" terminated the rearward hover. Distance again was 60 to 70 feet.

Tables 3A and 3B indicate that this maneuver took over 1 1/2 times longer on the average to complete than did the forward hover. Additionally, the eyes were more active, making approximately 30 transitions per min., rather than 22 for the forward hover. Inside time increased about 7% over the forward hover, and sectors 2 and 3 still remained the areas of primary interest, containing the largest percentage of total time and the longest dwell time.

TABLE 3A

Rearward Hover



	TOTAL		SUBJECT MEAN	SUBJECT STD DEVIATION	SUBJECT RANGE
Time (secs.)	192.35		32.06	6.60	22.52 - 44.70
Sectors Used	18		3.00	.37	3 - 4
Sector Transitions (Permutations)	104		17.33	12.78	1 - 35
Mean Sector Transition/min.			29.68	18.54	2.66 - 55.18
Mean Dwell Time (secs.)			5.64	7.65	1.09 - 22.52
% Time Out	90.0	Time Out (secs.)	29.26	6.28	22.27 - 41.74
% Time In	10.0	Time In (secs.)	3.13	2.35	.26 - 6.05

TABLE 3B

REARWARD HOVER

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		7	23											30
Q2	7		18											25
Q3	29	19		1										49
Q4														
Q5														
Q6														
Q7														
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	36	26	41	1										104

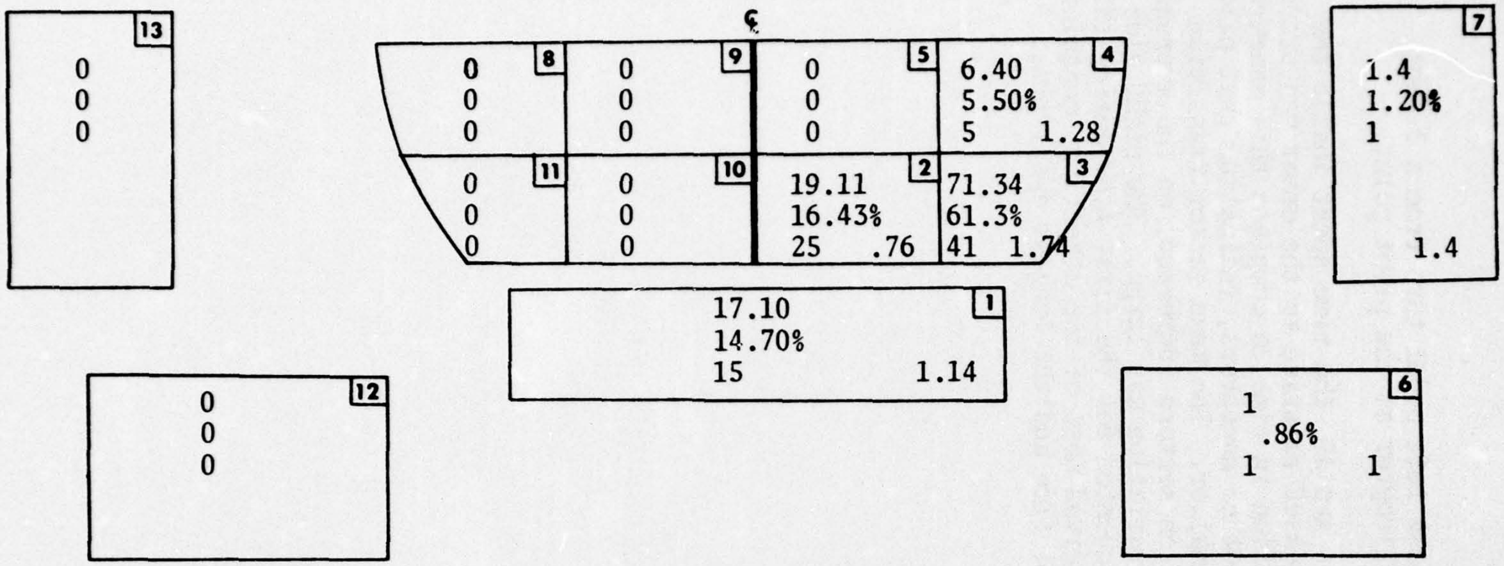
4. <u>Hover turn left (90°)</u>:

The pilot executed a 90° nose left pedal turn from a 3-foot hover using the mast of the helicopter as the pivot point.

As can be seen in Tables 4A and 4B, the time spent inside the cockpit for this maneuver increased relative to the other maneuvers thus far discussed. The variation in time to complete this maneuver was somewhat reduced over the other maneuvers, indicating that pilot variability in execution was smaller. The mean sector transition score, or visual activity between sectors increased, on the average indicating more activity, but variation was large. The right side and right chin bubble were frequented for the first time during this maneuver. Again, sector 3 received most of the attention, containing the largest percentage of total time and the longest dwell time.

TABLE 4A

Hover Turn Left (90°)



	TOTAL	SUBJECT MEAN	STD DEVIATION	RANGE
Time (secs.)	116.33	19.39	1.49	16.92 - 22.00
Sectors Used	22	3.67	.90	3 - 5
Sector Transitions (Permutations)	88	14.67	7.52	2 - 26
Mean Sector Transition/min.		45.39	21.96	6.31 - 79.96
Mean Dwell Time (secs.)		1.32	3.11	.75 - 9.51
% Time Out	85.3	Time Out (secs.) 16.54	2.85	10.31 - 19.01
% Time In	14.7	Time In (secs.) 2.85	2.18	1.32 - 6.61

TABLE 4B

HOVER TURN LEFT (90°)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		3	11	1										15
Q2	4		21											25
Q3	13	22		4		1	1							41
Q4		1	4											5
Q5														
Q6		1												1
Q7			1											1
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	17	27	37	5		1	1							88

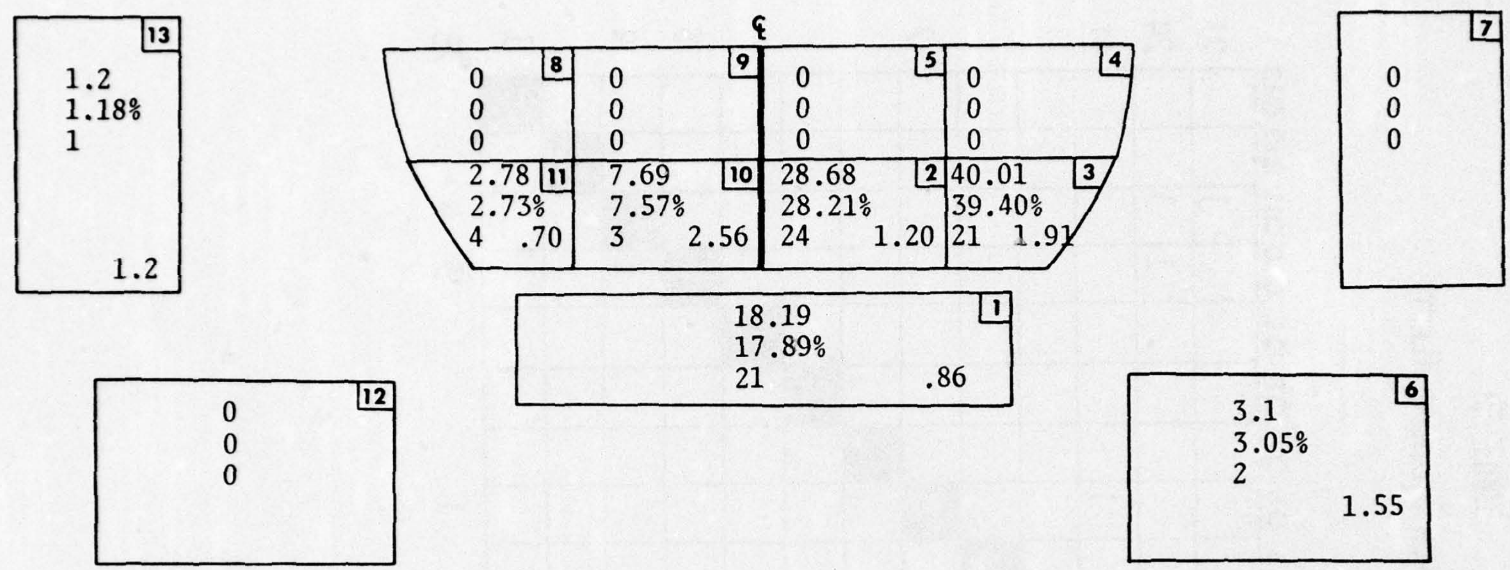
5. <u>Hover sideward (Left)</u>:

After completing the 90° turn the pilot hovered left for a distance of 60 - 70 feet and then was instructed to stop.

Tables 5A and 5B indicate that the time to complete this effort was on the average shorter than that of the forward hover and rearward hover. Subjects, of course, varied in how quickly they accomplished this maneuver. The eyes were active as indicated by the sector transition scores, though again, variability was great. Time spent inside the cockpit was increased over the previous maneuvers. Also, it can be seen that some of the left side of the windscreen was utilized (sectors 10, 11, and 13) and the right chin bubble was again frequented.

TABLE 5A

Hover Sideward (Left)



	TOTAL		SUBJECT MEAN	SUBJECT STD DEVIATION	SUBJECT RANGE
Time (secs.)	101.66		16.94	4.84	8.80 - 23.77
Sectors Used	21		3.5	.91	2 - 5
Sector Transitions (Permutations)	76		12.67	4.27	6 - 18
Mean Sector Transition/min.			48.51	19.92	18.97 - 79.01
Mean Dwell Time (secs.)			1.53	.79	.76 - 3.16
% Time Out	82.1	Time Out (secs.)	13.91	4.55	7.80 - 20.20
% Time In	17.9	Time In (secs.)	3.03	1.86	.50 - 5.87

TABLE 5B

Hover Sideward (Left)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		11	9								1			21
Q2	8		12							1	3			24
Q3	11	9				1								21
Q4														
Q5														
Q6		1	1											2
Q7														
Q8														
Q9														
Q10	1	2												3
Q11	1	2								1				4
Q12														
Q13										1				1
	21	25	22			1				3	4			76

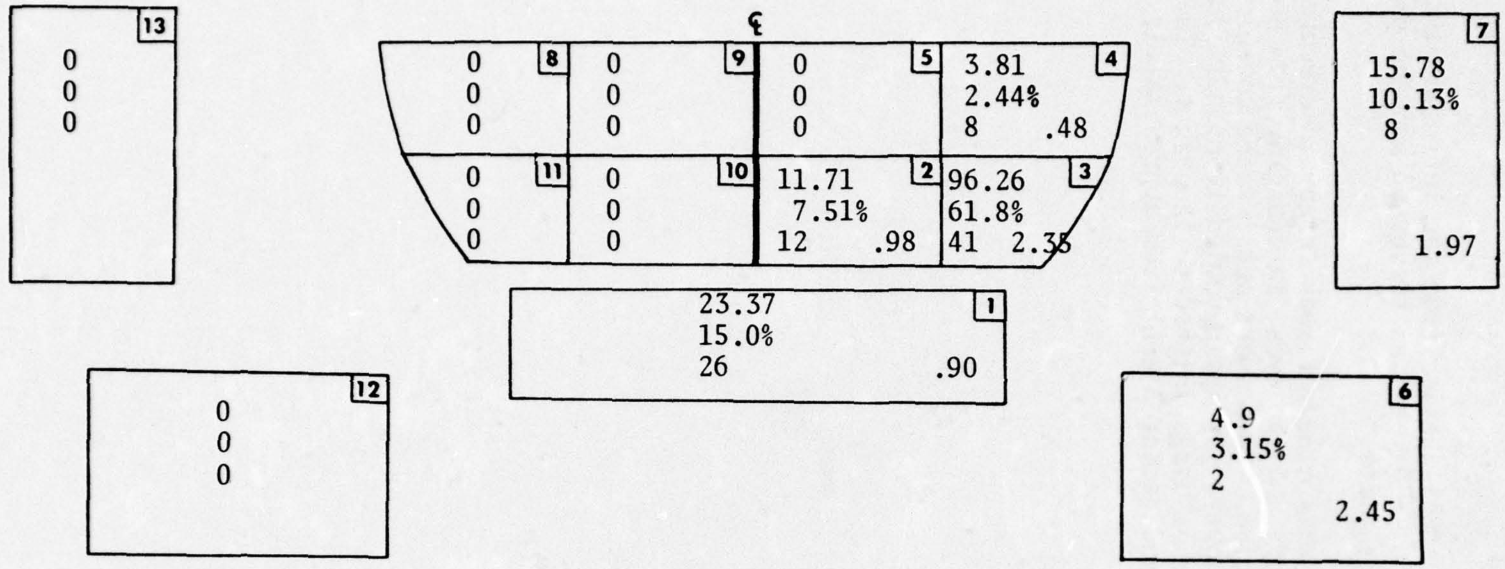
6. Hover sideward (Right):

This maneuver began after stabilization from the left sideward hover was attained. A distance of 60 - 70 feet was traversed and the pilot was then told to "stop" and stabilize.

Tables 6A and 6B indicate this maneuver took longer to execute than did the hover sideward left and the eyes, in changing from sector to sector, were a bit less active. Time spent outside the cockpit was similar to the left sideward hover, yet again varied from individual to individual. The total pattern of usage shifted to the right. The right side increased from 0 to 10% and sector 3 went from approximately 40% to 62%.

TABLE 6A

Hover Sideward (Right)



	TOTAL		SUBJECT MEAN	STD DEVIATION	RANGE
Time (secs.)	155.86		25.98	5.80	21.76 - 38.5
Sectors Used	23		3.83	1.53	2 - 7
Sector Transitions (Permutations)	97		16.17	8.99	6 - 35
Mean Sector Transition/min.			35.86	11.99	14.04 - 54.45
Mean Dwell Time (secs.)			2.00	1.05	1.10 - 4.27
% Time Out	85	Time Out (secs.)	22.08	5.74	14.09 - 24.01
% Time In	15	Time In (secs.)	3.90	2.37	1.11 - 8.12

TABLE 6B

HOVER SIDEWARD (RIGHT)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		1	22	2			1							26
Q2			7	2			3							12
Q3	25	9		3		2	2							41
Q4			6				2							8
Q5														
Q6			2											2
Q7		3	4	1										8
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	25	13	41	8		2	8							97

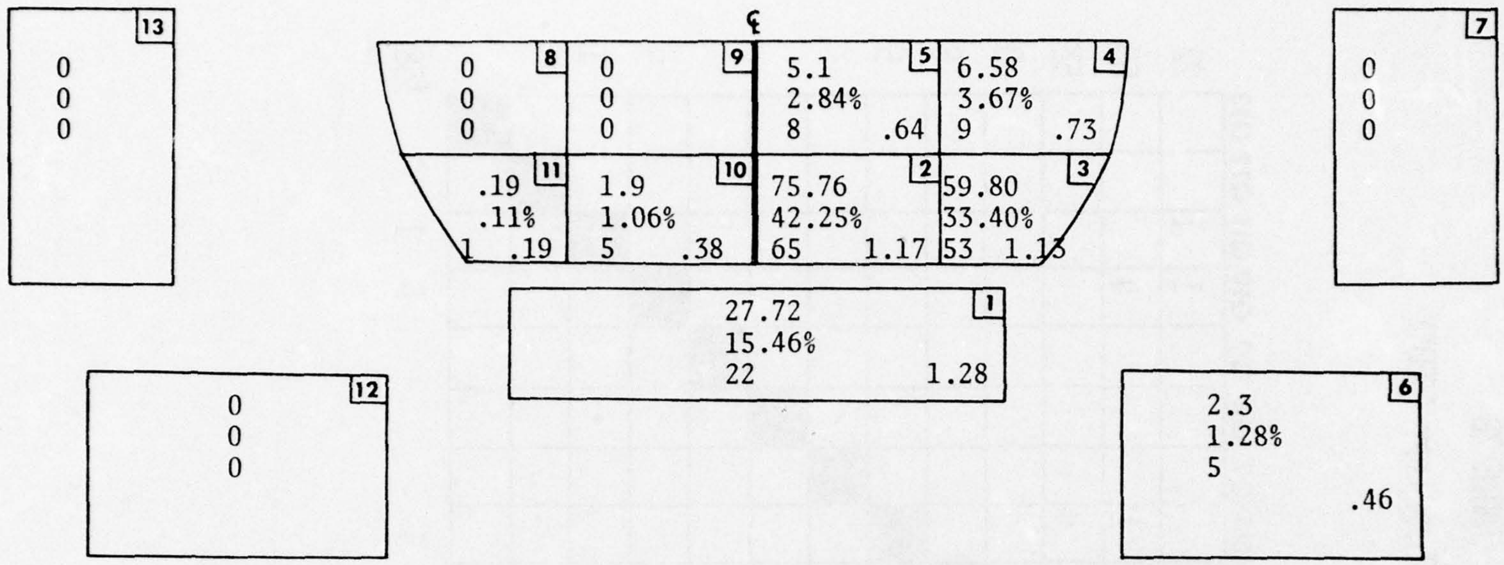
7. <u>Hover turn left (360°)</u>:

The pilot then made a 360° pedal turn to the right using the mast as a pivot point and ending when he again stabilized on his original heading.

Tables 7A and 7B show increased eye activity on this maneuver, which on the average started to approach one transition per sec. Sector 2 picked up the largest percentage of the time at approximately 42% and for the first time sector 5 picked up time. The inside mean dwell time went to a new high of 1.28 secs.

TABLE 7A

Hover Turn Left (360°)



	TOTAL		SUBJECT MEAN	SUBJECT STD DEVIATION	SUBJECT RANGE
Time (secs.)	179.30		29.88	5.28	19.06 - 34.50
Sectors Used	24		4.00	.82	3 - 5
Sector Transitions (Permutations)	168		28.00	11.21	14 - 48
Mean Sector Transition/min.			56.37	18.08	24.76 - 83.48
Mean Dwell Time (secs.)			1.23	.56	.72 - 2.42
% Time Out	84.5	Time Out (secs.)	25.26	6.72	10.41 - 30.3
% Time In	15.5	Time In (secs.)	4.62	2.81	1.19 - 8.65

TABLE 7B

Hover Turn Left (360°)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		17	2	1						1	1			22
Q2	8		45	2	5	1				4				65
Q3	9	36		3	1	4								53
Q4	2	3	2		2									9
Q5		3	2	3										8
Q6		3	2											5
Q7														
Q8														
Q9														
Q10	1	4												5
Q11	1													1
Q12														
Q13														
	21	66	53	9	8	5				5	1			168

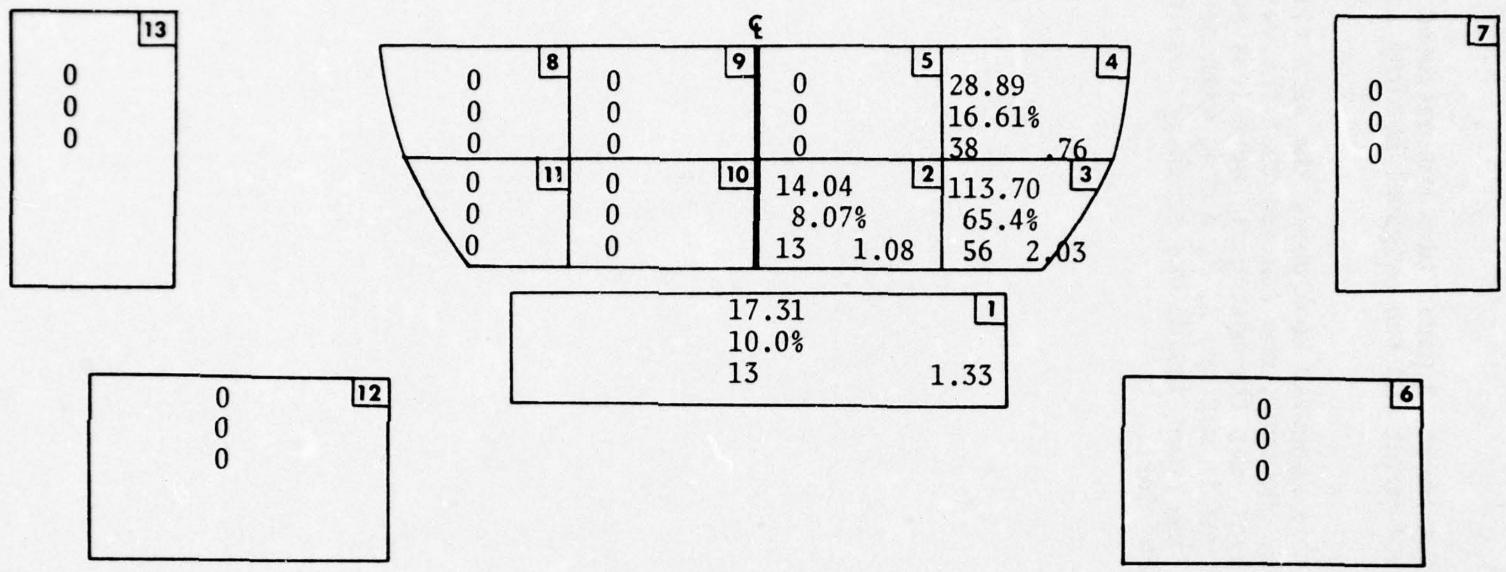
8. Hover turn right (360°):

Beginning again with a 3-foot hover, a pedal turn was executed to the left with the mast as a pivot point and the original heading as the stop point.

