Lunar Landing Vehicle Helicopter Landing Simulation Study

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HOVER-TO-TOUCHDOWN time, governing the amount of fuel which will be consumed in that period, is one major factor in computing the total fuel allowance for the Lunar Landing Vehicle (LLV). For any given vehicle, the time necessary for the maneuver to be performed at nominal translational velocities determines the fuel requirement. However, the total time involved is a function not only of system response time but also of human response time. The subject's perception and decision-making speed are, in turn, largely a function of terrain type and visual conditions. Consequently, in order for time values derived from terrestrial research to be applicable to the lunar situation, the area selected for the tests had to approximate the lunar surface in roughness and illumination.

When the LLV has descended to a level permitting more acute vision, the pilot may, in some instances, judge the first landing site selected to be unsuitable. An alternate, or even a second alternate site, will then have to be selected. The possibility of alternate site selection must therefore be included in calculations for an adequate safety margin in fuel allowance for the hover-to-touchdown time requirement.

With the goal in mind of eventually defining the desirable LLV landing fuel allowances, a simulation study was initiated to ascertain the average descent time under both first site and alternate site conditions, as well as the percentage of trials requiring an alternate site selection. Valuable supplementary data were simultaneously acquired concerning the maximum, minimum, and average distances traversed in this maneuver. The vehicle and terrain conditions approximated as closely as practicable those anticipated for the LLV in actual lunar landing. The details of the preliminary simulation study, performed in a Sikorsky S-58 helicopter, are presented in this report.

The purpose of this study was twofold: first, to determine a reasonable time allowable from hover-to-

Fig. 1. Topography map of landing area utilized in simulation study.

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touchdown for the LLV under manual control; and second, to define qualitatively, on the basis of nominal translation velocities of 26 knots (44 ft/sec), a reasonable value of the distance from the hover point to a suitable landing site. These tests were conducted in a helicopter flying on a trajectory duplicating, as closely as possible, that planned for the LLV and operating under conditions approximately those of lunar lighting and terrain.

PROCEDURE

Terrain with surface roughness equivalent to that estimated for the lunar surface was found near Crawford Mountain, south of Possum Kingdom Lake on the Brazos River, Texas (Figures 1 through 4) and used in the LLV Helicopter Landing Simulation Study.

Eight subjects and a helicopter pilot were used throughout the course of the tests. One of the subjects, incidentally, was monocular. Each of the eight subjects and his pilot made eight LLV runs from various directions over the Crawford Mountain target area between the hours of 1030 and 1430 CST. During these selected hours, the shadows fell at approximately the angles which would exist on the moon during the lunar phase recommended for the actual mission. In order to reduce the perceived light to the illumination provided by earthshine on the lunar surface, each subject wore dark goggles. The helicopter pilot established a rate of descent from about 1500 feet, although still translating in the horizontal flight path direction at up to 30 knots (51 ft/sec). Vertical descent was reduced to zero at 300 feet, the defined hover point.

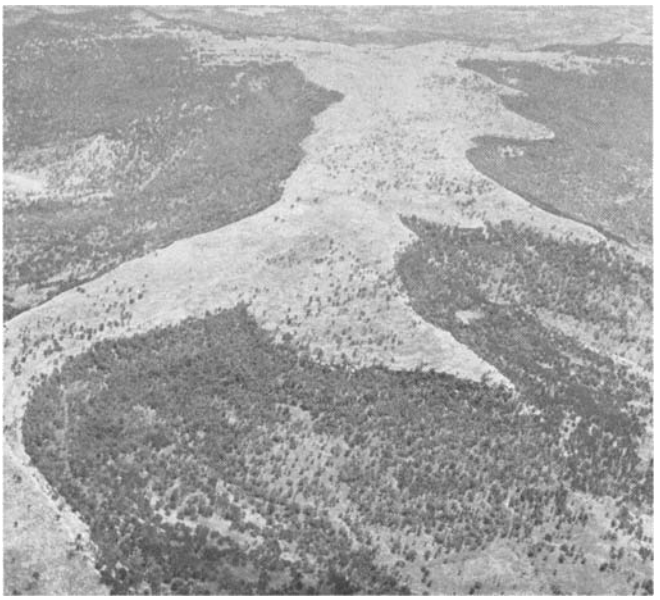

Fig. 2. Landing area utilized in simulation study — 2000 ft. altitude.

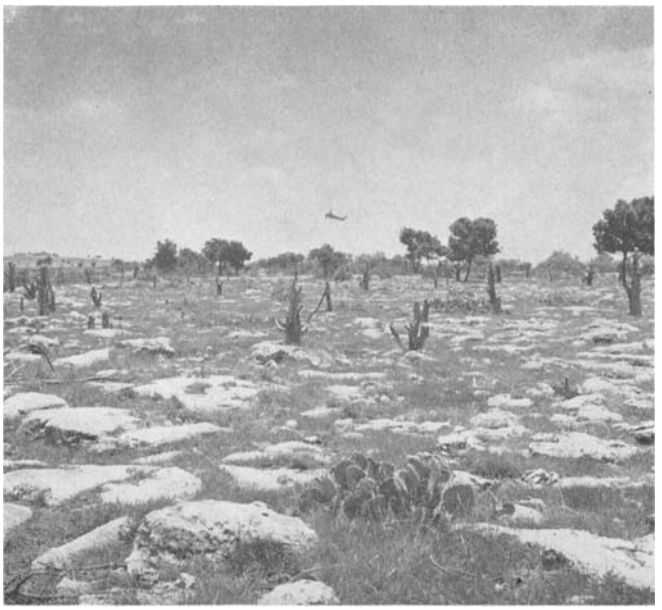

Fig. 3. Surface characteristics of landing area.

