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REPORT OF THE LIFT ROCKET ASSISTED LAYDOWN TEST PROGRAM FOR LARGE WEAPONS (CFRD)

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ABSTRACT

This report describes the results of a test program to evaluate lift rockets used to reduce the laydown delivery altitude for large, parachute-retarded nuclear weapons. Two tests were conducted with the B-53 and adaption of the lift rockets to the B-53 is discussed. The test results indicate that the allowable delivery altitude of the B-53 can be reduced from 650 feet to 300-350 feet by the use of lift rockets.

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REPORT OF THE LIFT ROCKET ASSISTED LAYDOWN TEST PROGRAM FOR LARGE WEAPONS

Introduction

During the feasibility study for the TX-53 weapon, 1000 feet above the terrain was considered to be a practical release altitude for this weapon. For this release altitude, a parachute system alone would provide the desired impact conditions of 55 feet per second vertical velocity and an impact attitude angle of ±10 degree from vertical. When the final Military Characteristics were published, the altitude was stated as 1000 feet maximum and 500 feet desired for laydown delivery. However, in attempts to obtain a 500-foot delivery altitude, a long history of failures was experienced. The B-53 entered the stockpile with a minimum release altitude of 650 feet above terrain.

The Air Force continued to develop a parachute system that would allow a 500-foot delivery of the B-53. It was observed that this goal was not being accomplished by simple parachute retardation and, therefore, additional means were probably needed to achieve a 500-foot delivery.

SCTM 174-61(71), The Use of Combinations of Rockets and Parachutes in Laydown Bomb Applications, was reviewed for application to the B-53. In analyzing the B-53 trajectory (Figure 1), it was noted that the parachute decelerates the unit from release speed (800 fps) to 100 fps in 5.5 seconds. By this time, the unit has turned so its longitudinal axis is about 35 degrees from horizontal and the unit has also fallen approximately 300 feet. Approximately 4 additional seconds are needed for the unit to be slowed to 55 fps and to turn to within 10 degrees of vertical. Therefore, it was obvious that half the delivery altitude was consumed in decelerating the unit while very little turnover occurred. If the unit could be sustained at or near its release altitude for about 6 seconds while a parachute is decelerating it to 100 fps, acceptable impact conditions could be achieved in a fall distance of 200 to 300 feet.

Preliminary Study

To achieve the above results, a lift rocket system of 18,000 pounds (2 g) vertical thrust for 3 seconds was studied. This study indicated that the theoretical trajectory shown in Figure 2 was feasible. This trajectory was based on the assumptions that: (1) a bomb/parachute system could be lifted by vertical thrust on the bomb; (2) roll of the bomb during rocket firing would be of small magnitude, hence it would not significantly detract from the vertical thrust; (3) a proper location for the vertical thrust could be found (not necessarily through the bomb CG) so the bomb/parachute system would remain aerodynamically stable during rocket burning.

When the study was being conducted, Division 1513 (formerly 7125) was conducting a test program to study rocket assisted laydown. See SCDR 98-63, Report of the Rocket Assisted Laydown Test Program. This test program was being conducted on the TX-57 shape, which is considerably smaller and lighter in weight than the B-53. One main interest was to reduce impact shocks by using retrorockets with lift rockets. However, since these tests were performed on the TX-57, the results were not directly applicable to the B-53. Tests were conducted with the B-53 to determine the feasibility of a rocket assisted laydown system for this size of weapon.