Tables 8A and 8B indicate this maneuver took about the same time as did the 360° hover left turn. However, one can see that the variability was much smaller. The eyes, for the most part, were less active, and all the time spent outside was in sectors 2, 3, and 4, with sector 3 receiving 65% of the time. Time spent inside was slightly less on the 360° right as opposed to the 360° left.

TABLE 8A

Hover Turn Right (360°)



TOTAL		SUBJECT	MEAN	STD DEVIATION	RANGE
Time (secs.)	173.90		28.98	2.13	26.17 - 32.23
Sectors Used	20		3.33	.96	2 - 5
Sector Transitions (Permutations)	120		20.00	13.75	2 - 40
Mean Sector Transition/min.			41.83	30.36	4.53 - 91.71
Mean Dwell Time (secs.)			3.66	4.38	.65 - 13.25
% Time Out	90	Time Out (secs.)	26.13	1.86	24.77 - 29.48
% Time In	10	Time In (secs.)	2.85	2.01	.16 - 5.00

TABLE 8B

HOVER TURN RIGHT (360°)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1			10	3										13
Q2	1		12											13
Q3	9	13		34										56
Q4	3		35											38
Q5														
Q6														
Q7														
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	13	13	57	37										120

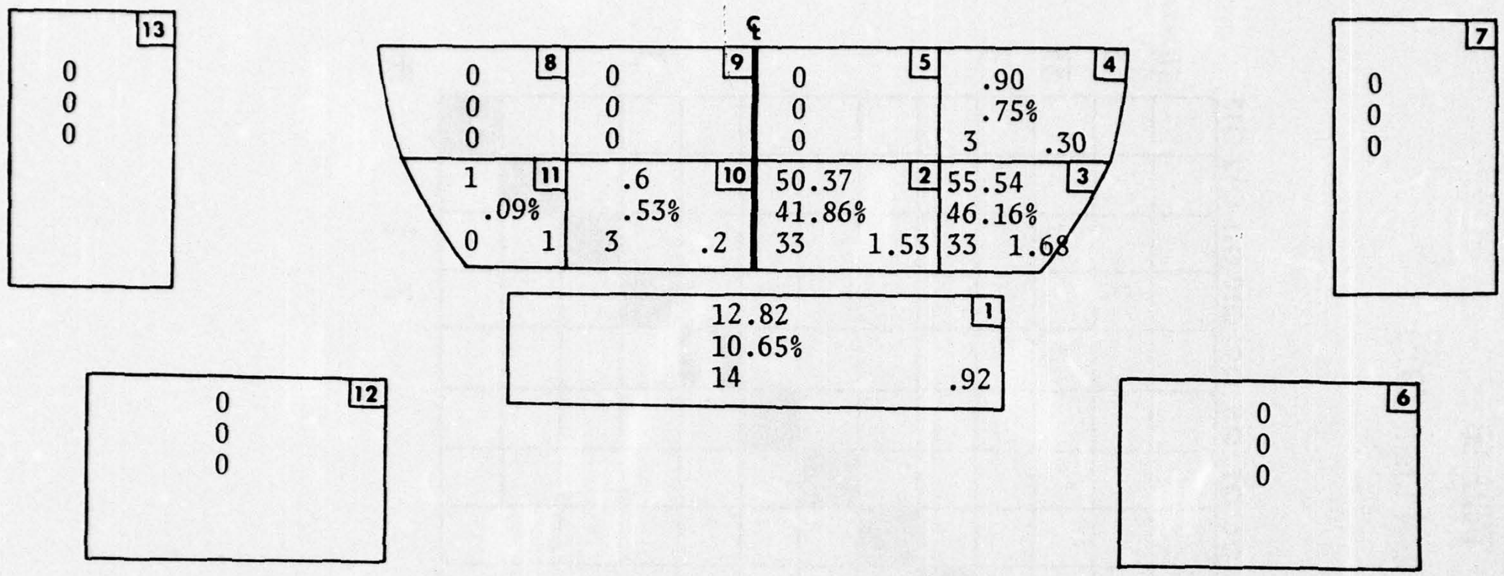
9. Hover turn right (90°):

These instructions were to again align the aircraft with the center line and were made using the mast as a pivot point and a 3-foot hover.

Tables 9A and 9B show that the 90° right is quite similar to the 90° turn left (4A and 4B) with respect to the time to execute, sectors used, eye activity, and dwell time. The major difference is in the shift from sector 3 to sector 2.

TABLE 9A

Hover Turn Right (90°)



	TOTAL	SUBJECT MEAN	SUBJECT STD DEVIATION	SUBJECT RANGE
Time (secs.)	120.34	20.06	7.43	10.71 - 34.39
Sectors Used	21	3.50	.76	3 - 5
Sector Transitions (Permutations)	86	14.33	4.88	7 - 21
Mean Sector Transition/min.		42.88	14.37	24.78 - 66.74
Mean Dwell Time (secs.)		1.40	.54	.90 - 2.42
% Time Out	89.4	Time Out (secs.) 17.92	7.06	9.58 - 30.91
% Time In	10.6	Time In (secs.) 2.14	1.37	.61 - 4.44

TABLE 9B

Hover Turn Right (90°)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1	■	6	7	1										14
Q2	7	■	24							2				33
Q3	8	23	■	2										33
Q4		1	2	■										3
Q5					■									
Q6						■								
Q7							■							
Q8								■						
Q9									■					
Q10		2								■	1			3
Q11											■			
Q12												■		
Q13													■	
	15	32	33	3						2	1			86

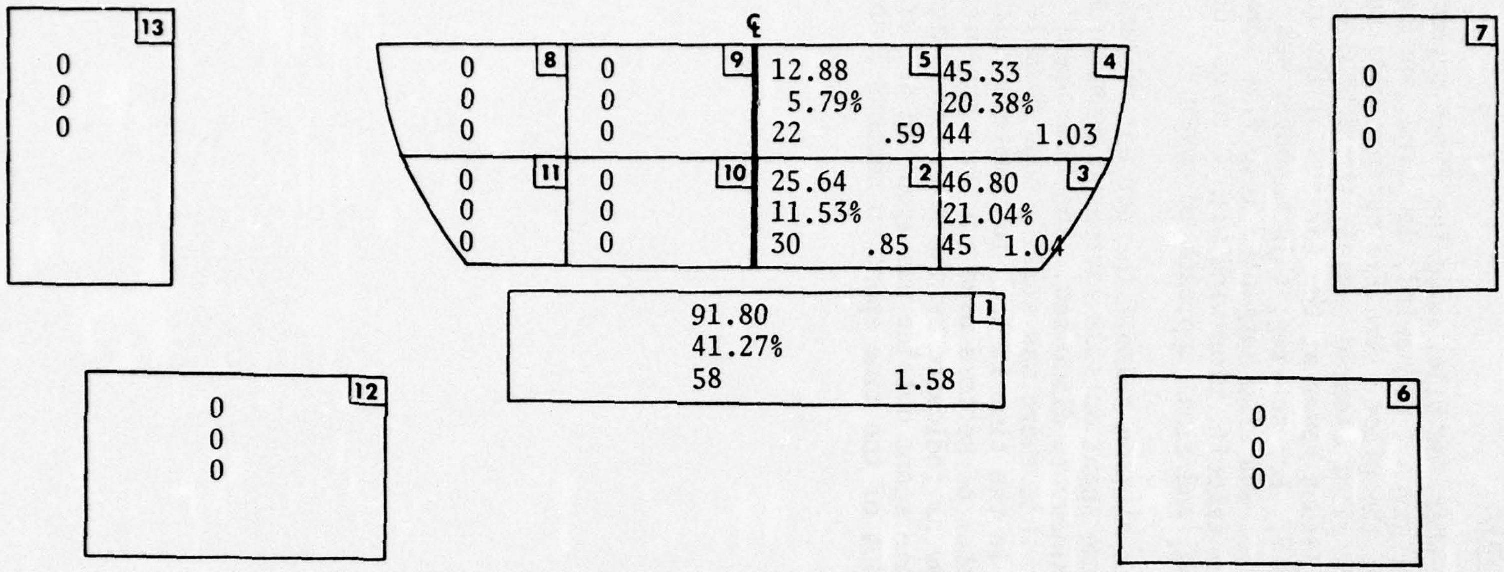
10. Normal takeoff (Left pattern):

The recorded segment began when the pilot made the first movement after takeoff instructions were given. Crosswind, downwind, and base turns were at the discretion of the pilot. Traffic pattern altitude was 1000 feet MSL. The subject pilot cleared himself throughout all turns. The approach was to a 3-foot hover at the far end of the runway to the base of a large pointed T. For scoring, this maneuver was treated as an individual maneuver and also segmented into five separate maneuvers. The 5 segments were takeoff, crosswind with 2 turns, downwind leg, base leg with 2 turns, and final approach to hover.

Tables 10A and 10B indicate that on takeoff the percent of time spent inside vs. percent of time spent outside increased considerably for this maneuver over the other maneuvers discussed. The time spent inside reached 41.3%. It can be seen that there was still a considerable amount of variation between subjects in the time it took to complete this maneuver. There were a limited number of sectors used for this maneuver, but the eyes were relatively active as indicated by the mean transition score. It can be seen that all the time spent outside was spent in sectors 2, 3, 4, and 5, with approximately 40% of the time spent in sectors 3 and 4.

TABLE 10A

Normal Takeoff (Left Pattern)



	TOTAL		SUBJECT MEAN	STD DEVIATION	RANGE
Time (secs.)	222.45		37.07	7.91	27.50 - 49.73
Sectors Used	27		4.50	.50	4 - 5
Sector Transitions (Permutations)	199		33.17	7.40	27 - 49
Mean Sector Transition/min.			55.06	11.79	40.34 - 74.18
Mean Dwell Time (secs.)			1.14	.25	.81 - 1.49
% Time Out	58.7	Time Out (secs.)	21.78	3.1	18.11 - 28.92
% Time In	41.3	Time In (secs.)	15.3	6.86	6.45 - 24.75

TABLE 10B

NORMAL TAKEOFF (LEFT PATTERN)

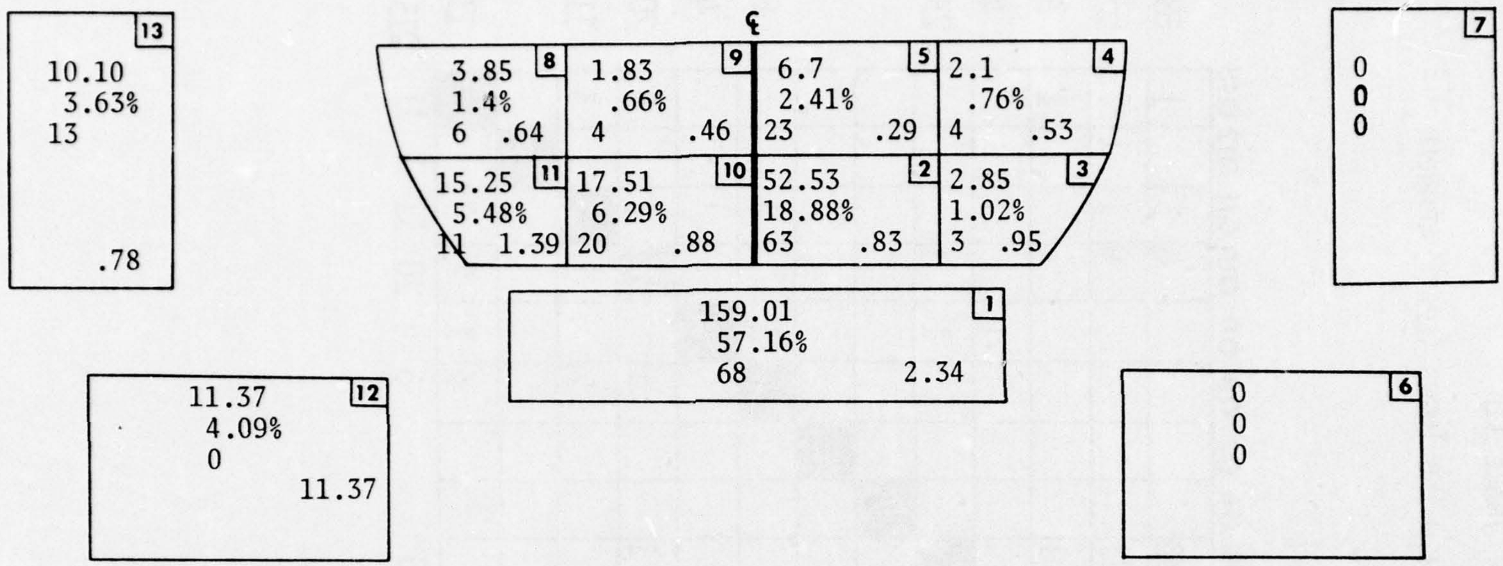
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		16	13	18	11									58
Q2	16		7		7									30
Q3	14	8		23										45
Q4	17		23		4									44
Q5	11	6	1	4										22
Q6														
Q7														
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	58	30	44	45	22									199

11. Crosswind with two turns (Left pattern):

It can be seen in Tables 11A and 11B that this is the first maneuver in which more time was spent inside than outside. Also, there was much less variation in time to complete this maneuver than in the other maneuvers thus far discussed. The mean sector transition per min. was fairly high, indicating a fair amount of visual activity. One can see from the ranges that one aviator spent a total of approximately 41 secs. inside. It can also be seen that the inside dwell time hit a high of 2.34 secs.

TABLE 11A

Crosswind with Two Turns (Left Pattern)



TOTAL		SUBJECT			
			MEAN	STD DEVIATION	RANGE
Time (secs.)	283.19		47.20	2.95	41.90 - 50.60
Sectors Used	44		7.33	.96	6 - 9
Sector Transitions (Permutations)	215		35.83	10.18	19 - 50
Mean Sector Transition/min.			45.55	13.73	23.26 - 63.01
Mean Dwell Time (secs.)			1.32	.55	.95 - 2.58
% Time Out	43.8	Time Out (secs.)	20.70	7.12	7.92 - 28.42
% Time In	56.2	Time In (secs.)	26.50	7.09	20.38 - 41.08

TABLE 11B

CROSSWIND WITH TWO TURNS (LEFT PATTERN)

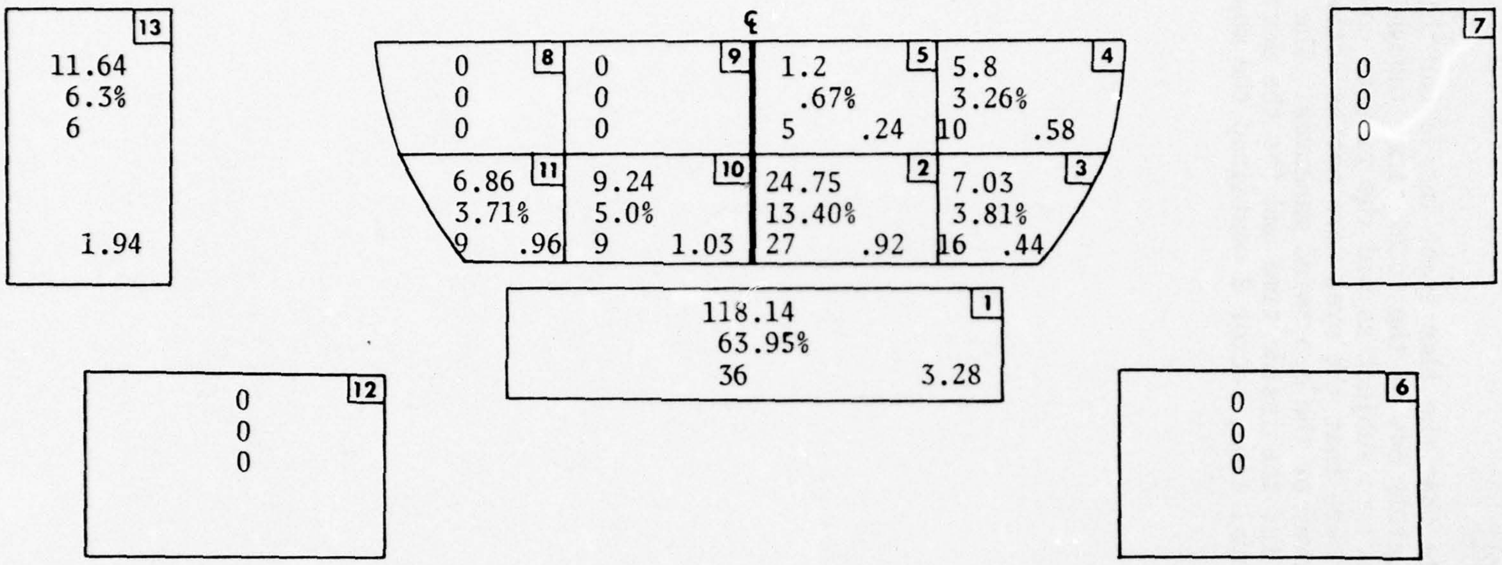
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		42	3	2	10					5	5		1	68
Q2	37		1	1	11					9	1	1	2	63
Q3		1			1								1	3
Q4	1	2							1					4
Q5	16	5							1	1				23
Q6														
Q7														
Q8	1	2							1	1	1			6
Q9	2	2												4
Q10	10	3			1			1			1		4	20
Q11	3	1						2		2			3	11
Q12														
Q13		4						3	1	2	3			13
	70	62	4	3	23			6	4	20	11	1	11	215

12. Downwind leg (Left pattern):

Tables 12A and 12B indicate that the time spent inside for this maneuver increased to approximately 64% of the total time, though of course, this varied from subject to subject as did the time to complete the maneuver. It can also be seen that the eyes were not as active as they were on the takeoff maneuver or the crosswind maneuver. The mean dwell time rose to 3.28 secs. for the inside time and for the sectors concerned with the outside visual time, sector 2 contained the most time.