Fig. 4. Typical test being performed.

The eight subjects, six of whom were also fixed-wing pilots, were briefed on test procedures. They were to be responsible for the monitoring of airspeed, altitude and altitude rate, as well as for the selection of a landing site. The sequence of steps in each test was as follows:

1. Subject put on dark goggles 20 minutes before beginning of test in order to adapt his eyes to the reduced lighting conditions.
2. Pilot gave "close eyes" warning to subject before target area was approached.
3. Pilot gave "MARK" signal at the established 300-foot altitude hover point in order to inform experimenter that the test had begun. Subject opened his eyes.
4. Subject looked for the nearest suitable landing sites, made the selections, and informed pilot accordingly.
5. Pilot translated LLV to the designated area, where he allowed vehicle to hover within 10 feet of the ground.
6. Pilot advised subject as to whether or not the selected site was suitable; if the first choice was unsuitable, they repeated steps 4 through 6 in the search for an alternate site.
7. Pilot gave "MARK" signal when he approved the landing site.
8. Experimenter then recorded on target map the

total time, flight path, distance, and touchdown site.

In the course of the study, each subject participated in eight LLV runs from various headings.

RESULTS

Data obtained from these tests showed that the first site selected was satisfactory in 71.87 per cent of the trials. The maximum time from hover point to first site was 60 seconds and the minimum was 12, the mean value therefore being 36.82 seconds. When the first site selected was not suitable for landing, the alternate site proved suitable in 88.99 per cent of the trials—an average 96.88 per cent successful selections for the first and second sites. These striking results were obtained even though the subjects involved had only a minimum amount of training for the exacting tests. When the first site proved unsatisfactory, the maximum time from initial hover point to final landing site was 125 seconds. For all trials the distance from initial hover point to final landing site was 1800 feet maximum and 250 feet minimum, with a mean value of 809 feet. Tables I and II present these values in greater detail.

TABLE I. HOVER-TO-LANDING MANEUVER INDIVIDUAL SUBJECT TIME SUMMARY

Subject		First Site Satisfactory Time (sec)	First Site Unsatisfactory Second Site Satisfactory Time (sec)
1	Max.	37	60
	Min.	12	39
	Mean	25.38	52.67
2	Max.	57	90
	Min.	18	58.5
	Mean	32	70
3	Max.	55	77
	Min.	17	40
	Mean	34.2	62.33
4	Max.	48	90
	Min.	19	90
	Mean	32.43	90
5	Max.	57	70
	Min.	35	70
	Mean	42.57	70
6	Max.	37	125
	Min.	25	60
	Mean	32	83.33
7	Max.	56	64
	Min.	28	60
	Mean	41.5	62
8	Max.	60	90
	Min.	20	90
	Mean	46.71	90

Research results indicated that, to the degree that the lunar surface conformed to the terrain chosen for the tests and on the assumption that the first site selected proved suitable for landing, an LLV pilot would be able to perform the terminal maneuver successfully within the 105 seconds of hover time allowed in the LLV study. If, however, an alternate site had to be selected and translation again accomplished, the time allowable would be marginal.

On the basis of this preliminary research a hover time of approximately 3 minutes is recommended as a fuel allowance for the hover-to-touchdown requirement. This estimate seems to provide an adequate safety margin for the successful completion of this phase of the LLV mission.

TABLE II. LLV HOVER-TO-LANDING MANEUVER TIME AND DISTANCE SUMMARY RESULTS

Subjects — 8	Recorded Runs — 63
A. Total time required when first site satisfactory (sec.):	
Max.	60
Min.	12
Mean	36.82
B. Total time required when first site is unsatisfactory and alternate site required (sec.):	
Max.	125
Min.	39
Mean	69.35
C. Percent of times first site selected was unsatisfactory:	28.13
D. Percent of times second site selected was unsatisfactory:	11.11
E. Distance (Hover point to final landing point) (ft.):	
Max.	1800
Min.	250
Mean	808.73

SUMMARY

A simulated hover-to-touchdown landing by helicopter on the lunar surface was the subject of this study. The purpose was to determine the hover-to-touchdown time necessary for the Lunar Landing Vehicle under manual control, and also to define qualitatively, on the basis of nominal translational velocities, a reasonable value of distance from hover point to suitable landing site. The test vehicle, a Sikorsky S-58 helicopter, followed the planned LLV trajectory as closely as possible. Each of the eight test subjects made eight runs from various directions over terrain approximating in roughness that thought to exist on the lunar surface. To obtain earthshine values equivalent to lunar surface illumination, the tests were conducted between 1030 and 1430 CST with the subjects wearing dark goggles. The subject's vision was restricted as to landing area until the pilot gave a signal of "MARK" about 5 seconds before the initial hover point, at which time visibility of the landing area was made available and the site was selected. The pilot then translated to a point 10 feet above the landing site and gave another "MARK" signal to indicate termination of timing. Both time and distance were recorded for this hover-to-touchdown interval.

Results of the test program indicated that when the first site proved suitable for landing, the LLV would be able to land with the study allowance of 105 seconds. If, however, an alternate site had to be selected and traversed, the time allowed would be marginal. Based on these findings, it was recommended that a hover time of approximately 3 minutes be reserved for the lunar landing maneuver.

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