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B-53 Trajectory

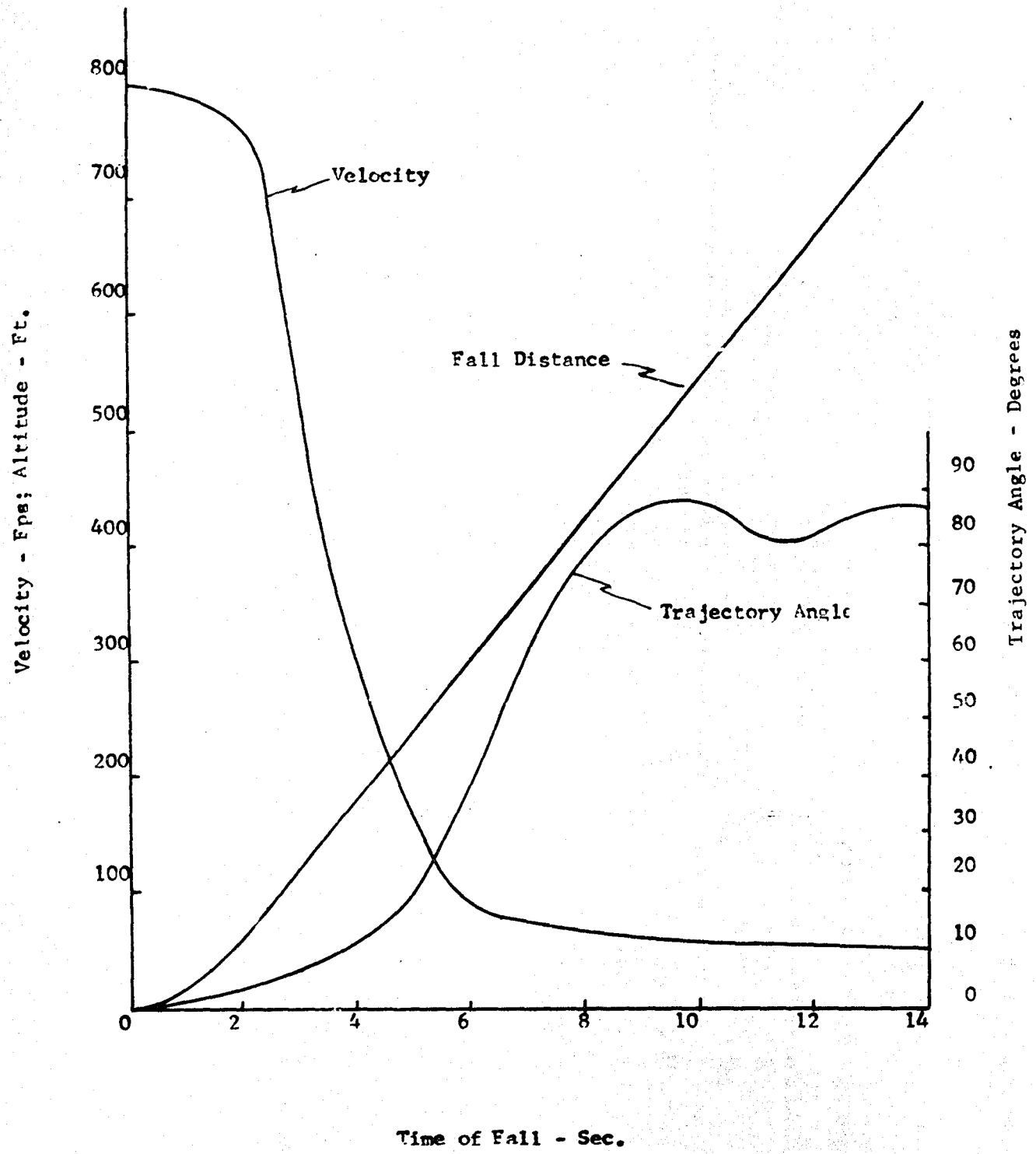

Figure 1. Trajectory Angle (Degrees)

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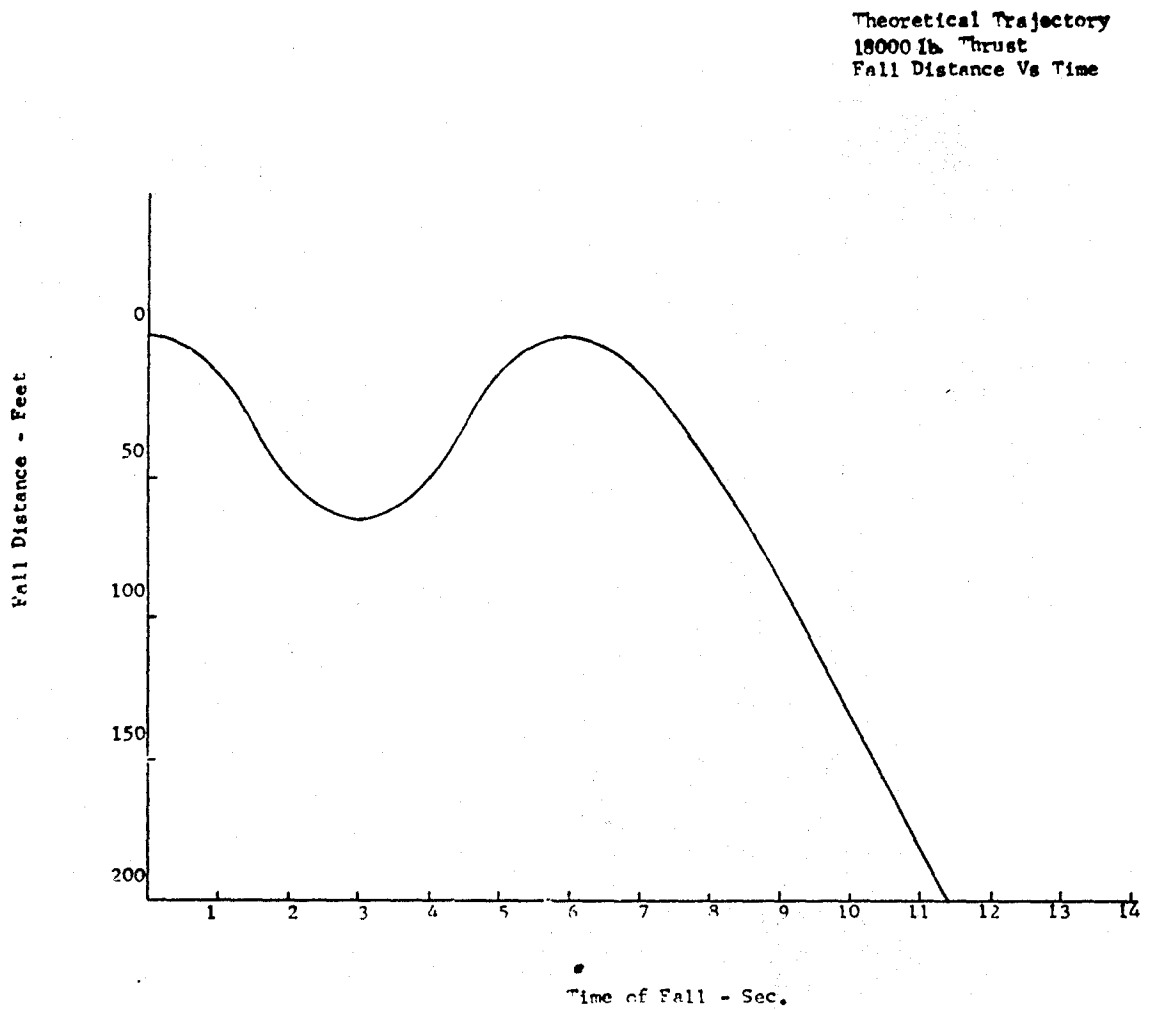