TABLE 12A

Downwind Leg (Left Pattern)



	TOTAL	SUBJECT MEAN	STD DEVIATION	RANGE
Time (secs.)	184.74	30.79	11.01	17.91 - 52.85
Sectors Used	35	5.67	1.25	4 - 7
Sector Transitions (Permutations)	119	19.83	6.94	8 - 31
Mean Sector Transition/min.		40.88	16.19	22.71 - 71.13
Mean Dwell Time (secs.)		1.70	.61	.84 - 2.64
% Time Out	36.1	Time Out (secs.) 11.10	2.26	8.23 - 15.34
% Time In	63.9	Time In (secs.) 19.69	10.88	9.68 - 42.88

TABLE 12B

DOWNWIND LEG (LEFT PATTERN)

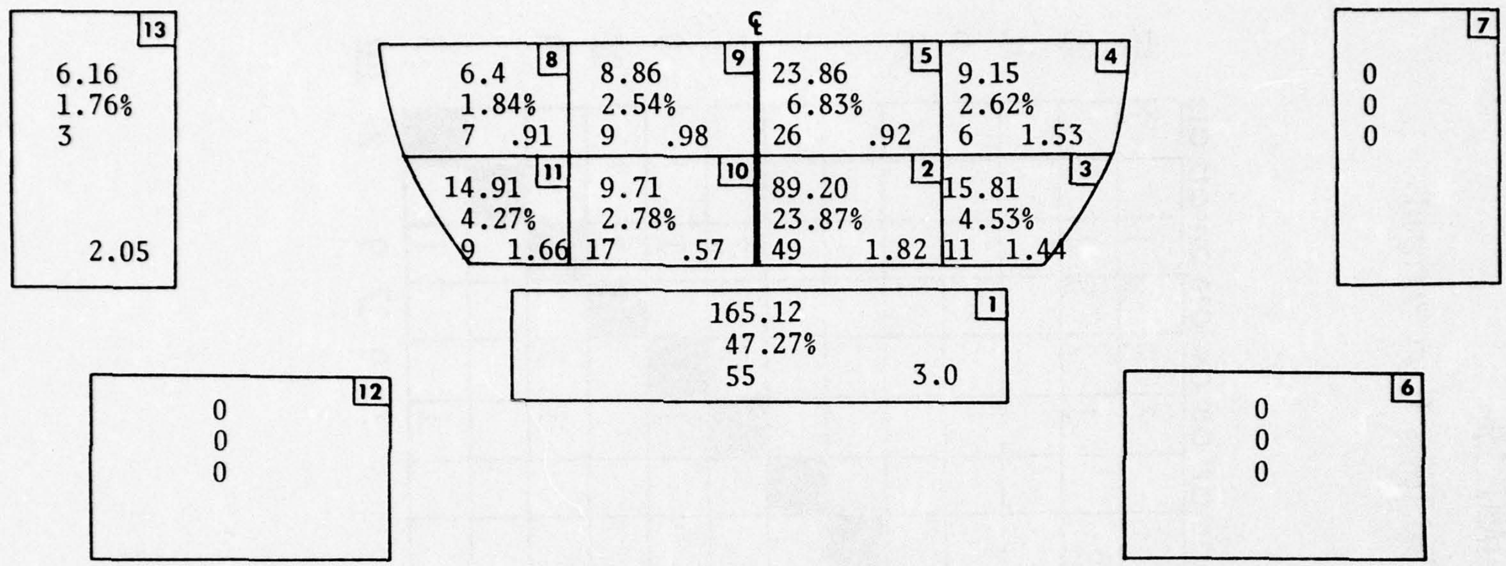
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		11	9	3						7	3		3	36
Q2	14		3		1					2	3	1	3	27
Q3	4	8		4										16
Q4	5	1	1		3									10
Q5	3	1		1										5
Q6														
Q7														
Q8														
Q9														
Q10	3	2	1	1	1						1			9
Q11	7	2												9
Q12														
Q13	1	2									3			6
	37	27	14	9	5					9	10	1	6	118

13. Base leg with two turns (Left pattern):

Tables 13A and 13B show that this maneuver took longer on the average than did the crosswind with two turns. The eyes were not quite as active, and the mean dwell times were slightly longer. The same sectors were used as in the crosswind with the exception of 12, or the left chin bubble. Sector 2, as with the crosswind maneuver, contained the largest percentage of the outside time. The dwell time in this sector, however, more than doubled for the maneuver. The dwell time in most sectors increased, with inside time going to 3 secs.

TABLE 13A

Base Leg with Two Turns (Left Pattern)



	TOTAL		SUBJECT MEAN	STD DEVIATION	RANGE
Time (secs.)	349.29		58.22	30.82	34.86 - 126.12
Sectors Used	48		7.83	1.68	5 - 10
Sector Transitions (Permutations)	192		32.00	8.27	22 - 44
Mean Sector Transition/min.			40.88	11.01	19.98 - 55.91
Mean Dwell Time (secs.)			1.79	.61	1.07 - 3.00
% Time Out	52.7	Time Out (secs.)	30.70	14.45	17.01 - 60.16
% Time In	47.3	Time In (secs.)	27.52	18.97	11.39 - 65.97

TABLE 13B

Base Leg with Two Turns (Left Pattern)

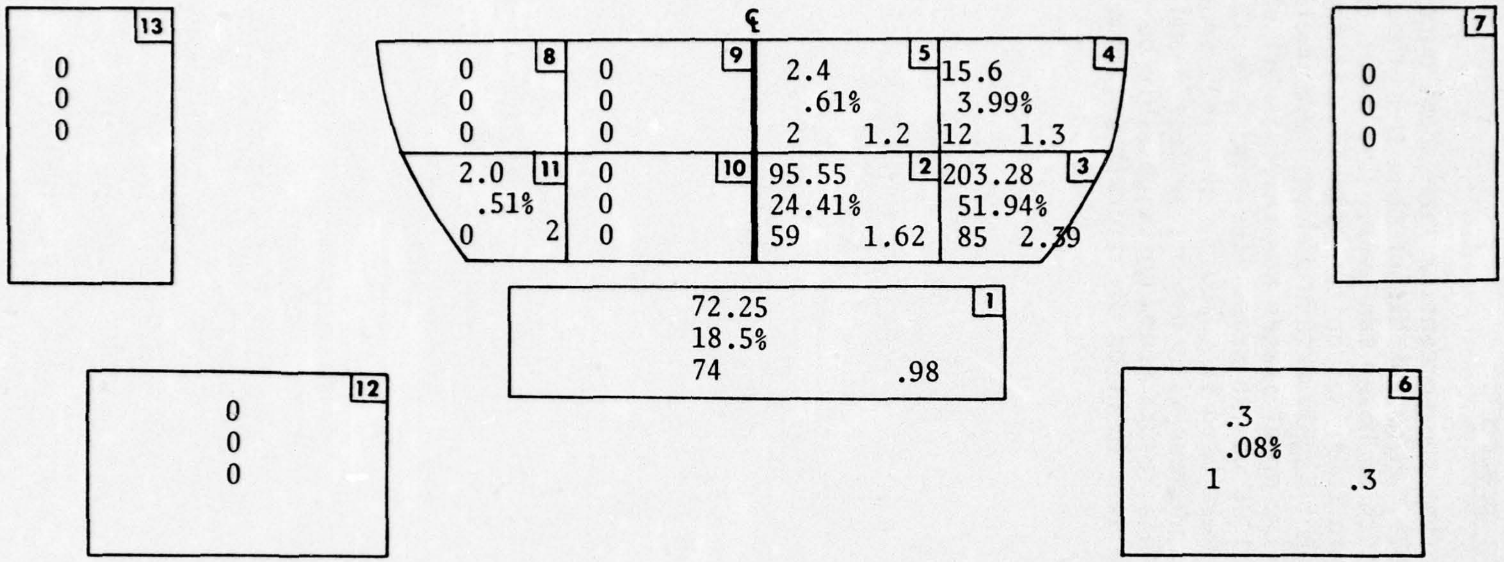
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		20	3		13			3	4	9	1		2	55
Q2	22		6	1	11			1	2	5	1			49
Q3	4	5		2										11
Q4	4	1	1											6
Q5	14	8	1	2						1				26
Q6														
Q7														
Q8		2			1				1	1	2			7
Q9	2	4			1			1			1			9
Q10	6	7	1								3			17
Q11	4	1						1	2	1				9
Q12														
Q13		1						1			1			3
	56	49	12	5	26			7	9	17	9		2	192

14. Final approach to hover (Left pattern):

Tables 14A and 14B indicate that the percent of time spent outside in final approach increased to 82%, which was higher than the other segments of this takeoff and return to hover maneuver. The total time to complete this final approach to hover was quite variable. It can also be seen that the eyes were not highly active and the mean dwell time was 1.69 secs. The dwell time spent inside was fairly short when compared to takeoff, going from 1.98 to .98 secs. The same general sectors were used in landing as were used in takeoff. However, sectors 2 and 3 contained the most time, whereas with takeoff sectors 3 and 4 contained most of the time. This result could quite possibly be due to the shift in the horizon line as a function of aircraft attitude.

TABLE 14A

Final Approach to Hover (Left Pattern)



TOTAL		SUBJECT			
			MEAN	STD DEVIATION	RANGE
Time (secs.)	391.39		65.23	18.79	44.12 - 91.18
Sectors Used	25		4.17	.90	3 - 5
Sector Transitions (Permutations)	233		38.83	9.82	32 - 60
Mean Sector Transition/min.			36.98	7.01	22.75 - 44.88
Mean Dwell Time (secs.)			1.69	.34	1.34 - 2.16
% Time Out	81.54	Time Out (secs.)	49.86	15.49	35.30 - 69.33
% Time In	18.46	Time In (secs.)	12.04	7.36	1.80 - 21.86

TABLE 14B

Final Approach to Hover (Left Pattern)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		26	45	2							1			74
Q2	19		35	4	1									59
Q3	49	29		5		1							1	85
Q4	3	2	6		1									12
Q5		1		1										2
Q6			1											1
Q7														
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	71	58	87	12	2	1					1		1	233

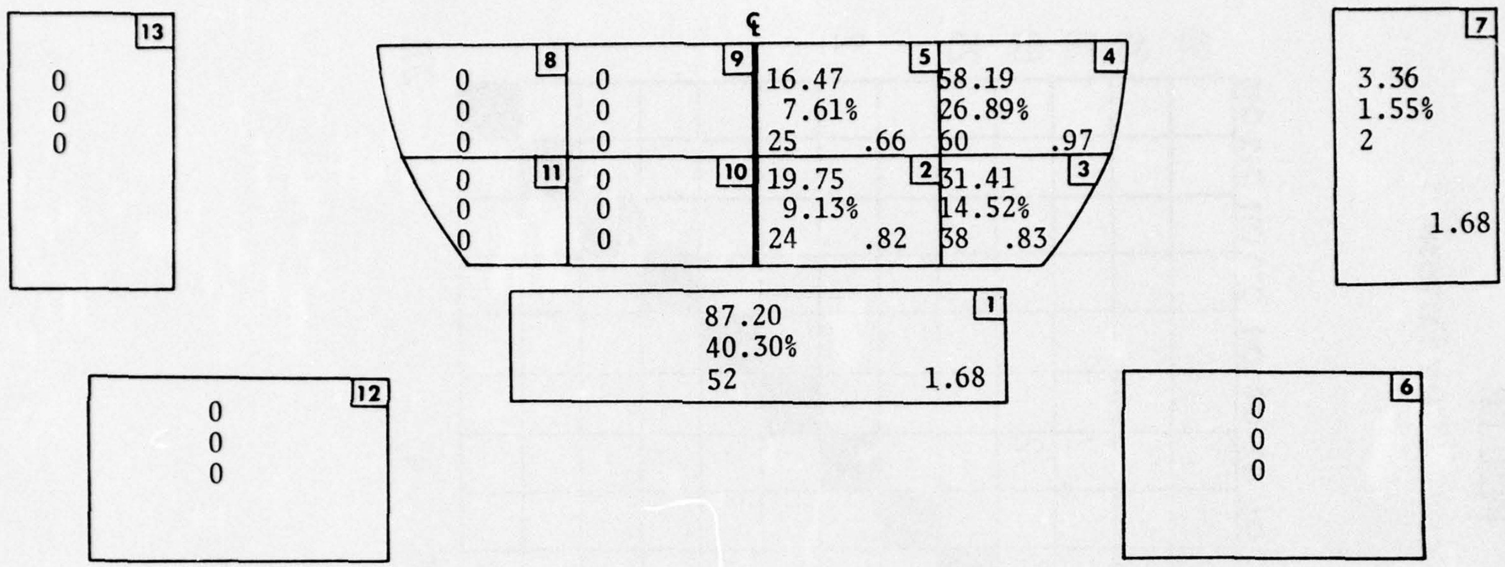
15. Normal takeoff (Right pattern):

The same criteria applied in this maneuver as in the normal takeoff (left pattern), except the direction of traffic was right and the approach was to the ground at the base of the T. Recording time ended when the collective was fully lowered and the cyclic centered. Scoring was handled in the same way as the previous maneuver.

Tables 15A and 15B indicate that the time to takeoff in the right pattern was very similar to that given for takeoff in the left pattern. One can also note the similarities between the transition and dwell scores as well as the similarities between percent of time spent inside and the percent of time spent outside. In addition, the same general sectors were utilized.

TABLE 15A

Normal Takeoff (Right Pattern)



	TOTAL		SUBJECT MEAN	STD DEVIATION	RANGE
Time (secs.)	216.38		36.06	5.91	28.79 - 43.83
Sectors Used	30		5.00	.82	4 - 6
Sector Transitions (Permutations)	201		33.50	5.91	24 - 41
Mean Sector Transition/min.			55.75	4.83	50.02 - 65.39
Mean Dwell Time (secs.)			1.08	.09	.92 - 1.20
% Time Out	59.7	Time Out (secs.)	21.53	4.34	14.65 - 43.84
% Time In	40.3	Time In (secs.)	14.53	3.77	7.83 - 19.25

TABLE 15B

NORMAL TAKEOFF (RIGHT PATTERN)

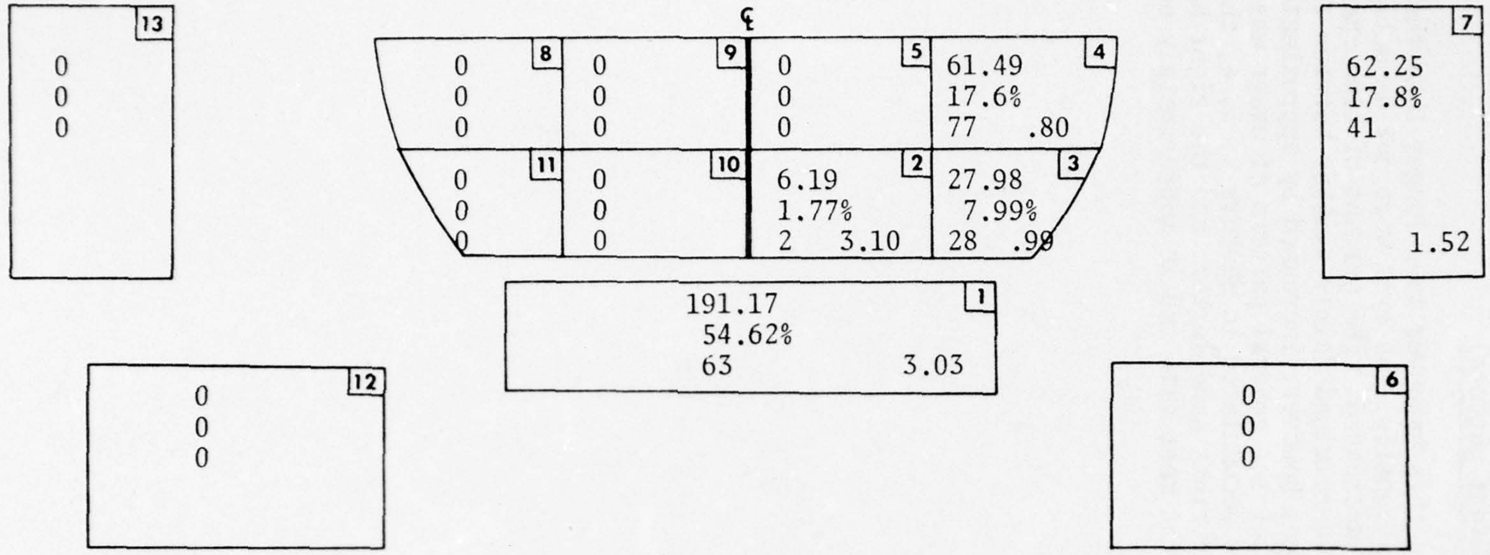
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Total
Q1		7	11	22	12									52
Q2	7		7	4	6									24
Q3	10	5		21			2							38
Q4	30	6	15		7		2							60
Q5	6	4	2	13										25
Q6														
Q7	2													2
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
Total	55	22	35	60	25		4							201

16. Crosswind with two turns (Right pattern):

Tables 16A and 16B indicate this maneuver took longer than the crosswind in the left pattern. Additionally, the eyes were not as active and the number of sectors used decreased. The percent of time spent inside vs the time spent outside remained fairly similar between the two patterns. The inside dwell time, however, increased by approximately .7 sec. It can also be seen that the general pattern of usage was not the same. All outside time was accumulated in sectors 2, 3, 4, and 7, with sectors 4 and 7, the upper right hand sector, and the right hand door respectively, containing the most time and in approximately equal amounts.

TABLE 16A

Crosswind with Two Turns (Right Pattern)



	TOTAL	SUBJECT			
			MEAN	STD DEVIATION	RANGE
Time (secs.)	350.06		58.34	8.76	46.58 - 74.21
Sectors Used	28		4.67	.47	4 - 5
Sector Transitions (Permutations)	211		35.17	9.51	23 - 48
Mean Sector Transition/min.			36.48	9.71	21.48 - 53.01
Mean Dwell Time (secs.)			1.79	.53	1.13 - 2.79
% Time Out	45.39	Time Out (secs.)	26.48	6.77	17.84 .- 46.58
% Time In	54.61	Time In (secs.)	31.86	9.22	20.57 - 46.40

TABLE 16B

CROSSWIND WITH TWO TURNS (RIGHT PATTERN)

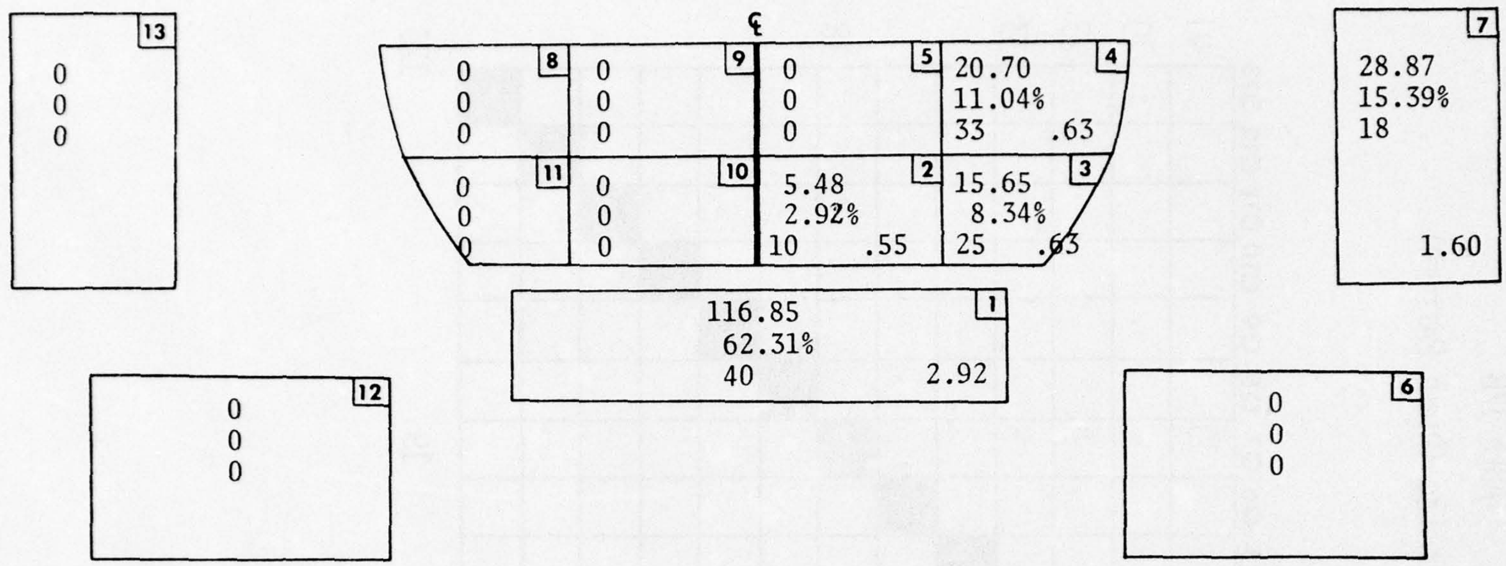
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		1	10	38			14							63
Q2	1						1							2
Q3	12			15			1							28
Q4	41	1	11				24							77
Q5														
Q6														
Q7	9		7	25										41
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	63	2	28	78			40							211

17. Downwind leg (Right pattern):

Tables 17A and 17B indicate that the time to complete the downwind leg on the right pattern was very similar to the time to complete the downwind leg on the left pattern. Also, eye activity, mean dwell scores, time in, and time out, were very similar. The sector dwell times decreased as did the general pattern of interest, an event which would be expected. The largest percentage of time out was accumulated in the right window, or sector 7. The general response pattern for this maneuver, as well as the relative time spent in each sector, was very similar to that of the crosswind maneuver with two turns, though the eyes were more active.