Figure 2. 18,000-Pound Thrust Trajectory

Test Objectives

Based on the studies, the objectives of this test program were:

1. To determine if the bomb parachute combination could be lifted by rockets. This point is quite important. If the system cannot be lifted, the delivery altitude would have to be at least 100 feet greater than that of the trajectory in Figure 2.

2. To verify that the roll would not be great enough to seriously detract from the vertical thrust.

3. Most important of all, to demonstrate a laydown delivery capability of less than 500 feet using a combined rocket parachute system.

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Discussion

One of the main concerns in the initial study was the physical configuration of the rocket motors required for compatibility with the stockpile configuration of the B-53 and an unmodified BA-53. The only space available to locate the rocket motors is inside the outer case segments and about 6 inches to the rear of them. The outer case segments are made of aluminum honeycomb to absorb secondary impact shocks and are 6.5 inches thick and 74 inches long. As a result, any motor considered for the stockpile application could not exceed 6.5 inches in diameter, could not be longer than 80 inches, and should have a 90 degree canted nozzle (not less than 70 degrees). This last requirement is necessary because the motor would be mounted parallel to the weapon longitudinal axis (Figure 3). Three solid propellant rocket motor manufacturers were contacted concerning the feasibility of such a motor. All three manufacturers stated such a motor was feasible and that development time could be made available. Once the feasibility of such a motor was established, the design of the test vehicle was started. For the test vehicle, standard motors with straight nozzles were used because they were available with no development required and at moderate cost. These motors were mounted through the test vehicle body perpendicular to the longitudinal axis.

In arriving at the configuration to be tested, safety of the drop aircraft was a major concern. Figure 4 shows the horizontal distance from the unit to the bomb bay of the drop aircraft versus time from release. Using the trajectory of Figure 2 and assuming a parachute failure, the unit might hit the tail of the drop aircraft. To safeguard against this, the thrust level for the test vehicles was reduced to 16,000 pounds. The reduction in thrust level decreases the height the unit is lifted so that the unit cannot hit the delivery aircraft. The resulting theoretical trajectory is shown in Figure 5. Rocket ignition was the same as the original trajectory, 1.5 seconds after release. This time was selected for the following reasons: With normal B-53 automatic deployment, the chute deployment starts 1.0 second after release. An additional 0.5-second is required to separate the main chute from the unit. Rocket ignition before the CG shift which results from parachute separation from the unit would cause severe pitching and could cause the unit to perform violent maneuvers. Also, too late an ignition time would result in a higher required delivery altitude. Therefore, rocket ignition should occur as soon as possible consistent with safety and stability requirements.

Description of Test Vehicles

Test vehicles used for this test program were modified B-53 ballistic units. Modifications consisted of:

1. Modifying the case and outer case segments to provide space and mounting provisions for rocket motors.

2. Modifying the rear case section (afterbody) to accept a 76-foot single canopy chute rather than the stockpile three-chute cluster of 48-foot chutes. (Single canopy chutes were available, but cluster systems were not.)

3. Addition of an electrical system for firing the rockets. This consisted of batteries, explosive switches, pullout switches and timers necessary for safety and reliability.

Each of the test weapons contained four Yuma II rocket motors, manufactured by Rocket Power, Inc., Mesa, Airzona, in accordance with Sandia Corporation specifications. The Yuma II motor produces 4000 pounds of thrust for 3.0 seconds, is 6.5 inches in diameter and 49.00 inches long. A typical thrust curve is shown in Figure 6.

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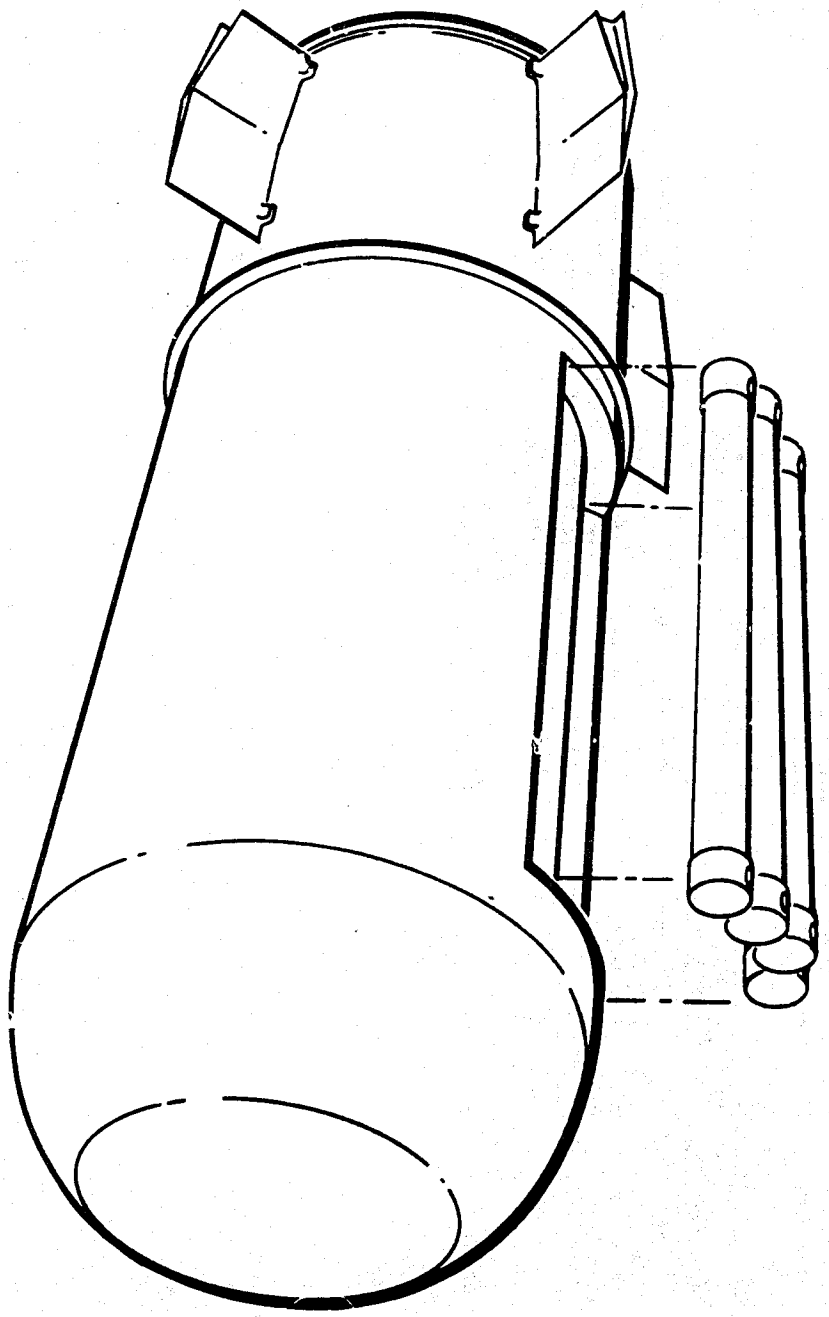