TABLE 17A

Downwind Leg (Right Pattern)



	TOTAL		SUBJECT MEAN	STD DEVIATION	RANGE
Time (secs.)	187.55		31.26	8.77	16.92 - 45.76
Sectors Used	29		4.83	.37	4 - 5
Sector Transitions (Permutations)	126		21.00	3.11	15 - 24
Mean Sector Transition/min.			45.02	19.61	27.70 - 85.11
Mean Dwell Time (secs.)			1.54	.51	.71 - 2.17
% Time Out	37.70	Time Out (secs.)	11.78	2.51	9.02 -16.36
% Time In	62.30	Time In (secs.)	19.48	7.81	6.80 - 32.41

TABLE 17B

DOWNWIND LEG (RIGHT PATTERN)

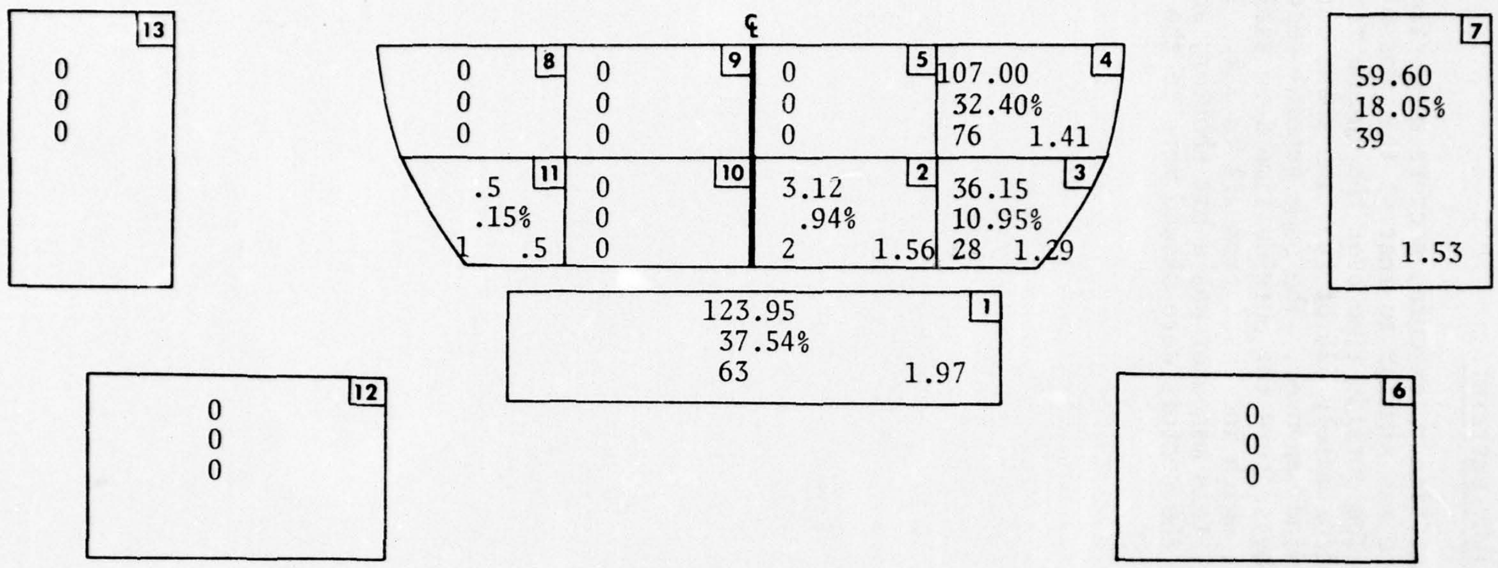
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		7	8	15			10							40
Q2	5		5											10
Q3	11	2		8			4							25
Q4	16		12				5							33
Q5														
Q6														
Q7	6	2	1	9										18
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	38	11	26	32			19							126

18. <u>Base leg with two turns (Right pattern)</u>:

Tables 18A and 18B show that time to execute, sectors used, transitions per min., and dwell time was similar to that of the crosswind with two turns right pattern. The outside time over the inside time, however, was reversed, with approximately 62% of the time spent outside as opposed to 45% in the crosswind maneuver. The same general sectors were used and the percentages by sectors for outside time were similar, with the exception of sector 4, which increased from 11% to 32%. In comparison with the left base leg, this maneuver was a bit shorter, and more time was spent outside. Also, the sectors were skewed more to the right than to the left.

TABLE 18A

Base Leg with Two Turns (Right Pattern)



TOTAL			SUBJECT		
			MEAN	STD DEVIATION	RANGE
Time (secs.)	330.27		55.04	7.27	41.56 - 65.86
Sectors Used	29		4.83	.69	4 - 6
Sector Transitions (Permutations)	209		34.83	7.66	19 - 41
Mean Sector Transition/min.			37.97	10.94	17.33 - 53.42
Mean Dwell Time (secs.)			1.58	.79	1.12 - 3.46
% Time Out	62.48	Time Out (secs.)	34.39	6.98	28.66 - 65.81
% Time In	37.52	Time In (secs.)	20.66	6.66	10.50 - 28.53

TABLE 18B

Base Leg with Two Turns (Right Pattern)

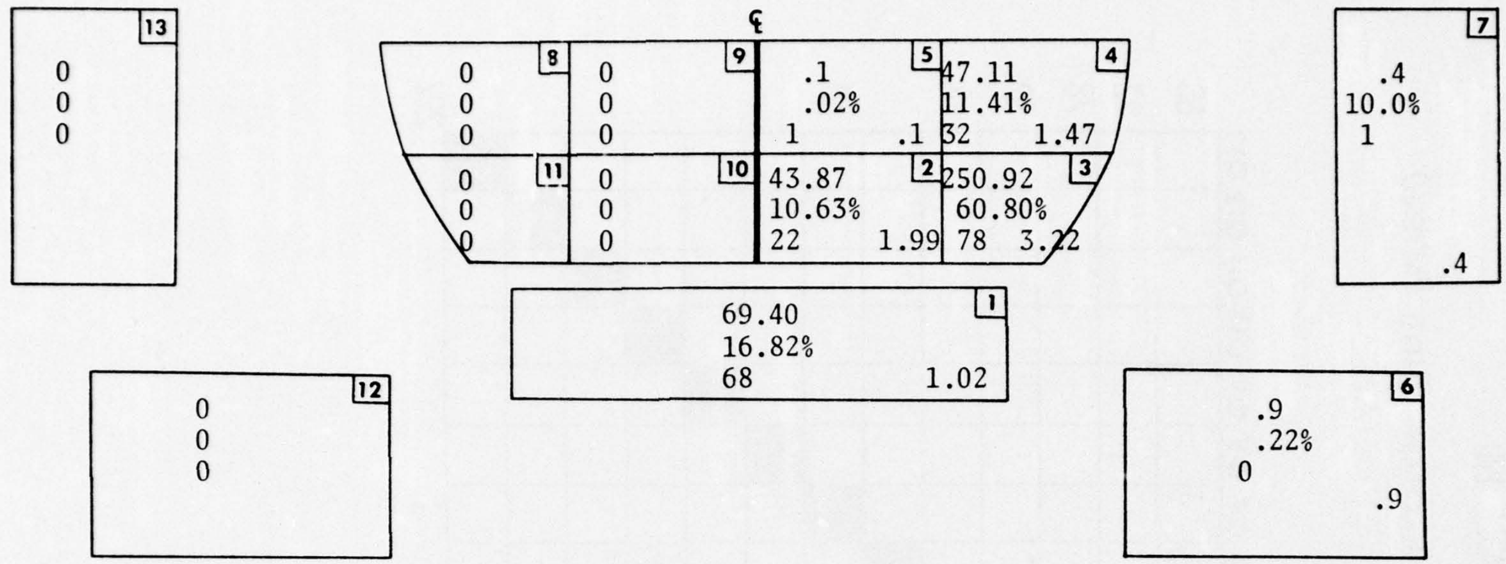
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1			11	39			13							63
Q2							1				1			2
Q3	18	1		9										28
Q4	35		18				23							76
Q5														
Q6														
Q7	10		1	28										39
Q8														
Q9														
Q10														
Q11		1												1
Q12														
Q13														
	63	2	30	76			37				1			209

19. Final approach and touchdown (Right pattern):

Tables 19A and 19B indicate that in general the data was much the same as approach to hover. Touchdown took slightly longer and did not exhibit as much eye activity. Quadrants 3 and 4 increased in time relative to the approach to a hover. Eye activity was less for the approach and dwell time was longer.

TABLE 19A

Final Approach and Touchdown (Right Pattern)



	TOTAL		SUBJECT MEAN	STD DEVIATION	RANGE
Time (secs.)	412.74		68.79	15.62	47.67 - 90.10
Sectors Used	26		4.33	.75	3 - 5
Sector Transitions (Permutations)	202		33.67	12.77	15 - 53
Mean Sector Transition/min.			29.36	7.20	18.88 - 36.99
Mean Dwell Time (secs.)			2.04	.61	1.62 - 3.18
% Time Out	83.19	Time Out (secs.)	57.22	12.42	46.72 - 70.59
% Time In	16.82	Time In (secs.)	11.57	6.34	3.25 - 19.72

TABLE 19B

FINAL APPROACH AND TOUCHDOWN (RIGHT PATTERN)

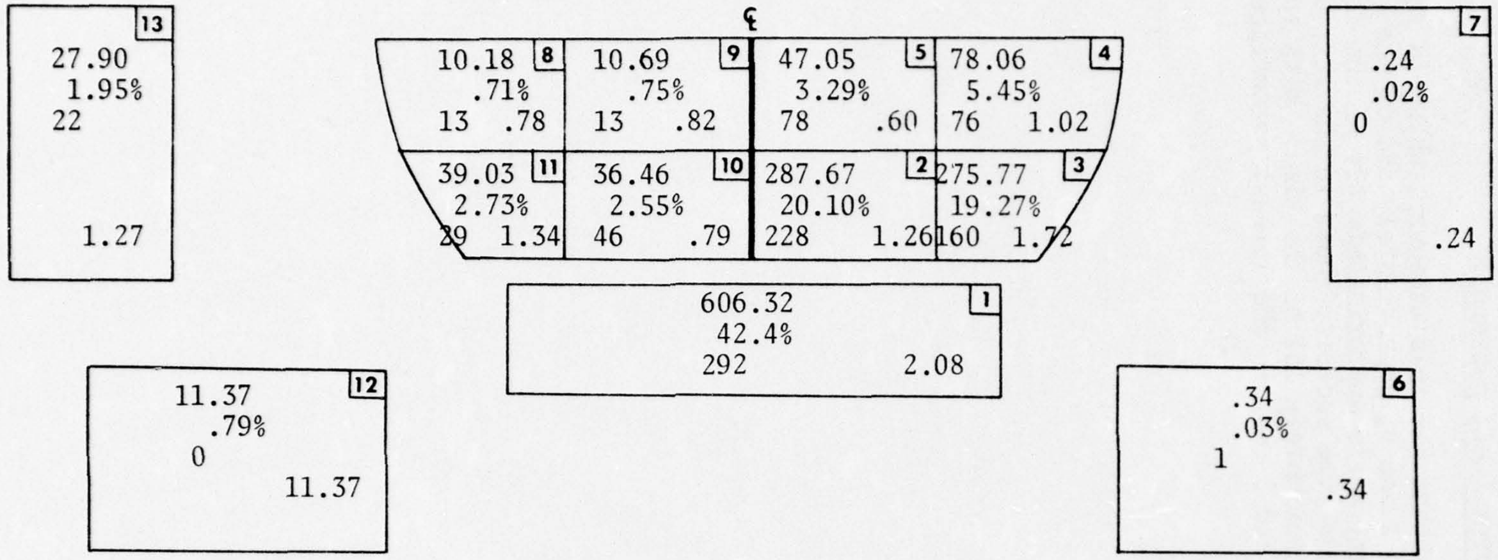
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		6	46	14		1	1							68
Q2	7		15											22
Q3	47	15		16										78
Q4	14	1	16		1									32
Q5				1										1
Q6														
Q7			1											1
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	68	22	78	31	1	1	1							202

20. Normal takeoff terminate hover (Left pattern):

Tables 20A and 20B indicate that for this maneuver, which is the summary of Tables 10 through 14 A and B, approximately 58% of the time was spent outside of the cockpit, while approximately 42% of the time was spent inside. Of the outside time sectors, those to the left of the center post account for approximately 16% of the time. With regard to the outside time, sectors 2 and 3 contain the largest percentages of total times.

TABLE 20A

Normal Takeoff Terminate Hover (Left Pattern)



	TOTAL	SUBJECT MEAN	SUBJECT STD DEVIATION	SUBJECT RANGE
Time (secs.)	1431.06	238.51	33.64	176.83 - 277.50
Sectors Used	179	29.83	2.71	27 - 35
Sector Transitions (Permutations)	958	159.67	19.35	127 - 187
Mean Sector Transition/min.		40.17	17.22	36.98 - 55.05
Mean Dwell Time (secs.)		1.49	.62	1.14 - 1.80
% Time Out	57.6	Time Out (secs.) 137.46	16.01	118.96 - 160.13
% Time In	42.4	Time In (secs.) 101.05	29.32	57.87 - 152.43

TABLE 20B

NORMAL TAKEOFF TERMINATE HOVER (LEFT PATTERN)

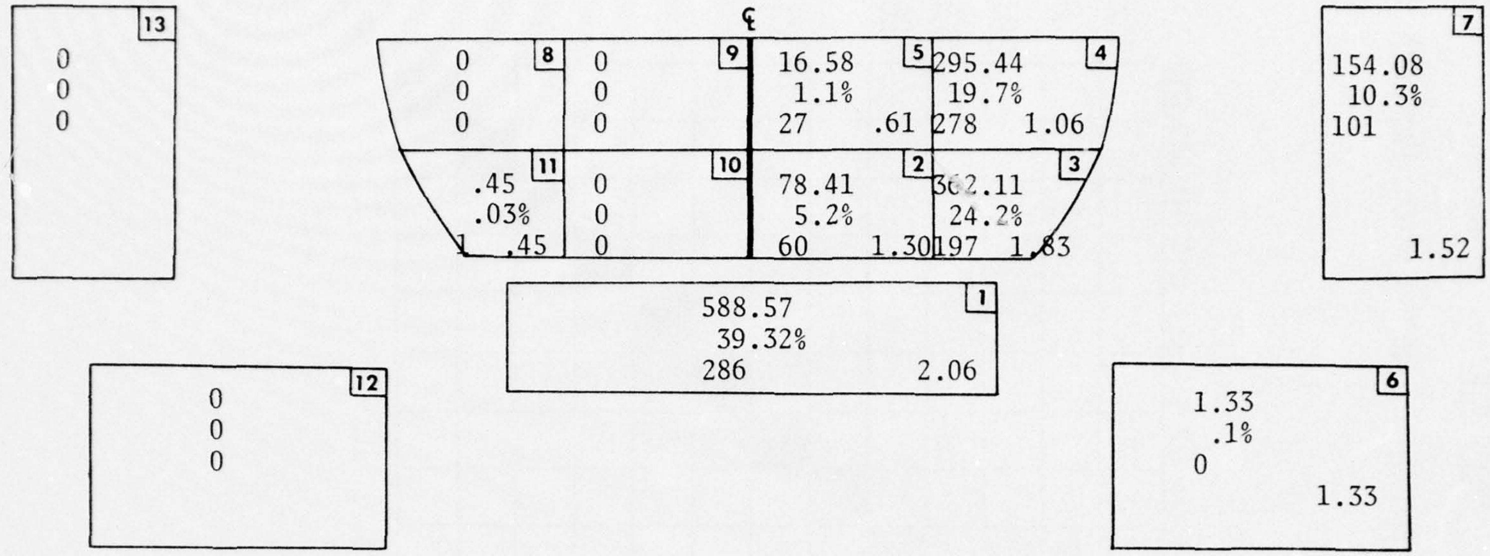
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		115	73	25	34			3	4	21	10	1	6	292
Q2	109		52	6	31			1	2	16	5	1	5	228
Q3	71	51		34	1	1							2	160
Q4	30	6	31		8				1					76
Q5	44	21	2	8					1	2				78
Q6			1											1
Q7														
Q8	1	4			1				2	2	3			13
Q9	4	6			1			1			1			13
Q10	19	12	2	1	2			1			5		4	46
Q11	14	4						3	2	3			3	29
Q12														
Q13	1	7						4	1	2	7			22
	293	226	161	74	78	1		13	13	46	31	2	20	958

21. Normal takeoff and approach to landing (Right pattern):

Tables 21A and 21B indicate that for this maneuver visual information was received primarily from sectors right of the center post. Sectors left of the center post accounted for only .05% of the total time. Compared to the left pattern, which was terminated to the hover, more time was spent outside and dwell times were slightly longer. The right window or sector 7, went from only .02% in the left pattern to approximately 10% for this maneuver.

TABLE 21A

Normal Takeoff and Approach to Landing (Right Pattern)



	TOTAL	SUBJECT MEAN	STD DEVIATION	RANGE
Time (secs.)	1497.00	249.50	28.16	198.41 - 284.70
Sectors Used	142	23.67	.69	23 - 25
Sector Transitions (Permutations)	949	158.33	18.95	119 - 174
Mean Sector Transition/min.		38.08	17.39	28.74 - 55.75
Mean Dwell Time (secs.)		1.58	.71	1.08 - 2.24
% Time Out	60.68	Time Out (secs.) 151.41	10.98	139.45 - 171.19
% Time In	39.32	Time In (secs.) 98.10	26.84	55.11 - 139.06

TABLE 21B

NORMAL TAKEOFF AND APPROACH TO LANDING (RIGHT PATTERN)

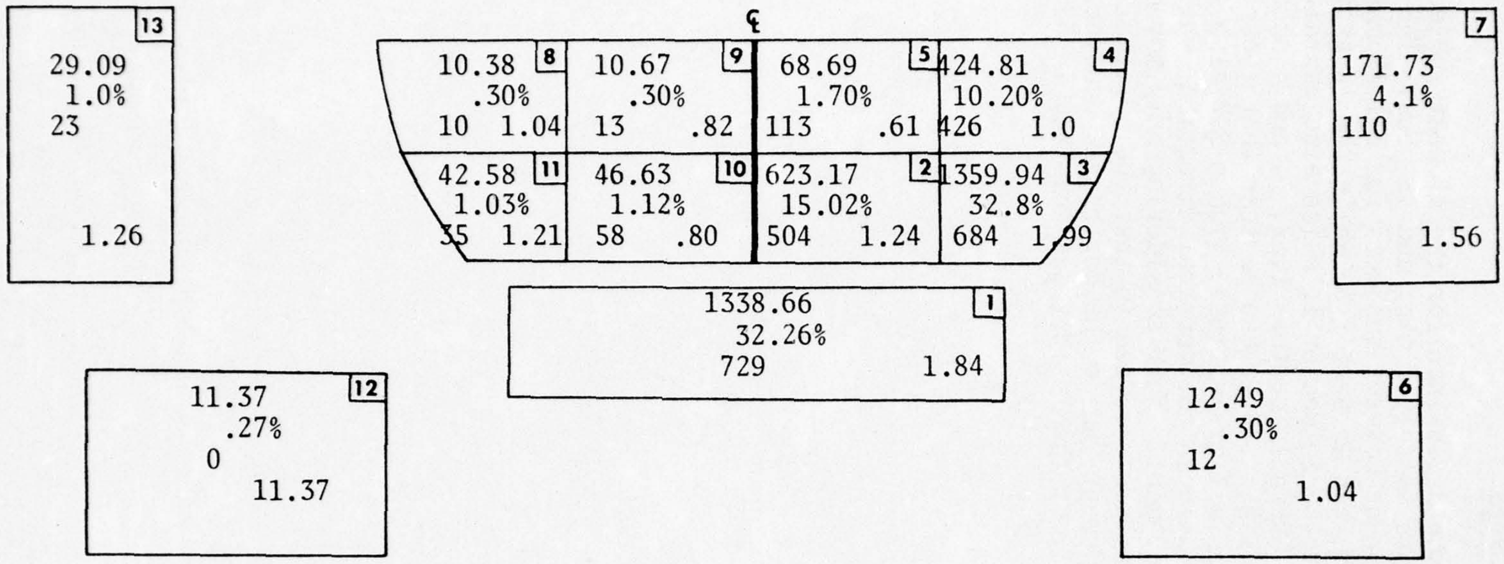
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		21	86	128	12	1	38							286
Q2	20		27	4	6		2				1			60
Q3	98	23		69			7							197
Q4	137	8	72		8		54							279
Q5	6	4	2	14										26
Q6														
Q7	27	2	10	62										101
Q8														
Q9														
Q10														
Q11														
Q12														
Q13														
	288	58	197	277	26	1	101				1			949

22. Summary table of ail maneuvers:

Table 22A indicates that the difference for the slowest subject to the fastest subject was approximately 2 min. and 45 secs. The total number of sector differences between subjects for all 19 maneuvers was 18. The longest dwell time was in sector 3, while the largest number of transitions was found to be in sector 1, which also contained the next highest dwell time. Overall, sectors 1, 2, 3, and 4 accounted for 90.28% of the time. From Table 22B it can be seen that these sectors were involved in 98.15% of all transitions. Table 22B also shows that 65.1% of the transitions were in the vertical direction, while horizontal yielded 34.9% of movement. When considering only movement on the windscreen, these values are reversed in that the vertical accounted for 44.2% of the movement, while the horizontal accounted for 55.8%. Additionally, sector 1, or the inside, was involved in 53.9% of all transitions.