Figure 3. Proposed Layout of Rockets

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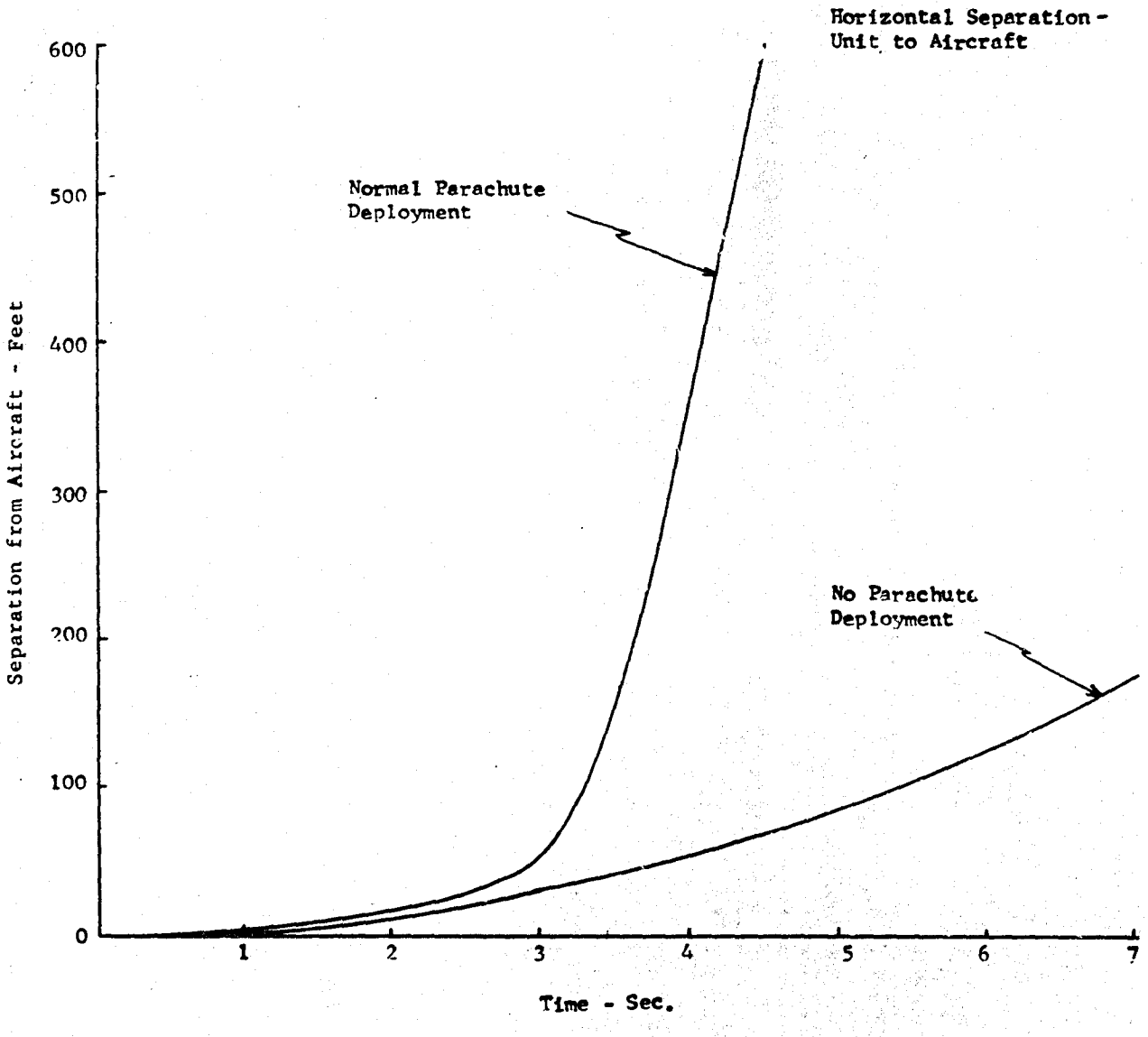

Figure 4. Plot of Horizontal Separation-Unit to Bomb Bay

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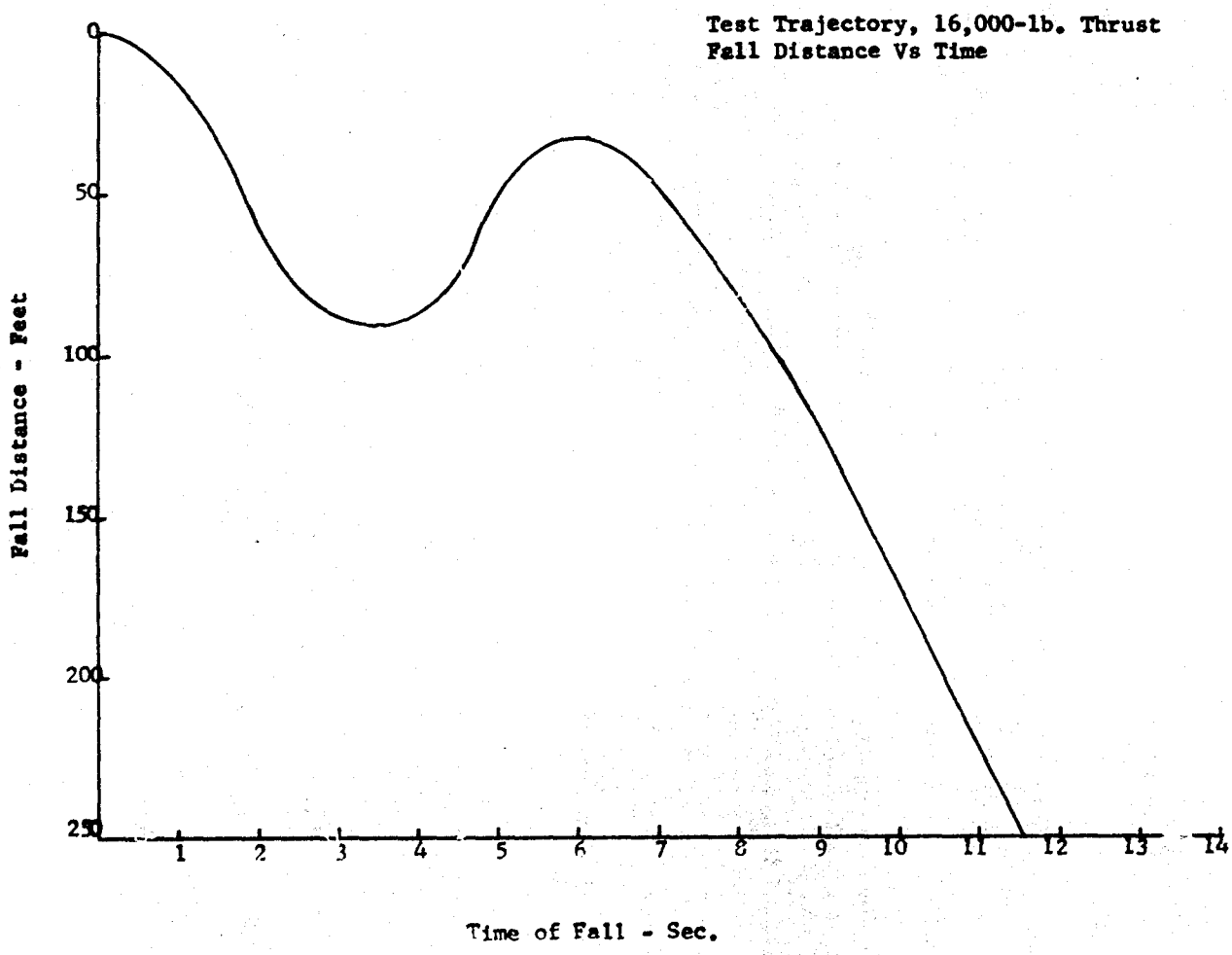

Figure 5. Test Trajectory (16,000-Pound)

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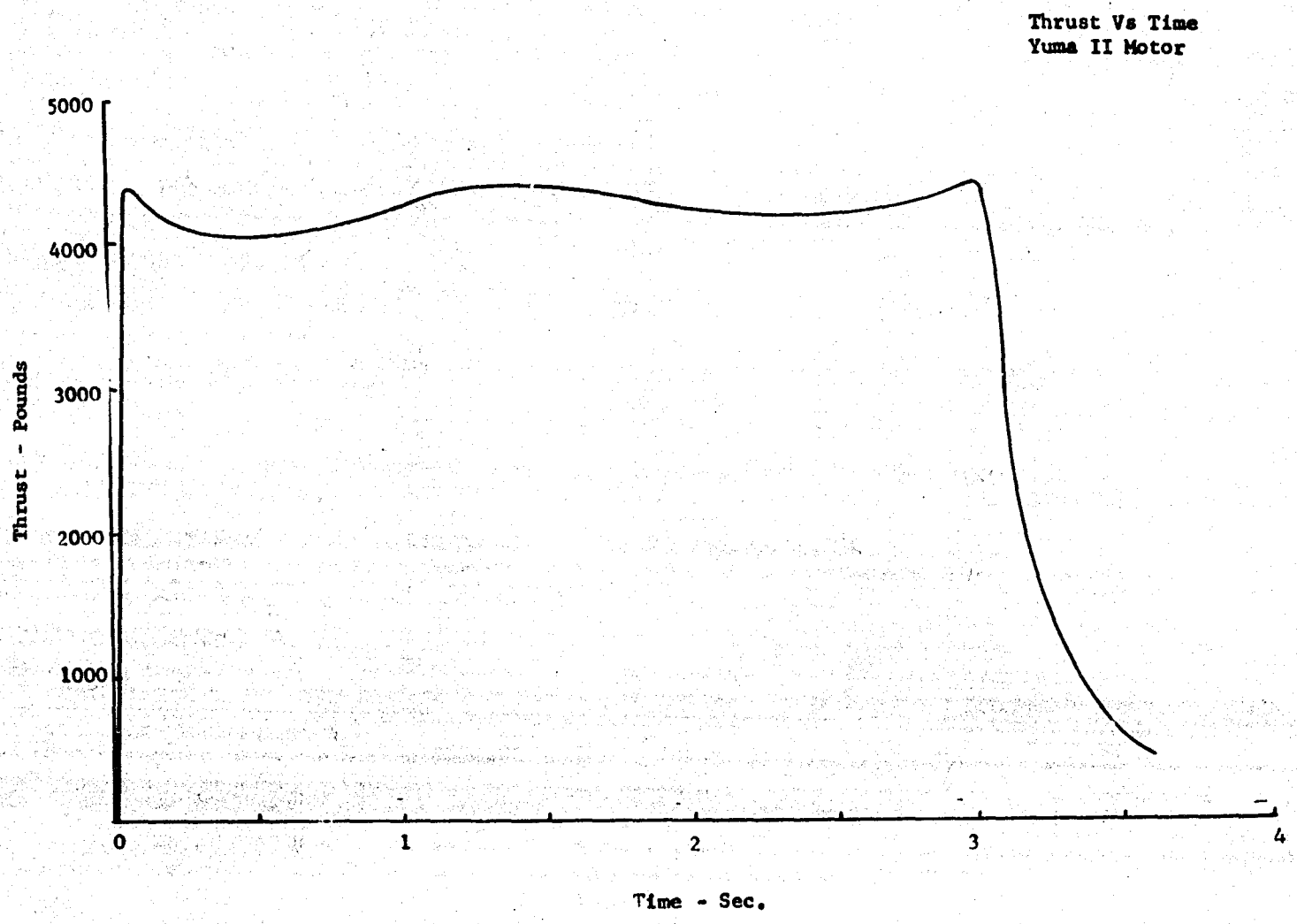

Figure 6. Thrust Curve - Yuma II

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The assembled test vehicle had the following physical characteristics compared with the B-53:

	Test Vehicle	B-53
Weight (lb)	9300	8825
CG Station	69.7	70
Length (in.)	144	144
Diameter (in.)	50	50
Fin Box (in.)	58.5	58.5

Test Results

Of the two tests conducted, only one was successful. On the first test (126-1) one rocket motor did not fire because of an internal short in the igniter. In addition, parachute suspension lines were severed because of insufficient radius of the suspension line bearing point on the rear case section. As a result, no significant data were obtained from this test.