TABLE 22A

Summary Table of All Maneuvers



TOTAL		SUBJECT			
			MEAN	STD DEVIATION	RANGE
Time (secs.)	4150.14		691.69	56.98	599.08 - 763.20
Sectors Used	500		83.33	5.85	74 - 92
Sector Transitions (Permutations)	2717		452.80	46.22	378 - 523
Mean Sector Transition/min.			39.28	5.65	33.28 - 49.43
Mean Dwell Time (secs.)			1.53	.66	1.48 - 2.97
% Time Out	67.74%	Time Out (secs.)	468.58	44.60	410.45 - 531.9
% Time In	32.26%	Time In (secs.)	223.11	47.34	171.08 - 308.18

TABLE 22B

SUMMARY TABLE OF ALL MANEUVERS

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	
Q1		182	253	161	46	1	39	3	4	22	12		6	729
Q2	165		236	14	42	1	5	1	2	23	9	1	5	504
Q3	280	222		158	2	8	10			2			2	684
Q4	172	19	160		18		56		1					426
Q5	50	28	7	25			1			2				113
Q6		4	6							2				12
Q7	27	5	15	63										110
Q8	1	4							2		3			10
Q9	4	6			1			1			1			13
Q10	21	20	3	1	2			1			6		4	58
Q11	16	7						3	2	4			3	35
Q12														
Q13	1	7						4	1	3	7			23
	737	504	680	422	111	10	111	13	12	58	38	1	20	2717

PART II

The results of questionnaire data may be seen in Tables 1C-12C. The sector numbering remains the same as in Part I and is as follows:

Sector 1	-	Inside the aircraft
Sector 2 & 3	-	Lower windscreen (Right half)
Sector 4 & 5	-	Upper windscreen (Right half)
Sector 10 & 11		Lower windscreen (Left half)
Sector 8 & 9	-	Upper windscreen (Right half)
Sector 7	-	Right door window
Sector 13	-	Left door window
Sector 6	-	Right chin bubble
Sector 12	-	Left chin bubble

The three values found for each scoring area for each maneuver in these tables represents the mean percent of time spent, or estimated mean time spent, in that visual area. The first of the three values, (Column I*) is based on the questionnaire information for the pilot's estimate of the time they used a particular area. This data was obtained three weeks after the subject's initial flight. The second value (Column II**) is based on the questionnaire data obtained immediately after a second flight of all maneuvers conducted six weeks after the initial flight. The third value (Column III) is based on the values obtained through the video recording of visual performance made during the initial flight.

It can be seen from the tables the questionnaire-based data is often at variance with itself, depending on when the questionnaire was administered, as well as with the data based on in-flight measurement. This can be observed by viewing the results in the tables, as well as the correlation coefficients seen at the bottom of each table. There is, as one can see, generally more agreement between the questionnaire data than the questionnaire data and the data obtained in flight. Also, there is more agreement between some maneuvers in some areas than others.

When viewing the values contained in the tables, pilots often rated areas high during a particular maneuver when the areas as reported in flight contained little or no time, for example:

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*Data from this questionnaire, to include means, standard deviations, and ranges in percent is presented in Appendix A.

**Data from this questionnaire, to include means, standard deviations, and ranges in percent is presented in Appendix B.

TABLE 1C

Liftoff to Stabilized Hover (mean %)

SCORING AREA	I	II	III
1	4.83	4.67	7.25
2	15.00	30.33	2.10
3	17.00	25.17	86.08
4	14.17	16.33	4.60
5	25.00	16.50	0
6	11.83	3.67	0
7	5.00	1.33	0
8	1.67	.87	0
9	3.83	1.17	0
10	.83	0	0
11	.83	0	0
12	0	0	0
13	0	0	0

$r_{I\ II} = .81$

$r_{I\ III} = .36$

$r_{II\ III} = .52$

TABLE 2C

Forward Hover (mean %)

SCORING AREA	I	II	III
1	2.33	4.50	2.81
2	18.33	30.83	20.62
3	19.17	26.50	75.38
4	17.67	15.83	1.19
5	26.17	15.83	0
6	12.00	3.33	0
7	1.17	1.50	0
8	1.50	.83	0
9	1.67	.83	0
10	0	0	0
11	0	0	0
12	0	0	0
13	0	0	0

$r_{I\ II} = .85$

$r_{I\ III} = .45$

$r_{II\ III} = .69$

TABLE 3C

Rearward Hover (mean %)

SCORING AREA	I	II	III
1	2.17	4.33	10.00
2	17.50	8.44	16.76
3	19.33	4.74	73.23
4	17.33	16.00	.01
5	19.50	16.00	0
6	10.33	3.17	0
7	4.83	4.17	0
8	1.17	.83	0
9	6.67	.83	0
10	0	0	0
11	0	0	0
12	0	0	0
13	1.17	0	0

$r_{I\ II} = .82$

$r_{I\ III} = .49$

$r_{II\ III} = .06$

TABLE 4C

Hover Turn Left (90°) (mean %)

SCORING AREA	I	II	III
1	2.17	3.50	14.70
2	15.33	6.87	16.43
3	10.83	5.79	61.30
4	8.33	9.43	5.50
5	14.17	19.17	0
6	2.83	6.67	.86
7	1.67	5.83	1.20
8	5.50	.83	0
9	10.83	2.50	0
10	5.83	1.86	0
11	4.17	0	0
12	3.33	0	0
13	15.00	.83	0

$r_{I\ II} = .39$

$r_{I\ III} = .22$

$r_{II\ III} = .09$

TABLE 5C

Hover Sideward (Left) (mean %)

SCORING AREA	I	II	III
1	3.00	2.67	17.89
2	12.50	15.67	28.21
3	7.50	11.67	39.40
4	.83	6.17	0
5	4.83	10.17	0
6	4.17	2.67	3.05
7	.83	4.17	0
8	6.67	6.67	0
9	8.17	8.33	0
10	9.17	13.83	7.57
11	7.33	9.67	2.73
12	1.67	0	0
13	33.33	5.33	1.18

$r_{I\ II} = .22$

$r_{I\ III} = .06$

$r_{II\ III} = .49$

TABLE 6C

Hover Sideward (Right) (mean %)

SCORING AREA	I	II	III
1	2.17	2.83	15.00
2	10.17	22.50	7.51
3	19.17	23.33	61.8
4	9.17	14.00	2.44
5	7.33	14.17	0
6	4.67	5.00	3.15
7	34.17	17.33	10.13
8	2.50	0	0
9	4.83	0	0
10	2.50	0	0
11	2.50	0	0
12	0	0	0
13	.83	.83	0

$r_{I\ II} = .73$

$r_{I\ III} = .47$

$r_{II\ III} = .59$

TABLE 7C

Hover Turn Left (360°) (mean %)

SCORING AREA	I	II	III
1	3.83	1.83	15.46
2	14.83	15.67	42.25
3	6.67	12.50	33.40
4	4.17	14.17	3.67
5	6.67	18.33	2.84
6	5.00	2.17	1.28
7	3.33	2.50	0
8	10.00	3.33	0
9	10.00	6.33	0
10	12.17	10.67	1.06
11	5.83	6.32	.11
12	2.50	0	0
13	15.83	6.67	0

$r_{I\ II} = .36$

$r_{I\ III} = .25$

$r_{II\ III} = .45$

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TABLE 8C

Hover Turn Right (360°) (mean %)

SCORING AREA	I	II	III
1	3.83	2.83	10.00
2	15.67	19.17	8.07
3	16.67	19.17	65.4
4	12.50	18.33	16.61
5	13.00	20.83	0
6	5.00	3.83	0
7	9.00	11.67	0
8	2.50	.83	0
9	3.83	.83	0
10	3.83	.83	0
11	2.50	.83	0
12	0	0	0
13	11.67	.83	0

$r_{I\ II} = .87$

$r_{I\ III} = .57$

$r_{II\ III} = .52$

TABLE 9C

Hover Turn Right (90°) (mean %)

SCORING AREA	I	II	III
1	3.00	2.67	10.65
2	14.00	20.00	41.86
3	16.67	20.00	46.16
4	7.50	17.50	.75
5	8.33	20.00	0
6	6.83	3.17	0
7	11.17	8.33	0
8	3.33	1.67	0
9	8.33	1.67	0
10	7.50	.83	.53
11	2.50	.83	.09
12	0	0	0
13	10.83	3.33	0

$r_{I\ II} = .69$

$r_{I\ III} = .67$

$r_{II\ III} = .63$

TABLE 10C

Normal Takeoff and Approach to Hover (Left pattern) (mean %)

SCORING AREA	I	II	III
1	7.00	6.67	42.4
2	11.67	19.67	20.10
3	11.17	21.33	19.27
4	14.17	15.50	5.45
5	16.67	15.50	3.29
6	5.83	1.92	.03
7	4.67	1.58	.02
8	2.92	1.75	.71
9	7.08	5.08	.75
10	5.00	5.08	2.55
11	5.00	.67	2.73
12	.83	0	.79
13	8.00	5.25	1.95

$r_{I\ II} = .86$

$r_{I\ III} = .23$

$r_{II\ III} = .43$

TABLE 11C

Normal Takeoff and Approach to Landing (Right pattern) (mean %)

SCORING AREA	I	II	III
1	7.17	6.50	39.32
2	14.17	20.50	5.20
3	16.17	18.00	24.20
4	13.00	17.67	19.7
5	15.83	17.67	1.10
6	6.67	1.92	.1
7	9.67	9.42	10.3
8	1.83	2.25	0
9	5.00	3.25	0
10	5.00	2.25	0
11	1.83	.17	.03
12	.83	0	0
13	2.83	.42	0

$r_{I\ II} = .96$

$r_{I\ III} = .42$

$r_{II\ III} = .41$

TABLE 12C

Summary Table of All Maneuvers (mean %)

SCORING AREA	I	II	III
1	3.77	3.91	32.26
2	14.47	22.32	15.02
3	14.58	20.24	32.8
4	10.80	15.44	10.20
5	14.32	16.74	1.70
6	6.83	3.41	.30
7	7.77	6.17	4.1
8	3.60	1.80	.30
9	6.39	2.80	.30
10	4.71	3.12	1.12
11	2.95	1.64	1.03
12	.83	0	.27
13	9.04	2.14	1.00

$r_{I\ II} = .91$

$r_{I\ III} = .35$

$r_{II\ III} = .51$

MANEUVER	SCORING AREA	MEAN % I	MEAN % II	MEAN % III
Stabilized hover	2	15.00	30.33	2.10
Stabilized hover	5	25.00	16.50	0
90° hover turn right	5	8.33	20.00	0
90° hover turn right	13	10.83	3.33	0
Sideward hover left	13	33.33	5.33	1.18

Conversely, with regard to other maneuvers and other areas, the pilots sometimes rated a visual area low, when the in-flight data showed the actual value to be much higher. For example:

MANEUVER	SCORING AREA	MEAN % I	MEAN % II	MEAN % III
Stabilized hover	3	17.00	25.17	86.08
Rearward hover	3	19.33	4.74	73.23
Sideward hover right	1	2.17	2.83	15.00
Normal T/O app to gnd rt	1	7.17	6.50	39.32

Most of the pilots, when questioned as to what areas they used for a particular maneuver, would state that their percentage estimate was a complete guess. The data obtained seems to, in many cases, verify this conclusion. Perhaps this is most amply demonstrated in Table 12C, which indicates that in scoring area 1, obtained during a fairly complete flight profile,*** a pilot would estimate that his instruments and guages are used about 4% of the time when the in-flight data puts this figure in excess of 30%. This condition also exists for scoring area 3, where the pilot's mean estimate is 17.4% against the in-flight data, yielding a value of 32.8%. Perhaps the closest estimates are in areas 4, 11, and 12, with respect to the in-flight obtained values, with area 4 being only 2.92% above that value obtained in-flight.

The sole purpose of the questionnaire data was to find how well subjective data correlated with objective values. The result of this particular effort would indicate that in many cases they do not correlate very well.

***This is excluding emergency maneuvers and procedures which were not looked at in this study.

This study illustrates that objective methods and techniques of studying visual performance can be employed in the helicopter environment. It may well provide information that would directly impact the efforts of design engineers. It will in time, hopefully, offer the capability to determine some of the basic cues used in flight control about which little information is known, but which much is needed to efficiently and effectively evolve displays required for tactical missions of the future.

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APPENDIX A

Questionnaire Data I

Tables 1-12

TABLE A-1

Lift Off to Stabilized Hover

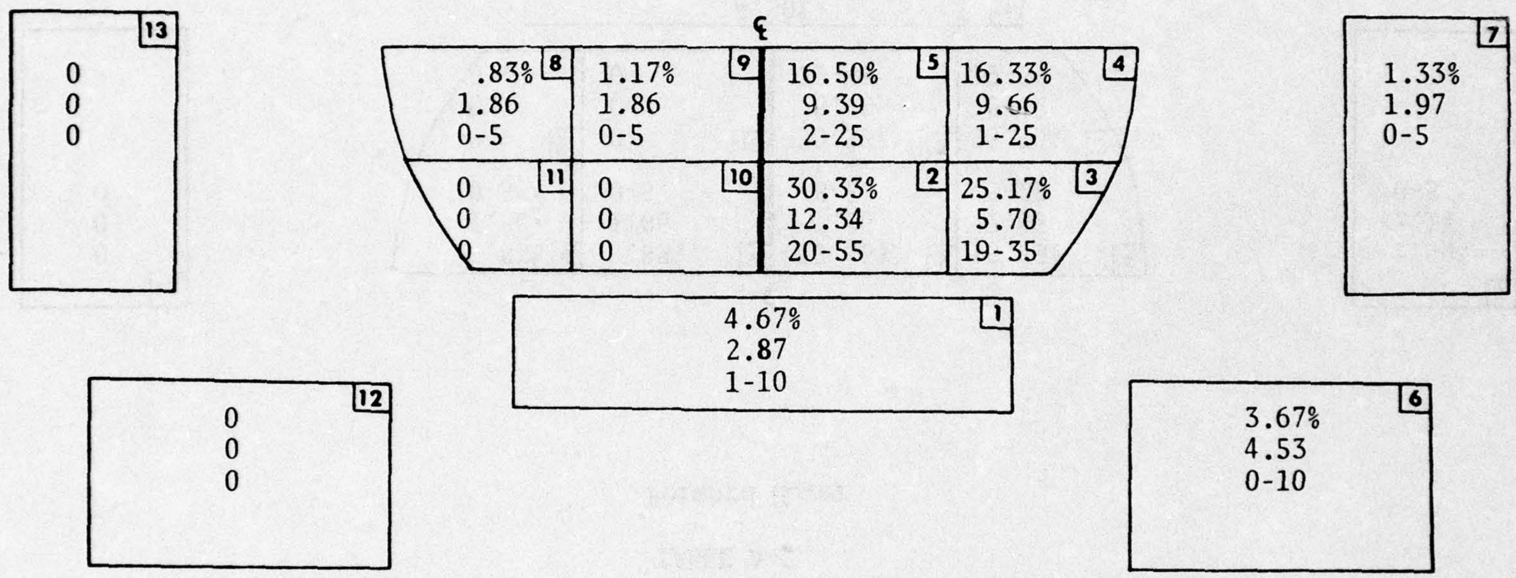


TABLE A-2

Forward Hover

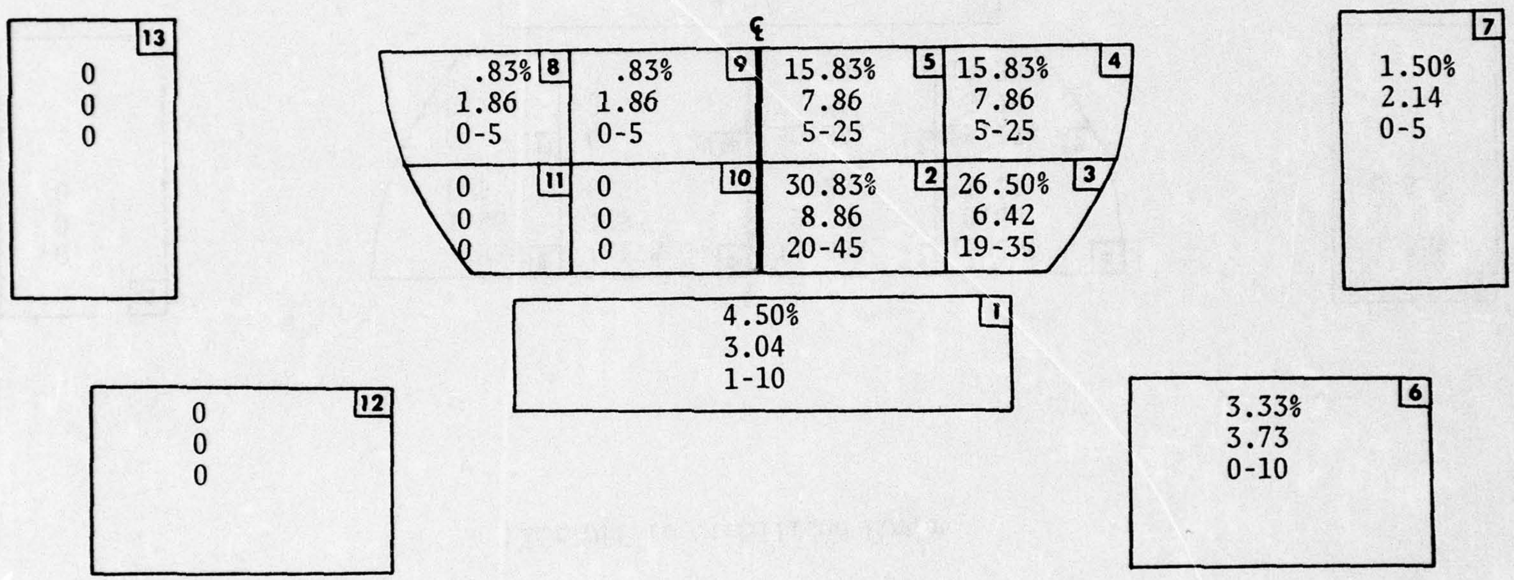


TABLE A-3

Rearward Hover

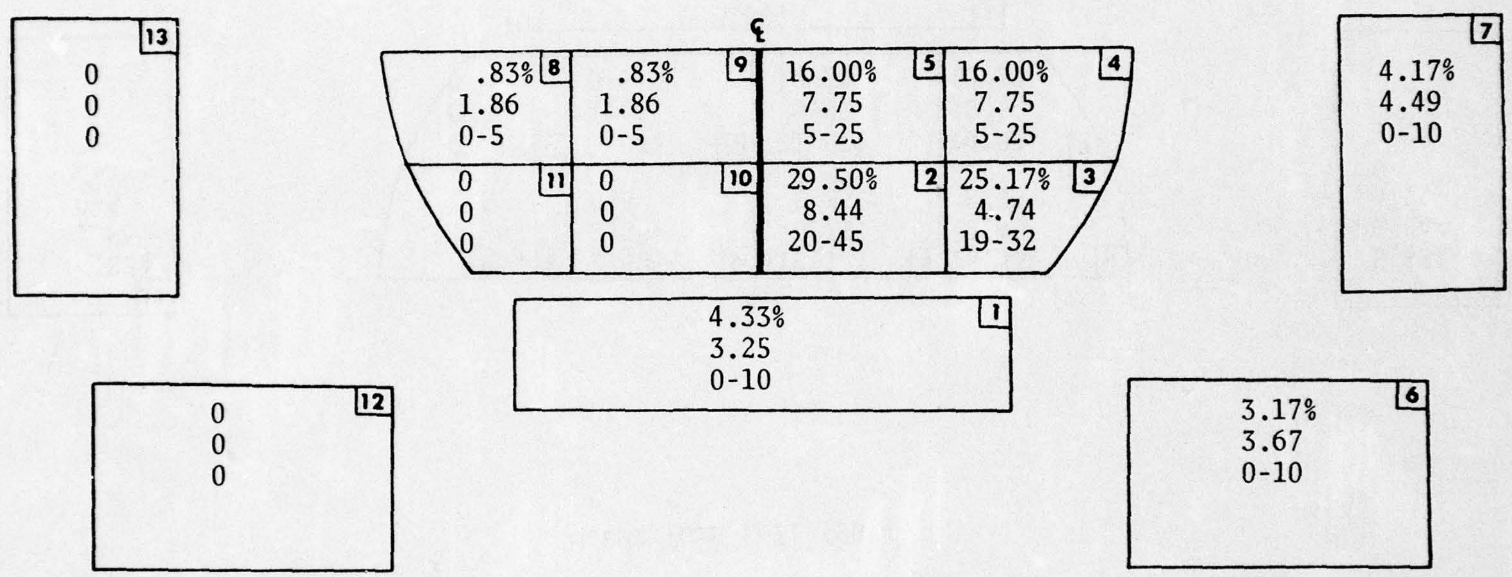


TABLE A-4

Hover Turn Left (90°)

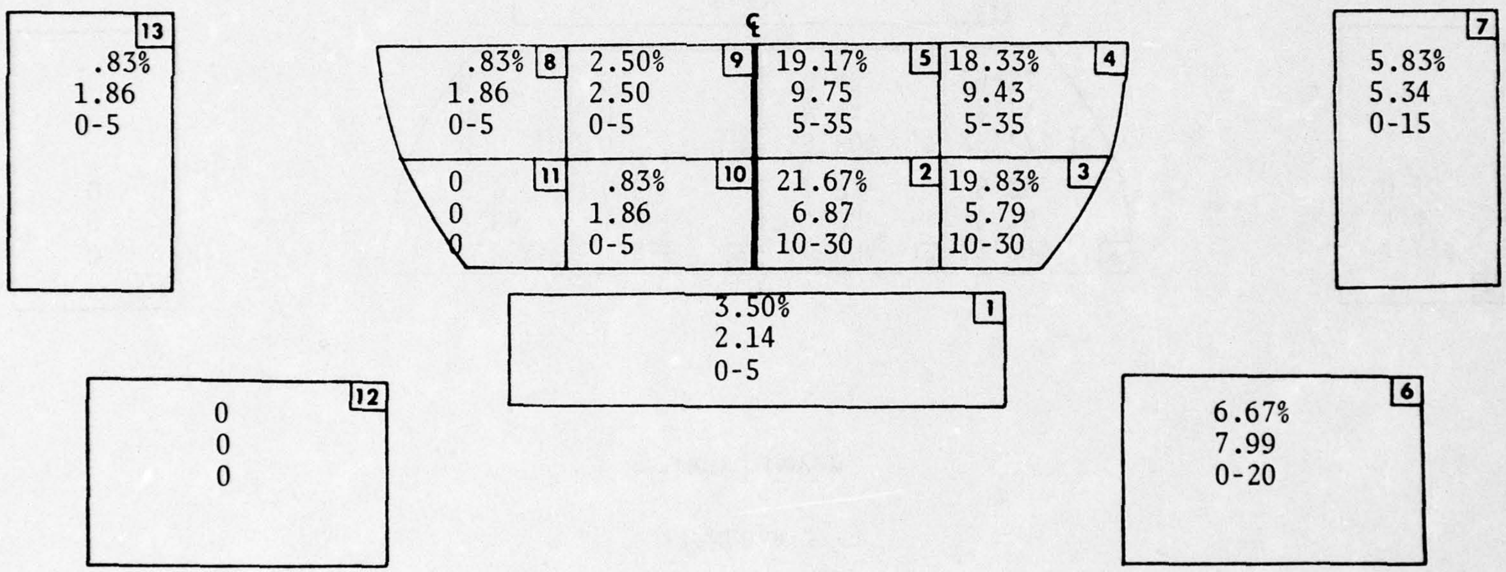


TABLE A-5

Hover Sideward (Left)

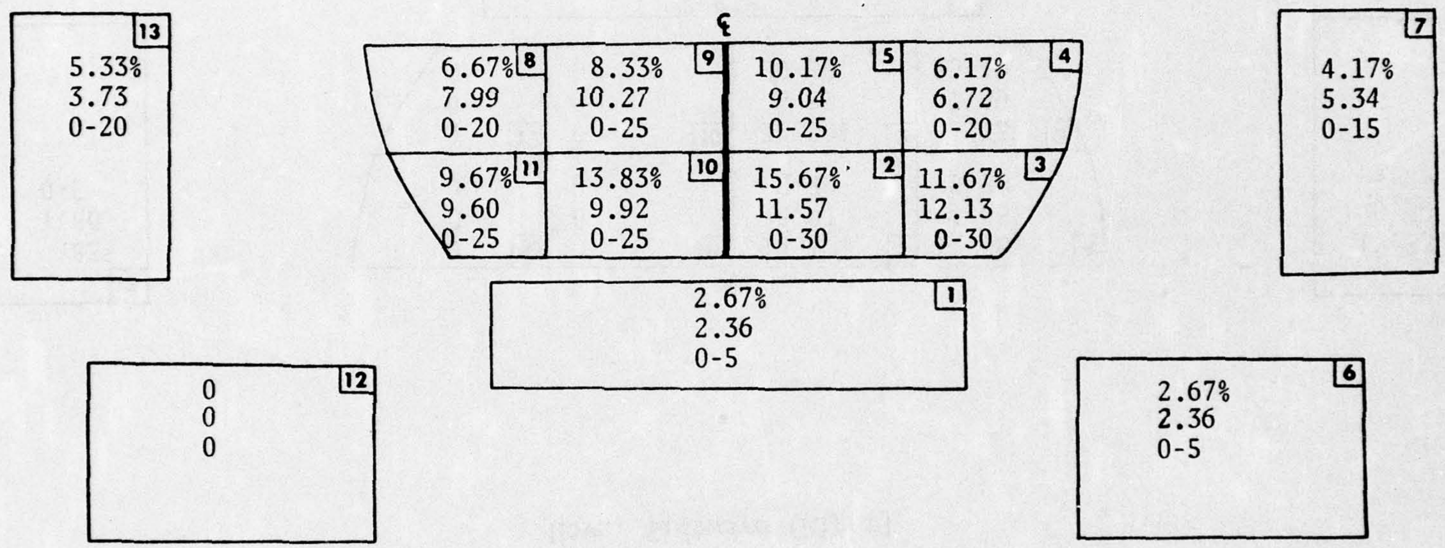


TABLE A-6

Hover Sideward (Right)

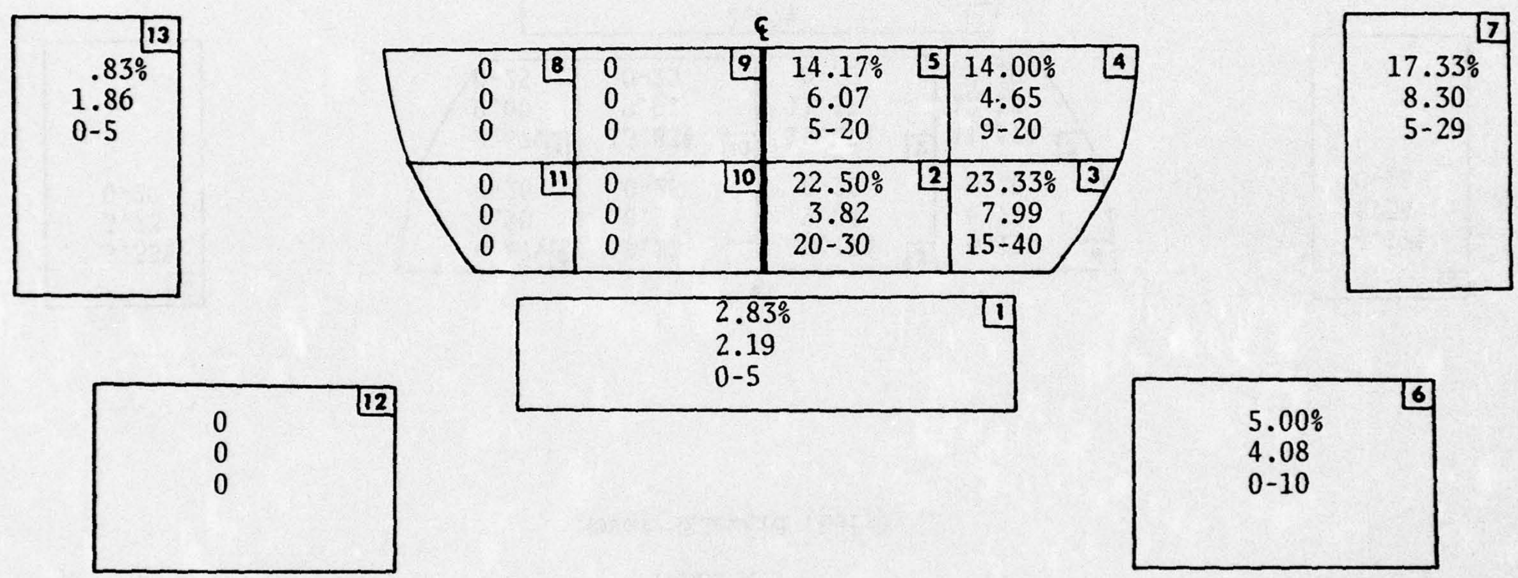


TABLE A-7

Hover Turn Left (360°)

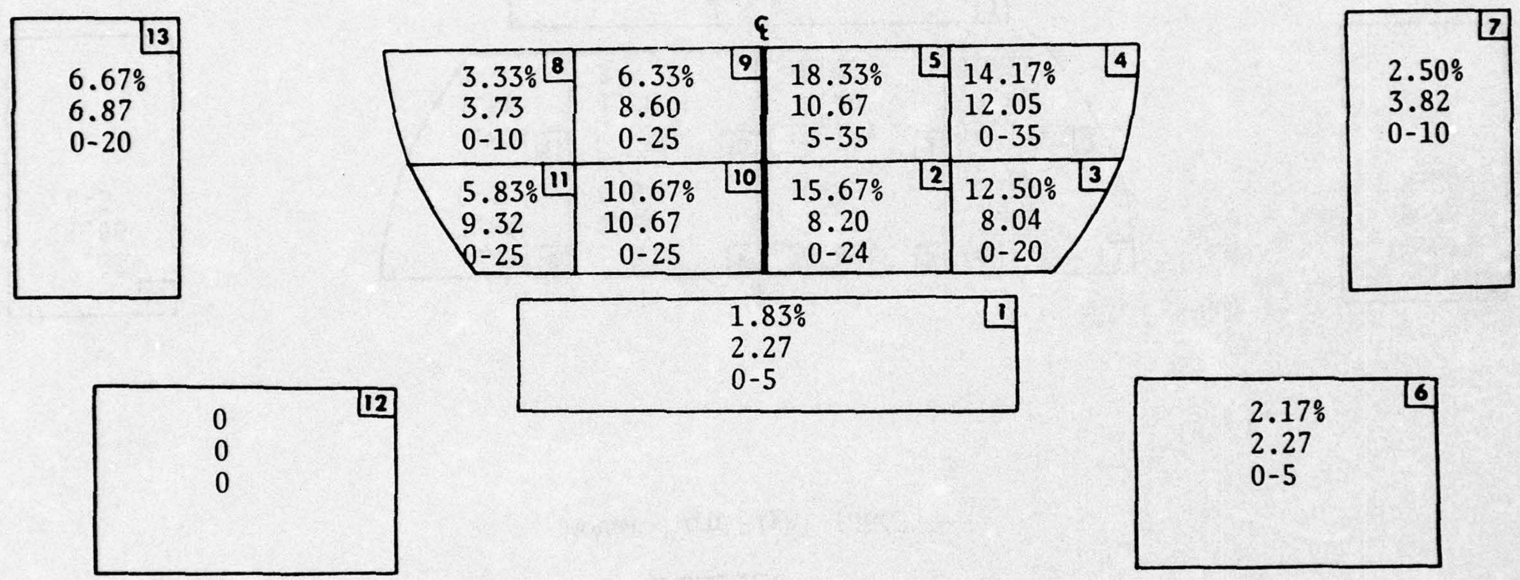


TABLE A-8

Hover Turn Right (360°)

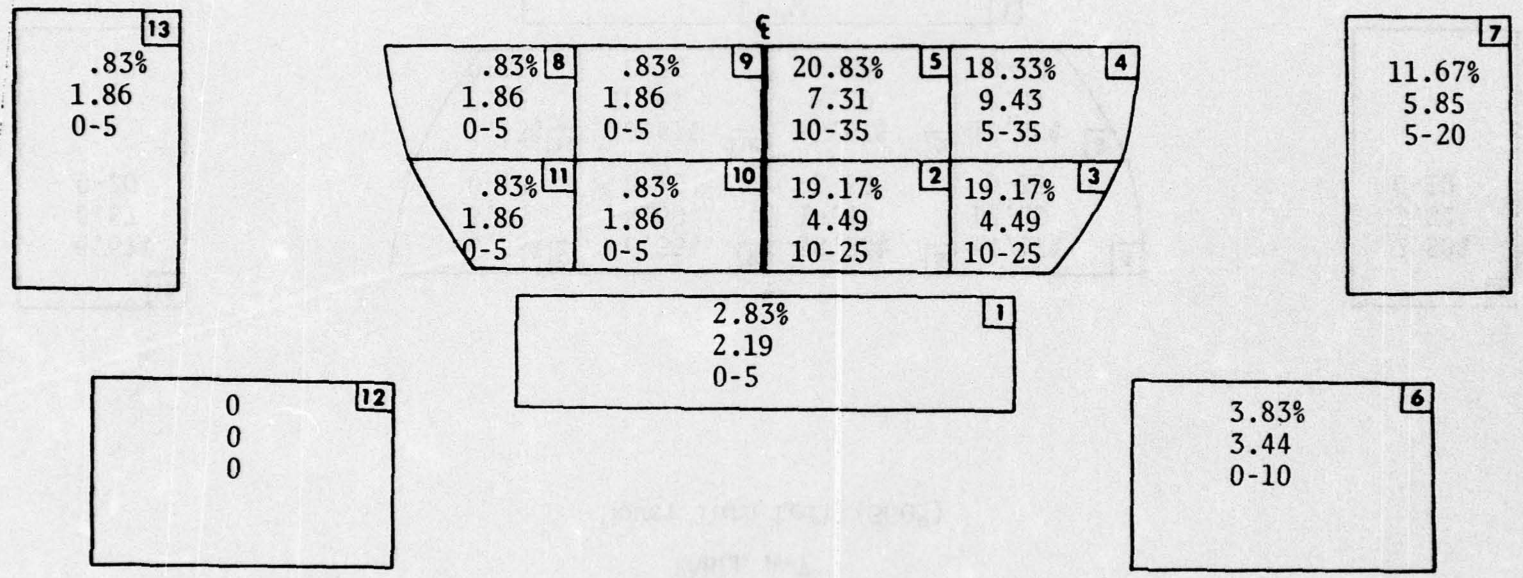


TABLE A-9

Hover Turn Right (90°)

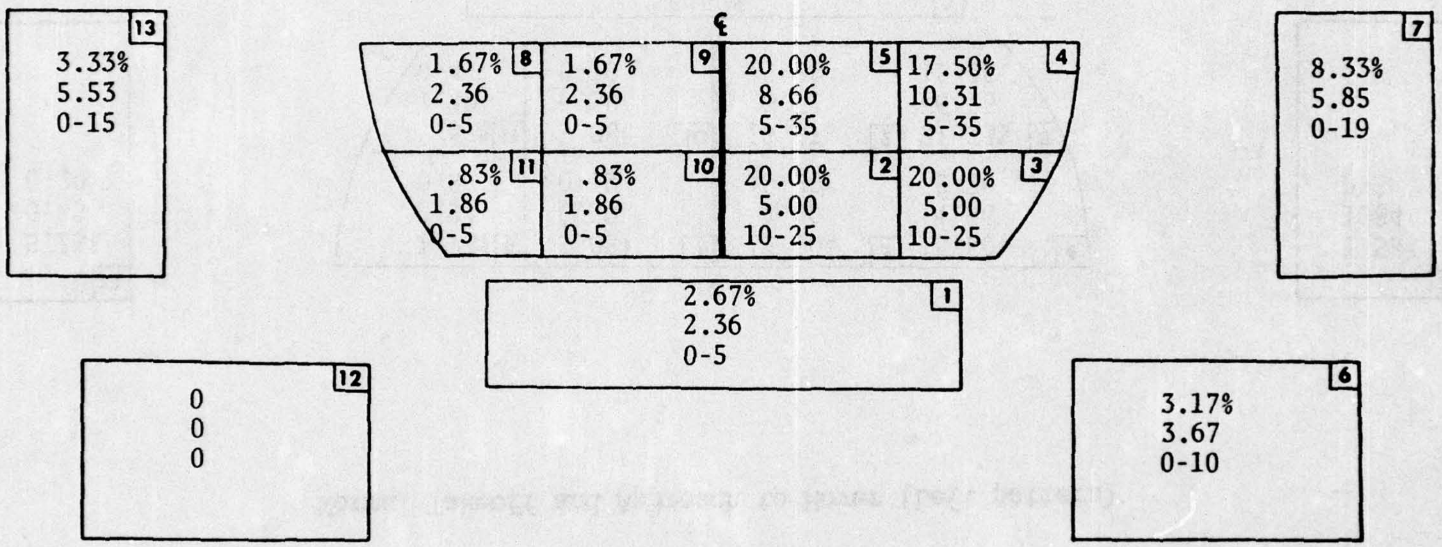


TABLE A-10

Normal Takeoff and Approach to Hover (Left pattern)

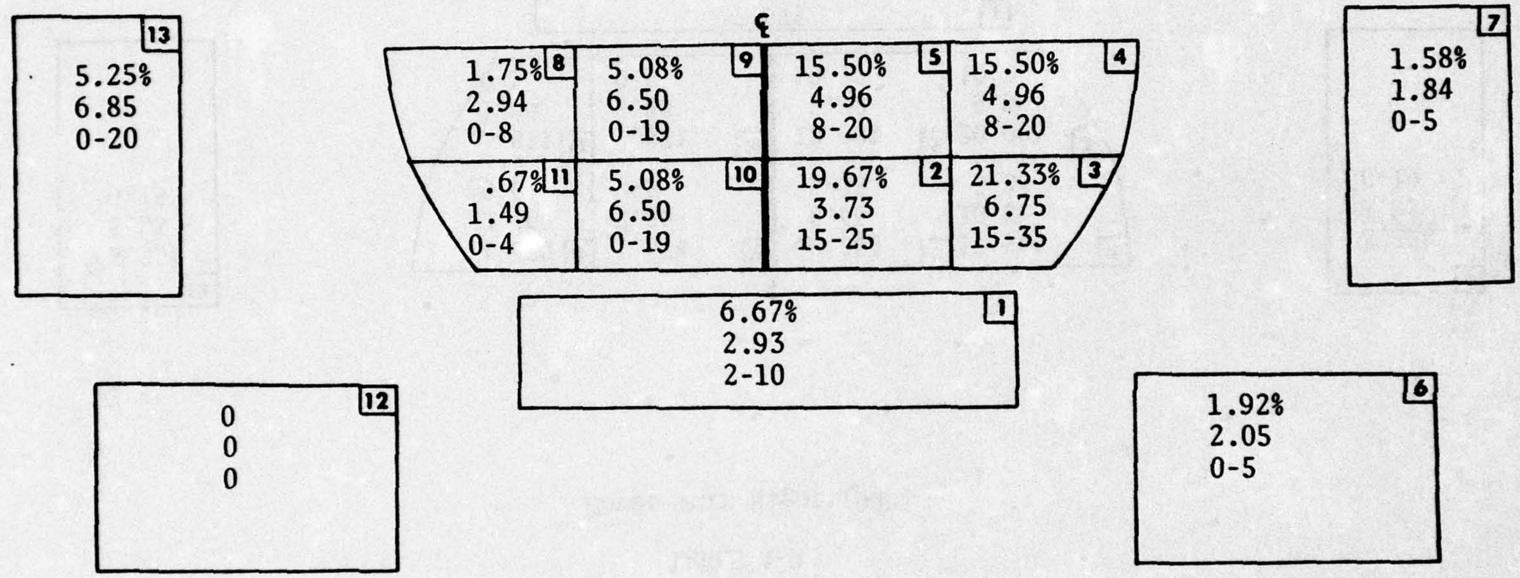


TABLE A-11

Normal Takeoff and Approach to Landing (Right pattern)