The second test (126-2) was successful with all the requested data being obtained. On this drop the unit rolled 40 degrees, stopped, backed up to 16 degrees from the 0-degree reference during rocket burning with no detrimental effect on performance. Figures 7 and 8 show the performance of this unit. In establishing the delivery altitude for this unit, required impact conditions are the controlling criteria. These conditions are: (1) a maximum vertical velocity of 55 feet per second and (2) the unit longitudinal axis being within 10 degrees of vertical (80 to 100-degree nose down pitch). The unit reached 80 degrees nose down in 282 feet, 100 degrees in 335 feet, but overshot to 118 degrees nose down (pitch), came back to 100 degrees in 447 feet and then stayed within 80 to 100 degrees. The vertical velocity requirement of 55 feet per second was reached in 328 feet. For this test, then, the controlling factor was attitude angle. The unit met all conditions in 328 feet; however, because the unit overshot the required attitude, the unit did not stay within the requirements until 447 feet of fall distance was reached. By exploring parachute parameters and/or rocket burn time, it should be possible to eliminate the attitude angle overshoot.

Conclusions

A 300- to 350-foot above terrain delivery capability is feasible. The rocket motors would be mounted in the bottom outer case segment as shown in Figure 3. This would require a new set of bomb shape components (BSC). Additional tests will be required to determine the feasibility of using 90° canted-nozzle rocket motors with the B-53.

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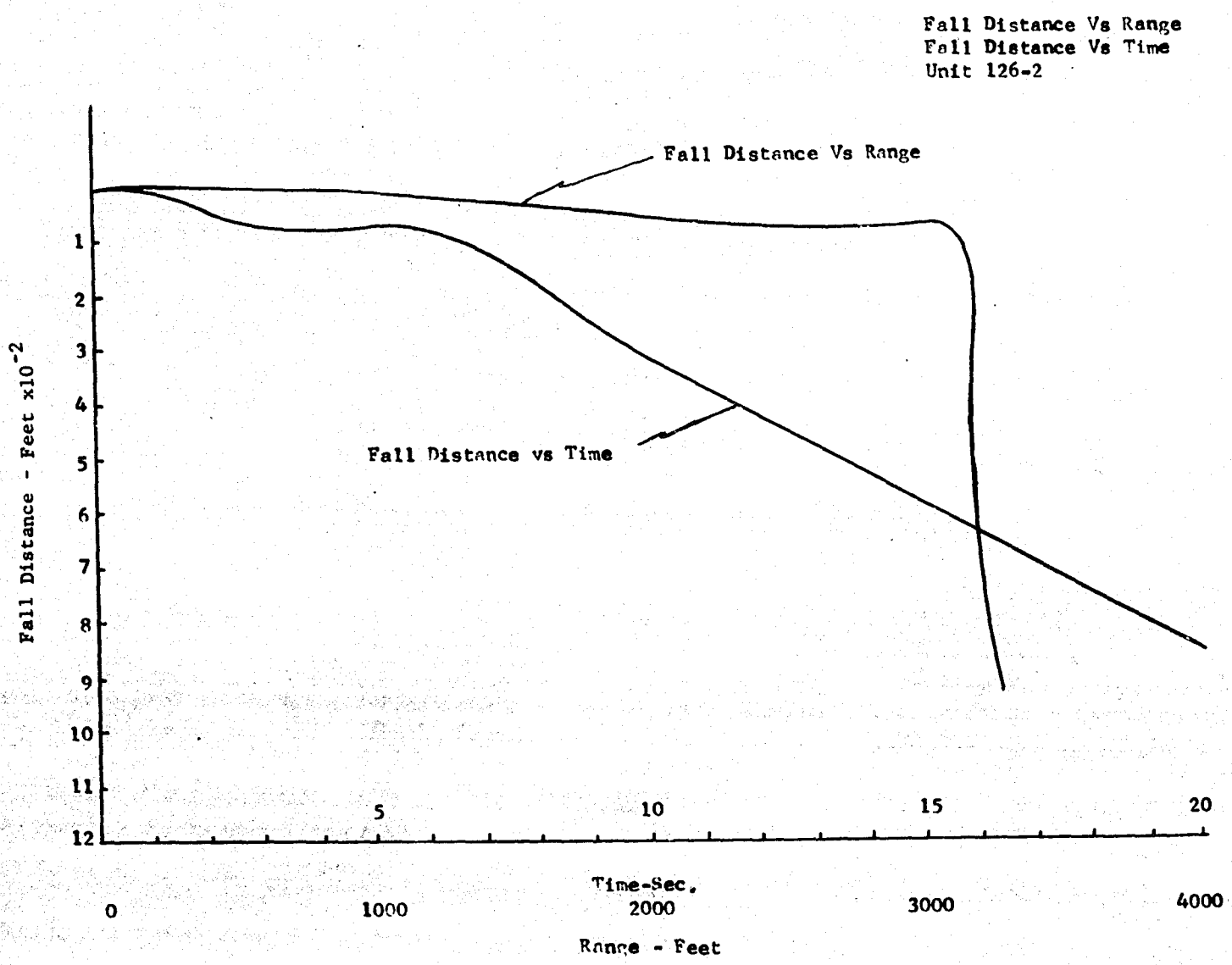