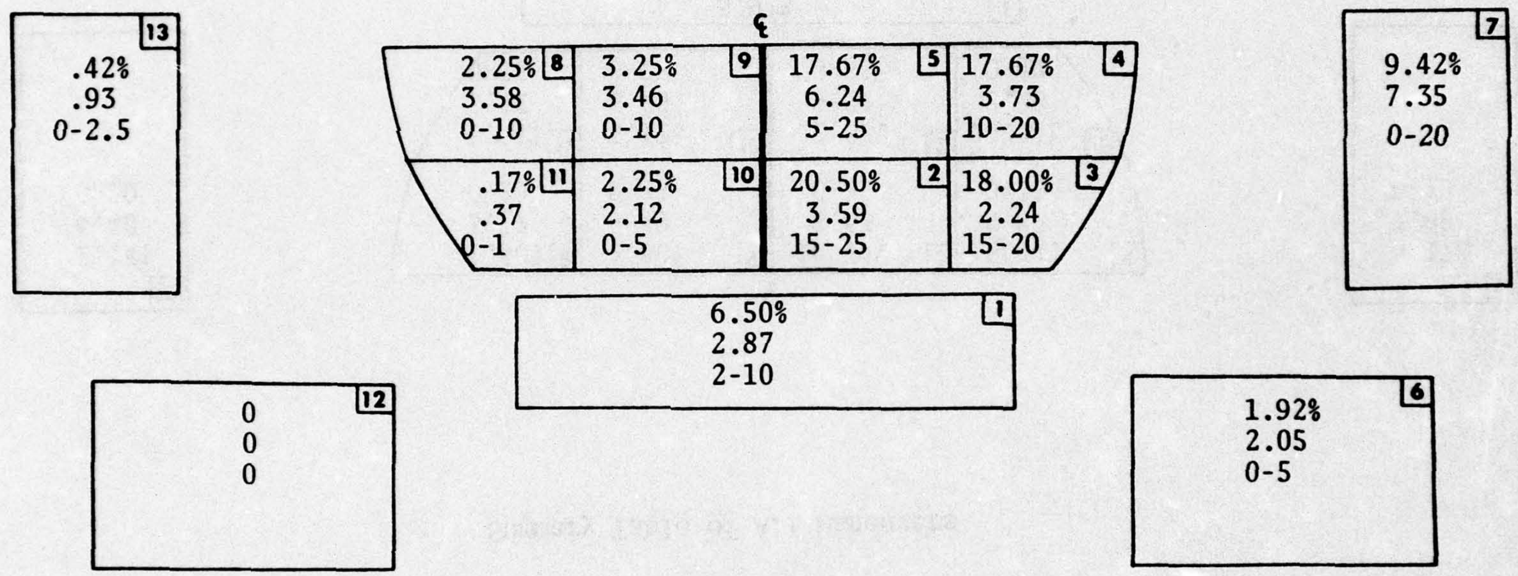
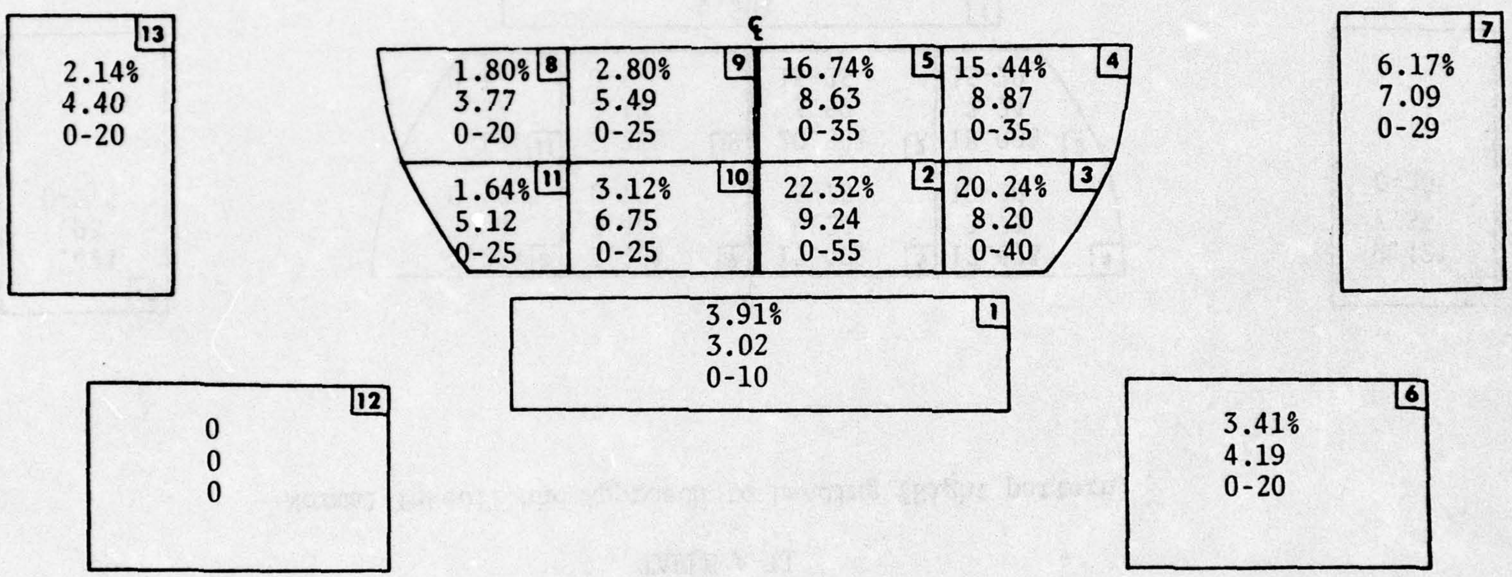


TABLE A-12

Summary Table of All Maneuvers



APPENDIX B

Questionnaire Data II

Tables 1-12

TABLE B-1

Lift off to Stabilized Hover

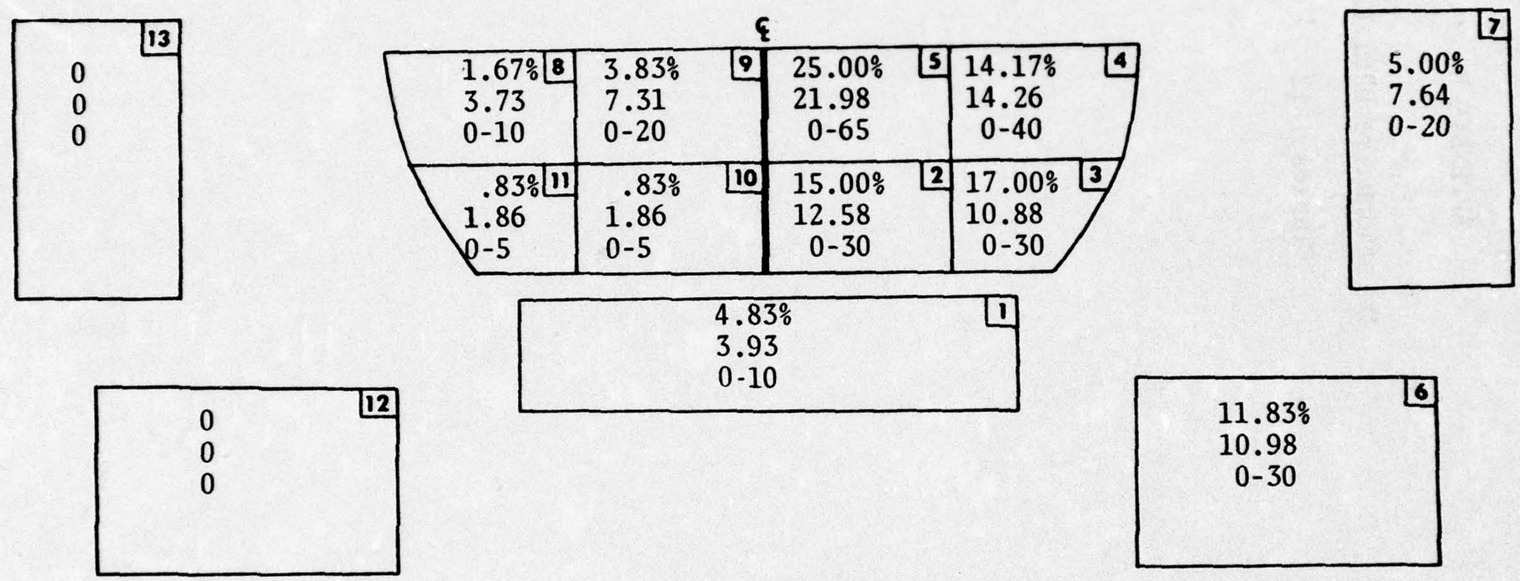


TABLE B-2

Forward Hover

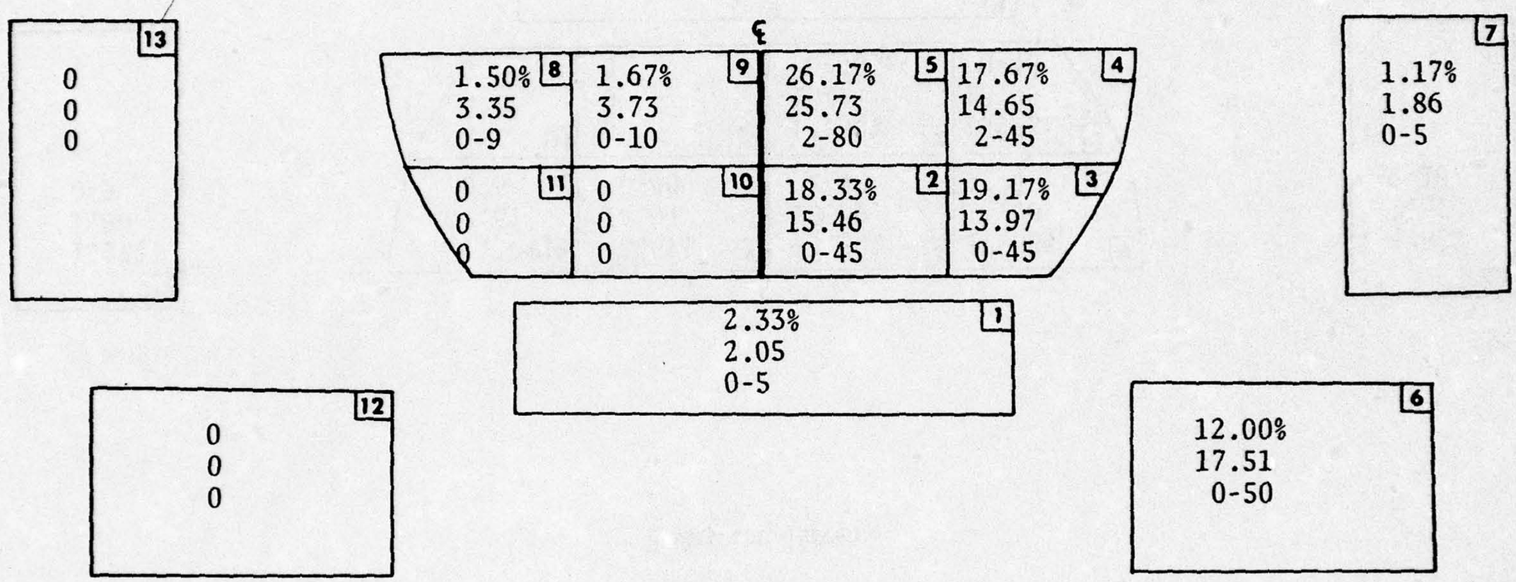


TABLE B-3

Rearward Hover

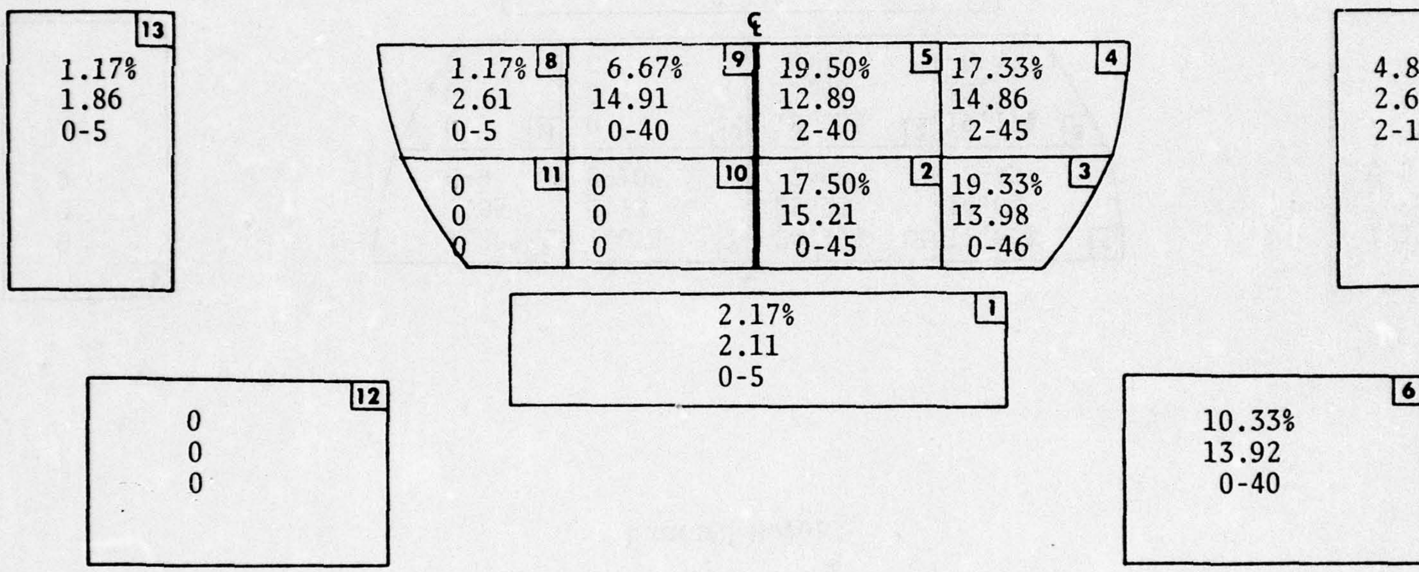


TABLE B-4

Hover Turn Left (90°)

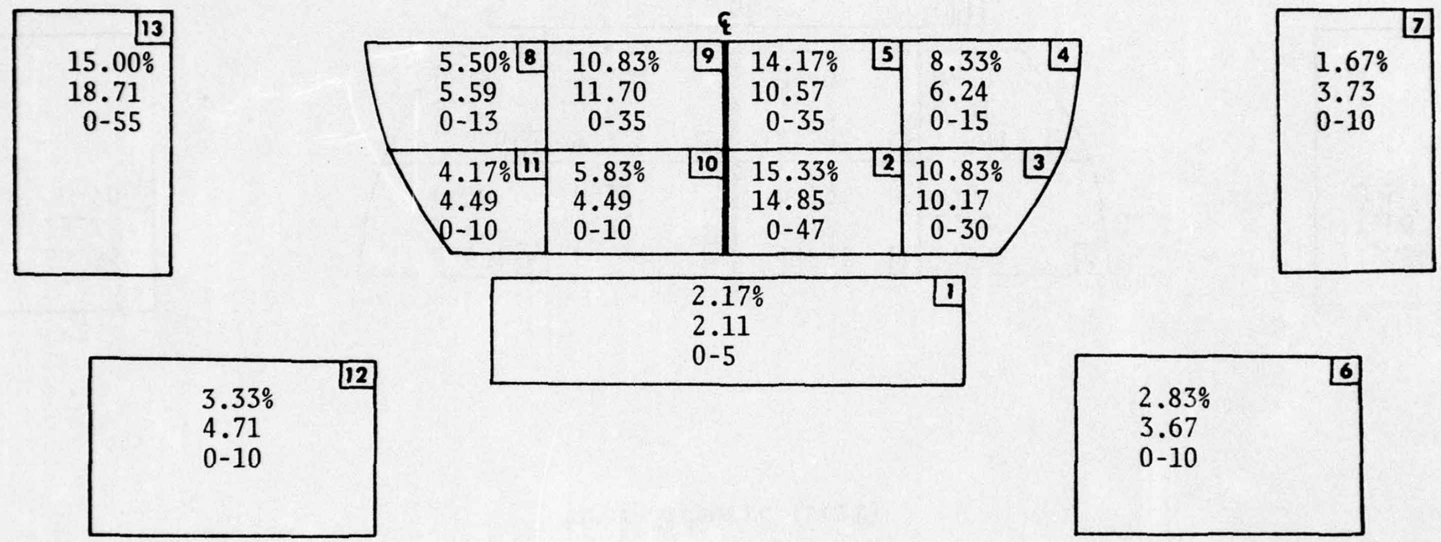


TABLE B-5

Hover Sideward (Left)

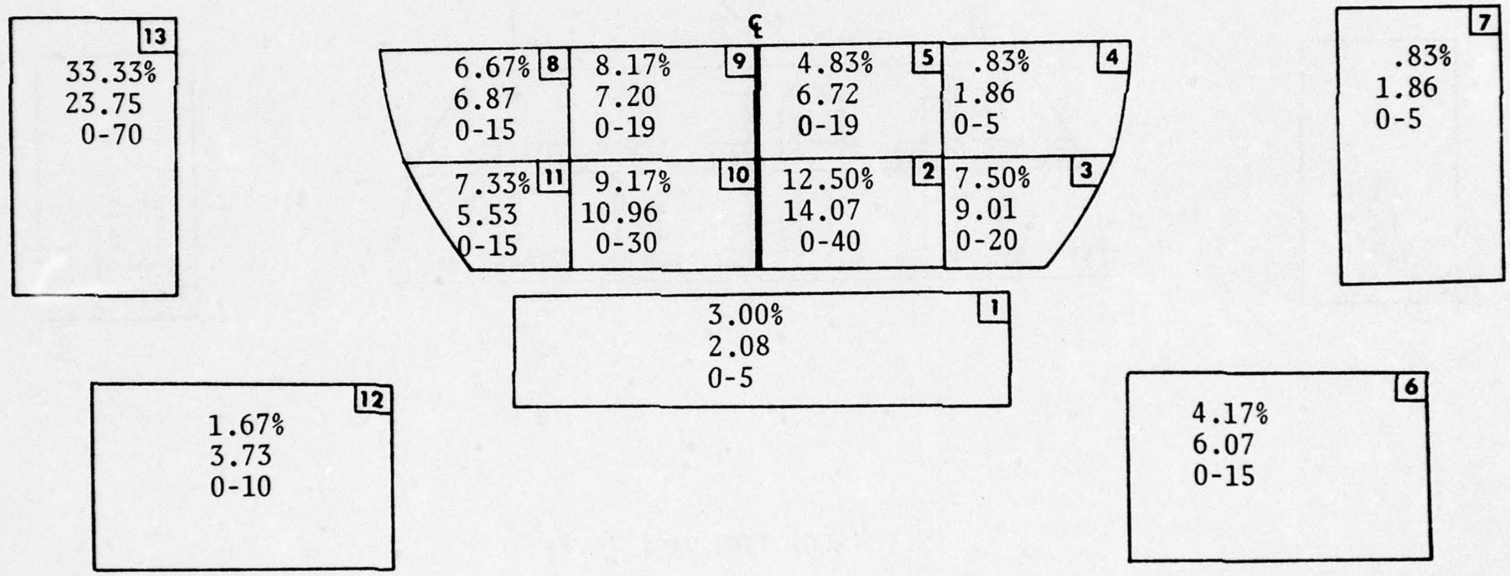


TABLE B-6

Hover Sideward (Right)

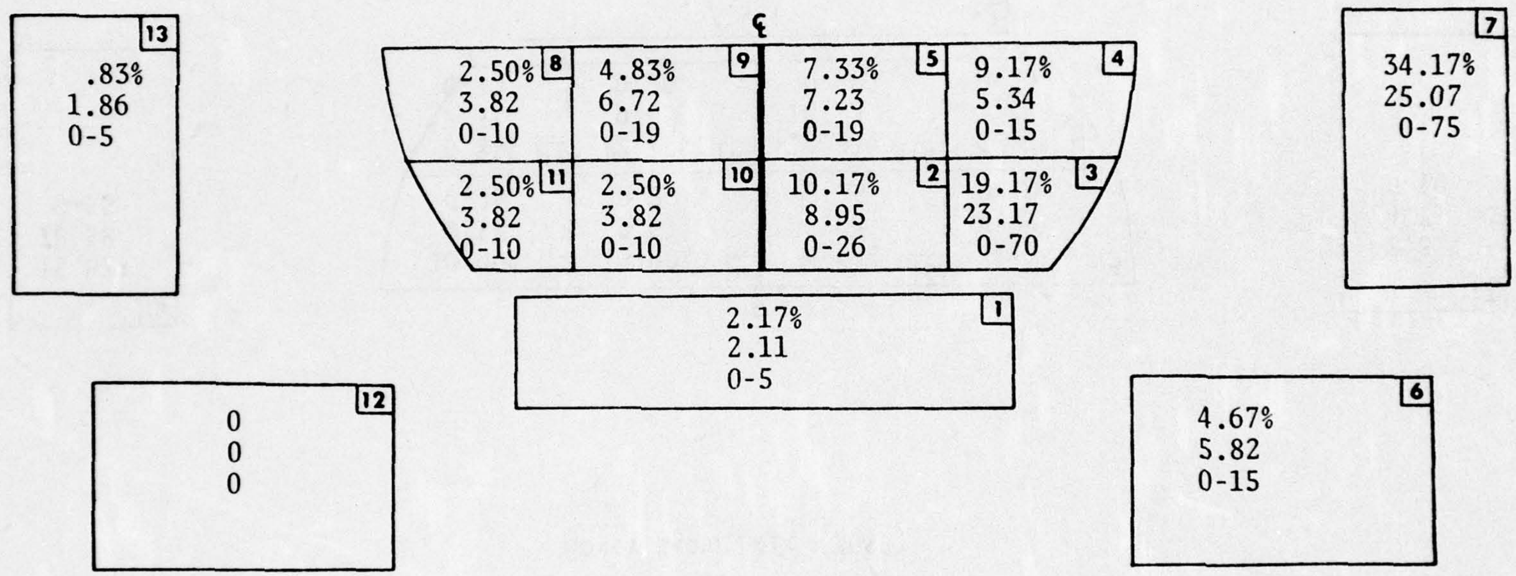


TABLE B-7

Hover Turn Left (360°)

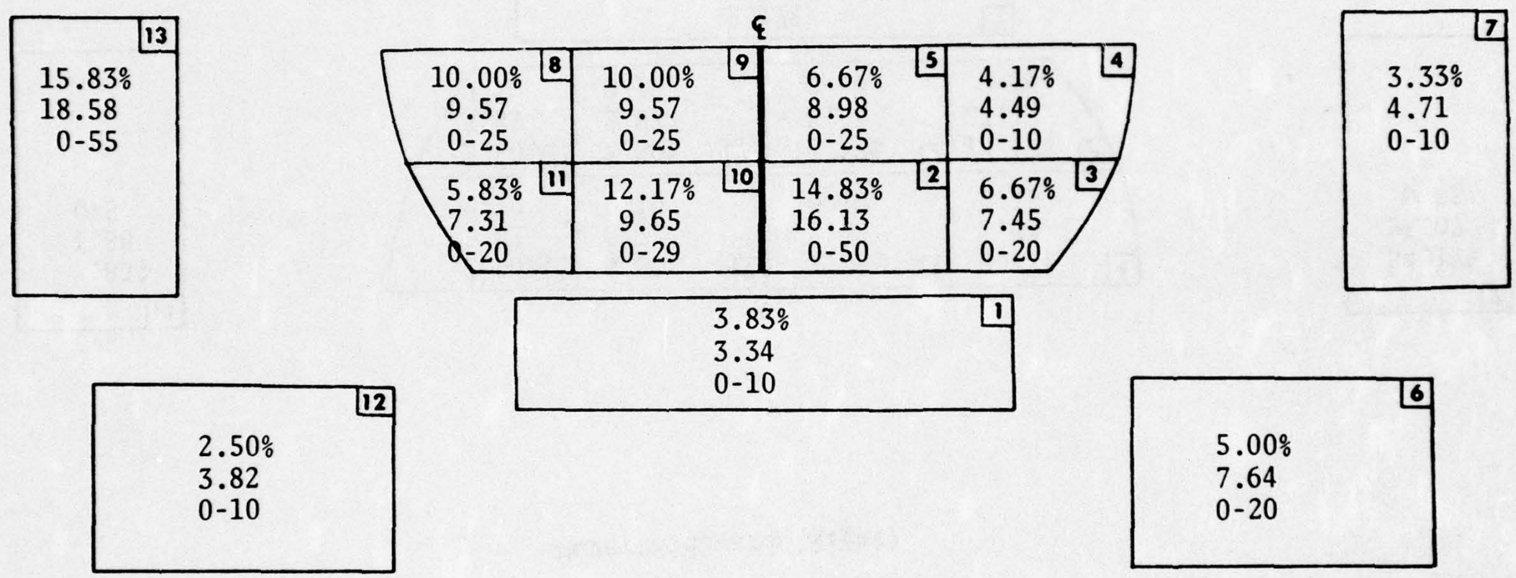


TABLE B-8

Hover Turn Right (360°)

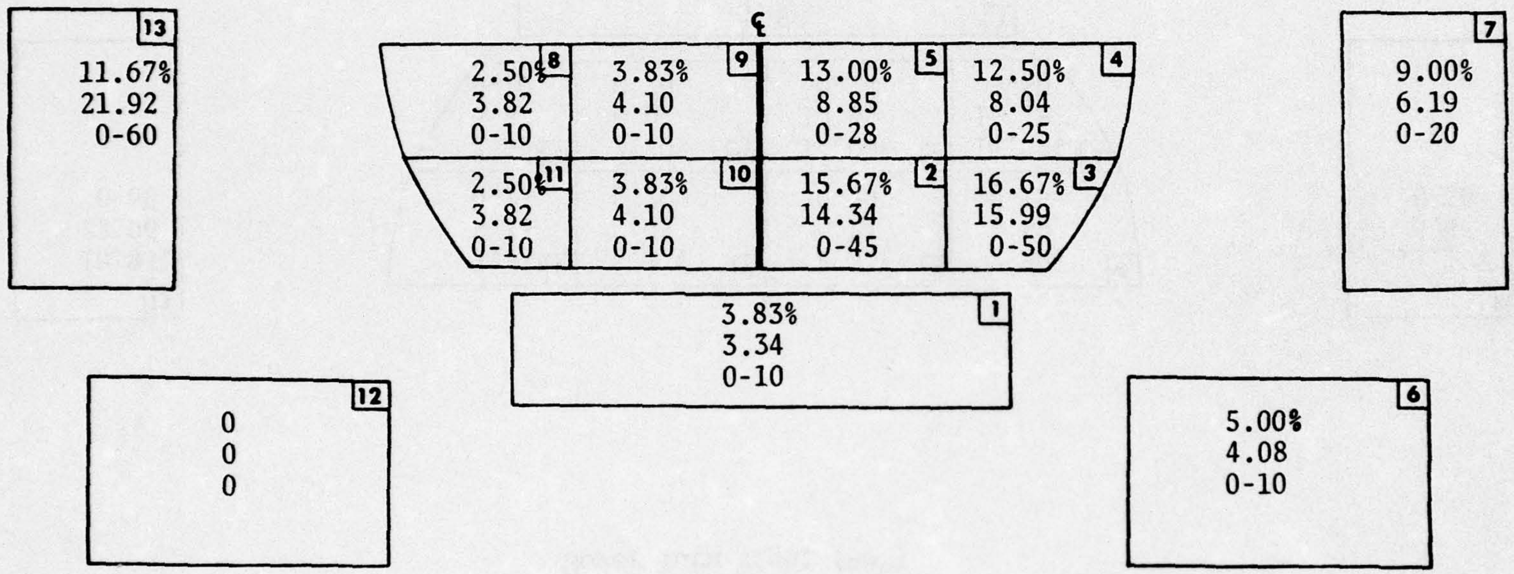


TABLE B-9

Hover Turn Right (90°)

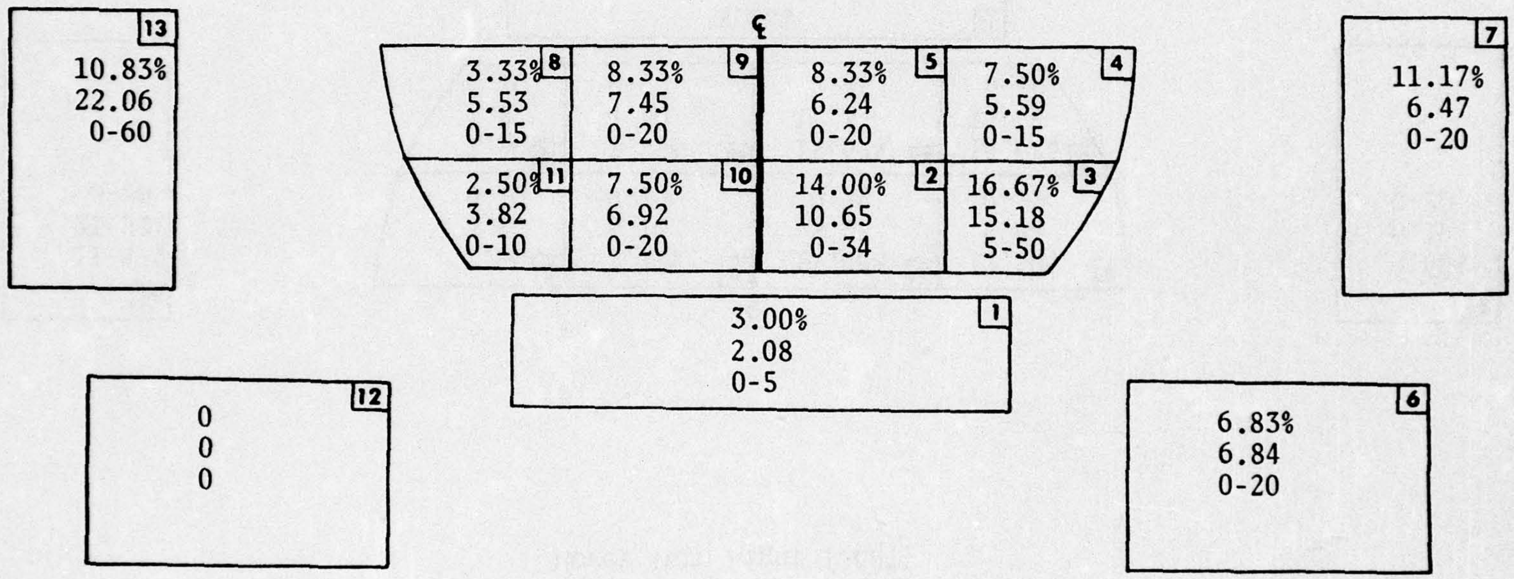


TABLE B-10

Normal Takeoff and Approach to Hover (Left pattern)

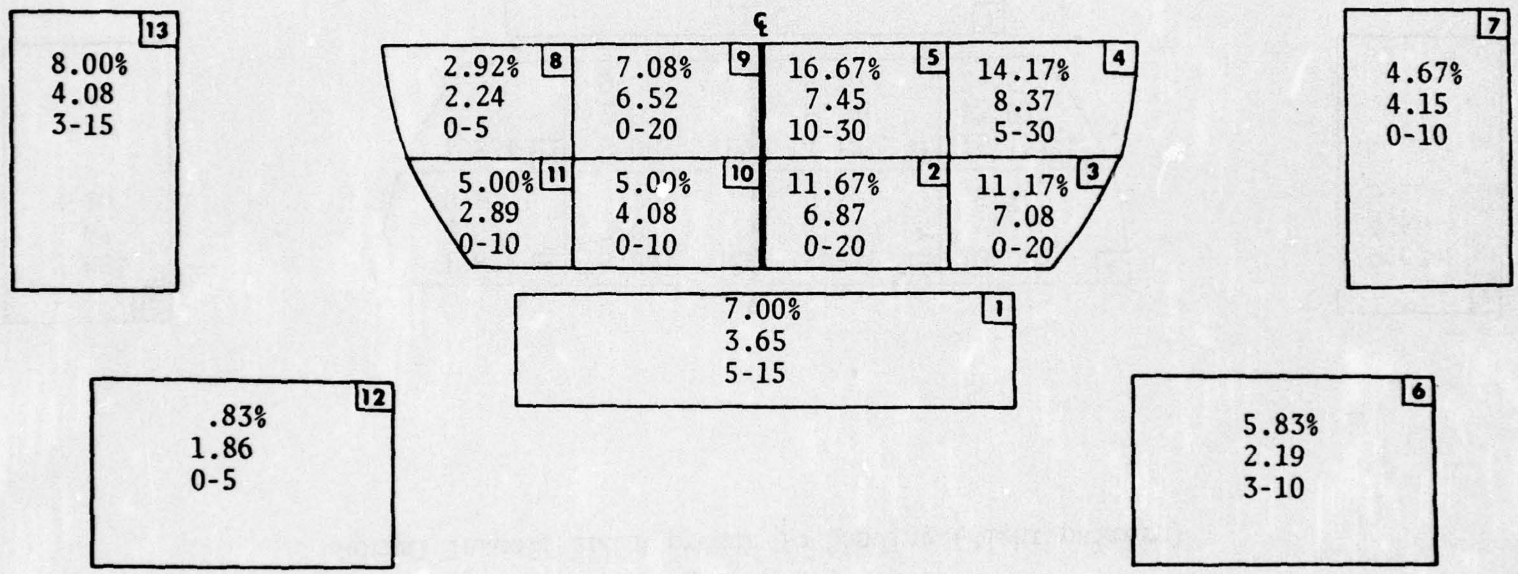


TABLE B-11

Normal Takeoff and Approach To Landing (Right pattern)

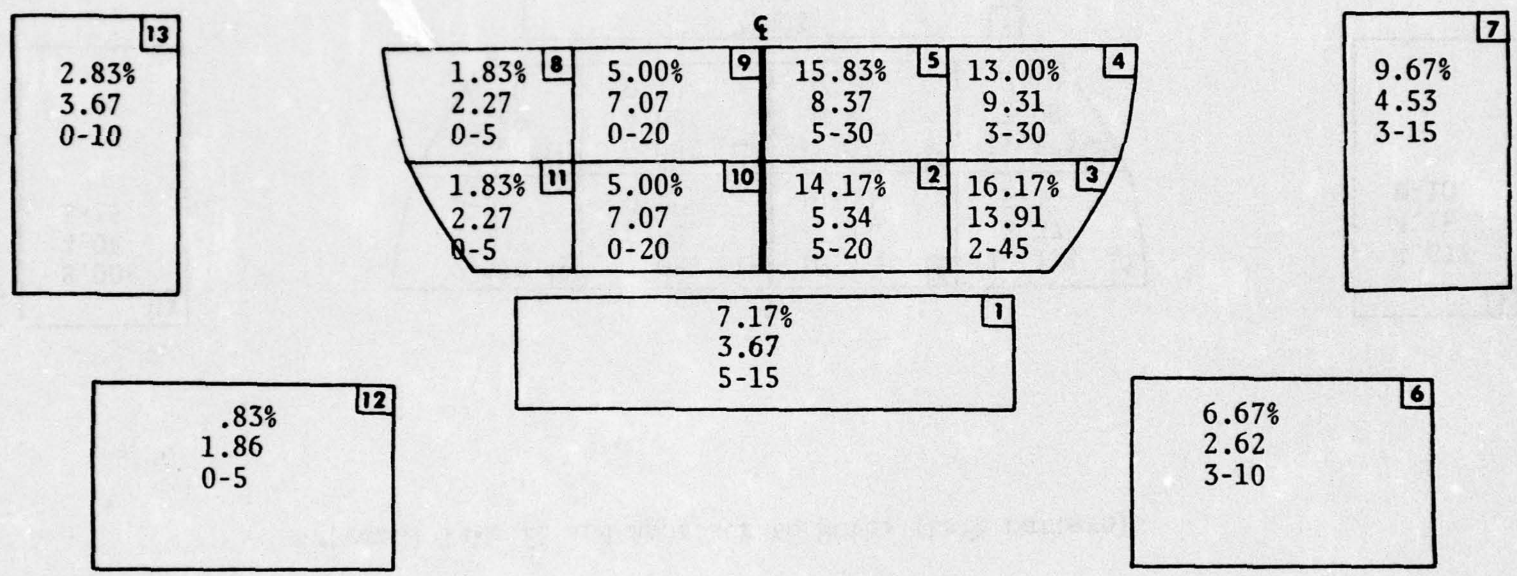
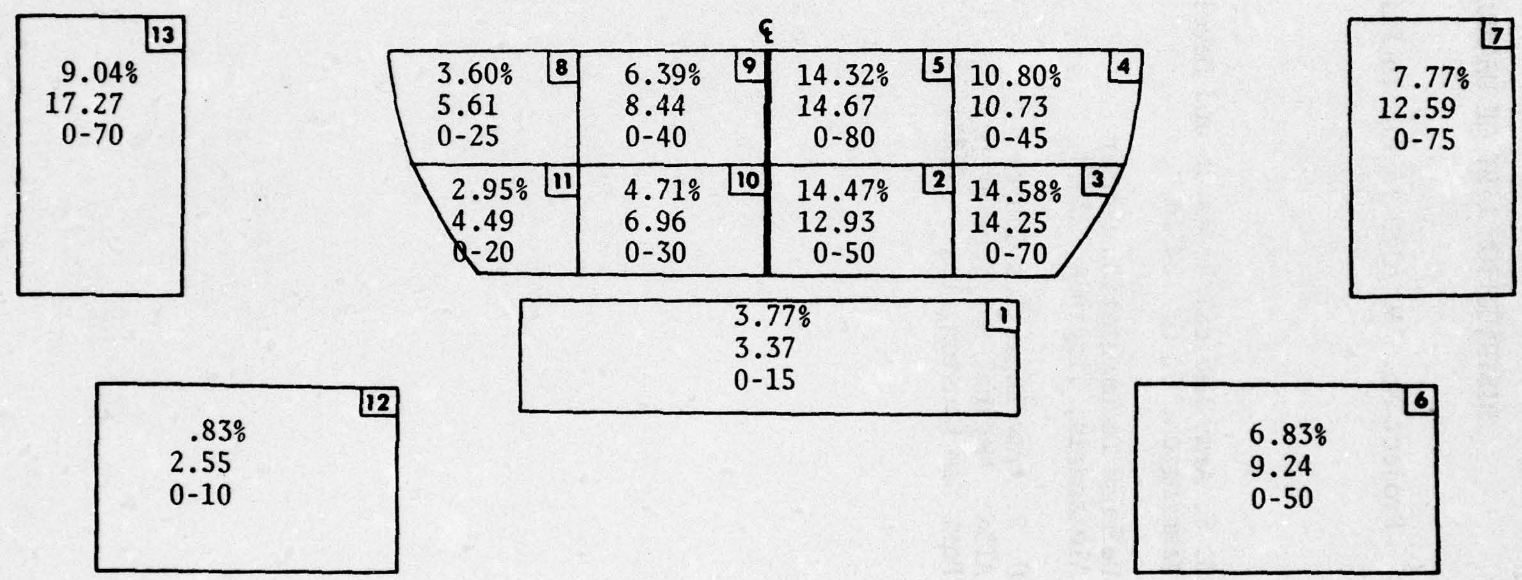


TABLE B-12

Summary Table of all Maneuvers



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13. ABSTRACT

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1. Pilot performance 2. Visual performance 3. Recording in-flight 4. Helicopter visual data 5. Eye movement recording 6. Pilot visual data 7. Flight data visual 8. Human volunteers						

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