Figure 7. Fall Distance (Altitude) Versus Range and Fall Distance (Altitude) Versus Time

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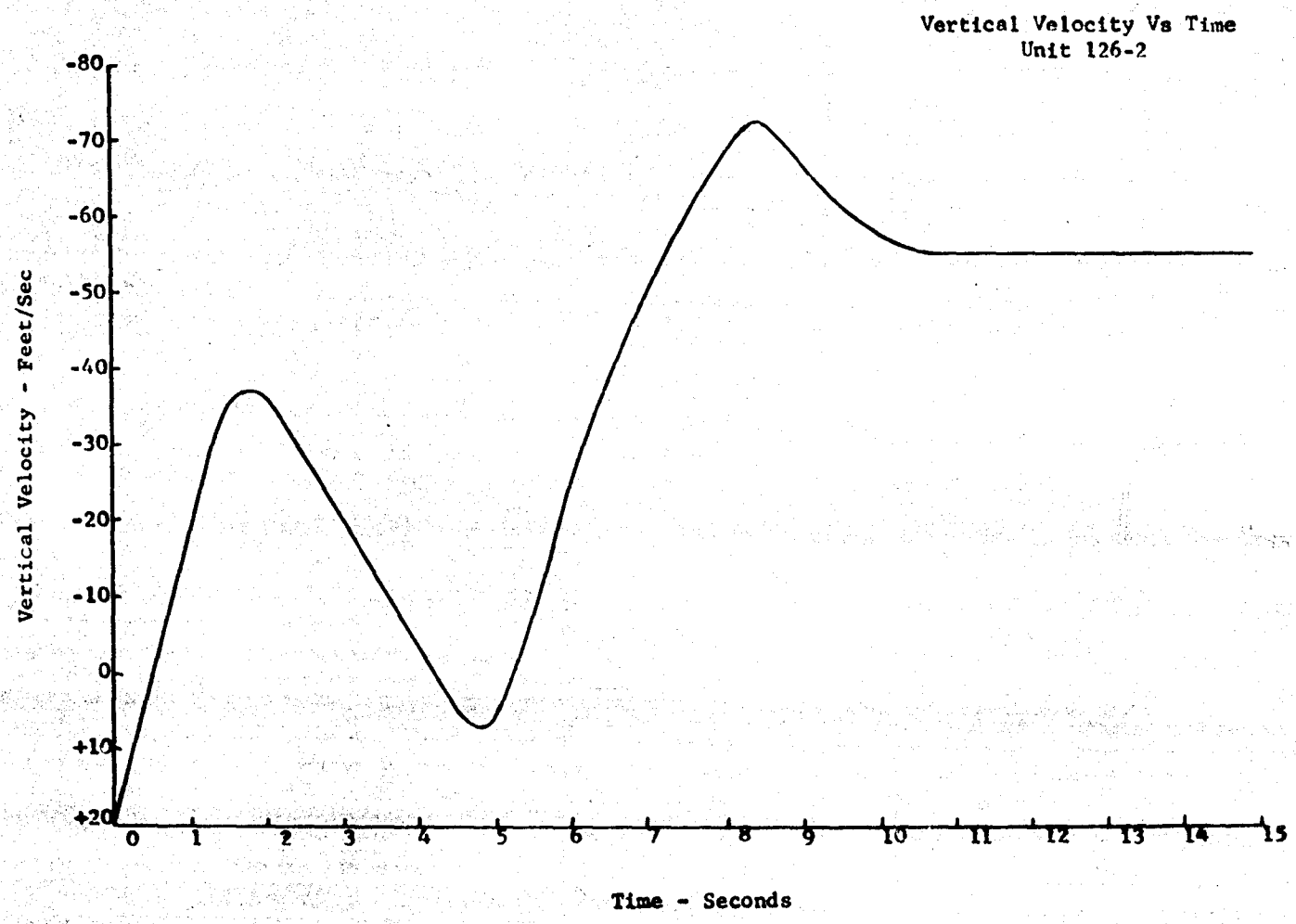

Figure 8. Vertical Velocity Versus Time