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# DISCOVERER

## RANGE SAFETY REPORT
## NUMBER 5

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# DISCOVERER
# RANGE SAFETY REPORT
## NUMBER 5

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Missiles and Space Division
Sunnyvale, California

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## FOREWORD

This range safety report has been prepared by the Lockheed Missiles and Space Division (LMSD) under Air Force Letter Contract AF 04(647)-181. It is submitted to comply with the Vandenberg Air Force Base requirement that all agencies using the range facilities for missile flight operation furnish range safety data substantiating the flight article's performance capabilities.

The information in this report is presented in a form that will provide rapid reference for future operations, thereby permitting a reduction in the amount of material to be presented in subsequent reports.

The fifth in a series, this report covers the flight of Discoverer satellite vehicle Model 2205 Serial 1023, and SM-75 booster DM-18 Serial 179.

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## SUMMARY

The Range Safety requirements established by the Vandenberg AFB Range Safety Officer are discussed herein, as are the means adopted by LMSD to comply with these requirements. In addition, the aerodynamic and trajectory data required for range safety evaluation are presented.

Calculations indicate that the Discoverer/Thor configuration cannot execute a trimmed turn; therefore, maximum-rate controlled turns are presented to comply with the Vandenberg AFB Range Safety Officer requirements. The maximum-rate controlled turn is the sharpest turn that the missile can execute and still remain under control. (Controlled turns could be programmed by gyro drift and/or error in the programmer.)

Because of the nature (cyclic) of a tumbling turn, the maximum velocity vector rotation is determined for the first one-half cycle of tumble. Further investigation shows that the worst case exists during the first 20 seconds of flight.

Information pertaining to the airborne flight termination system is presented in Section 2. (See Introduction.)

## CONTENTS

## ILLUSTRATIONS

## INTRODUCTION

The discussion and data presented in this report, the fifth in a series, have been prepared as aids to the Vandenberg AFB Range Safety Officer in establishing the safe operational flight limits for the Discoverer flight involving Discoverer satellite vehicle Model 2205 Serial 1023, and SM-75 booster DM-18 Serial 179.

Discoverer vehicle Serial 1023 will be launched with a departure azimuth of 175° East of North. Nominal orbit injection altitude will be 121 statute miles, with an eccentricity of 0.01. Vehicle 1023 will be the third Discoverer vehicle carrying a recoverable capsule.

A study was conducted to determine how range, altitude, velocity, and flight path angle would be affected by the 7.8° easterly change in departure azimuth (from the previous azimuth of 182.8° to the above-stated 175°). At the time of SM-75 burnout, the following differences exist in those parameters for the two departure azimuths:

| | |
|---|---|
| Range | 634 ft |
| Altitude | 1246 ft |
| Velocity | 2 ft/sec |
| Flight path angle | 0.09 deg. |

These differences are considered negligible. Therefore, to avoid delaying submittal of this report until new trajectory data are available, the trajectory data prepared for the previous flight departure azimuth of 182.8° is included herein. All other data in this report reflect the new azimuth of 175°.

## SECTION I
## DESCRIPTION OF DISCOVERER/THOR

The flight article used for the Discoverer Program consists of two stages: The Discoverer satellite vehicle and the SM-75 (Thor) booster. Overall dimensions of the Discoverer/Thor combination are shown in Figure 1. Figure 2 is an inboard profile of the Thor booster. Propulsion units for both stages are liquid bipropellant types, the Discoverer using an IRFNA/UDMH combination and the Thor using liquid oxygen and RP-1. Table I summarizes the weights at launch. (A plot of weight versus time for the boost phase appears in Figure 18.)

Aerodynamically, both the Discoverer/Thor and the Discoverer satellite vehicle configurations are unstable in all flight Mach regimes (refer to Appendix A). Attitude control in pitch and yaw is obtained by positioning the thrust vector of the gimbaled rocket engines. Roll control of the Discoverer/Thor combination is obtained by the swiveling of the vernier rocket motors during Thor boost and the use of gas jets on the Discoverer satellite after vehicle-booster separation.

Trajectory control is established by the use of the SM-75 autopilot and programmer for the SM-75 boost phase and the Discoverer guidance and flight control system for coast and orbital injection phases.

The Discoverer satellite vehicle Model 2205 Serial 1023 will be the third vehicle in the Discoverer series to carry a recovery capsule. Figure 3 is an inboard profile of the satellite vehicle, and shows the location of the recovery capsule.

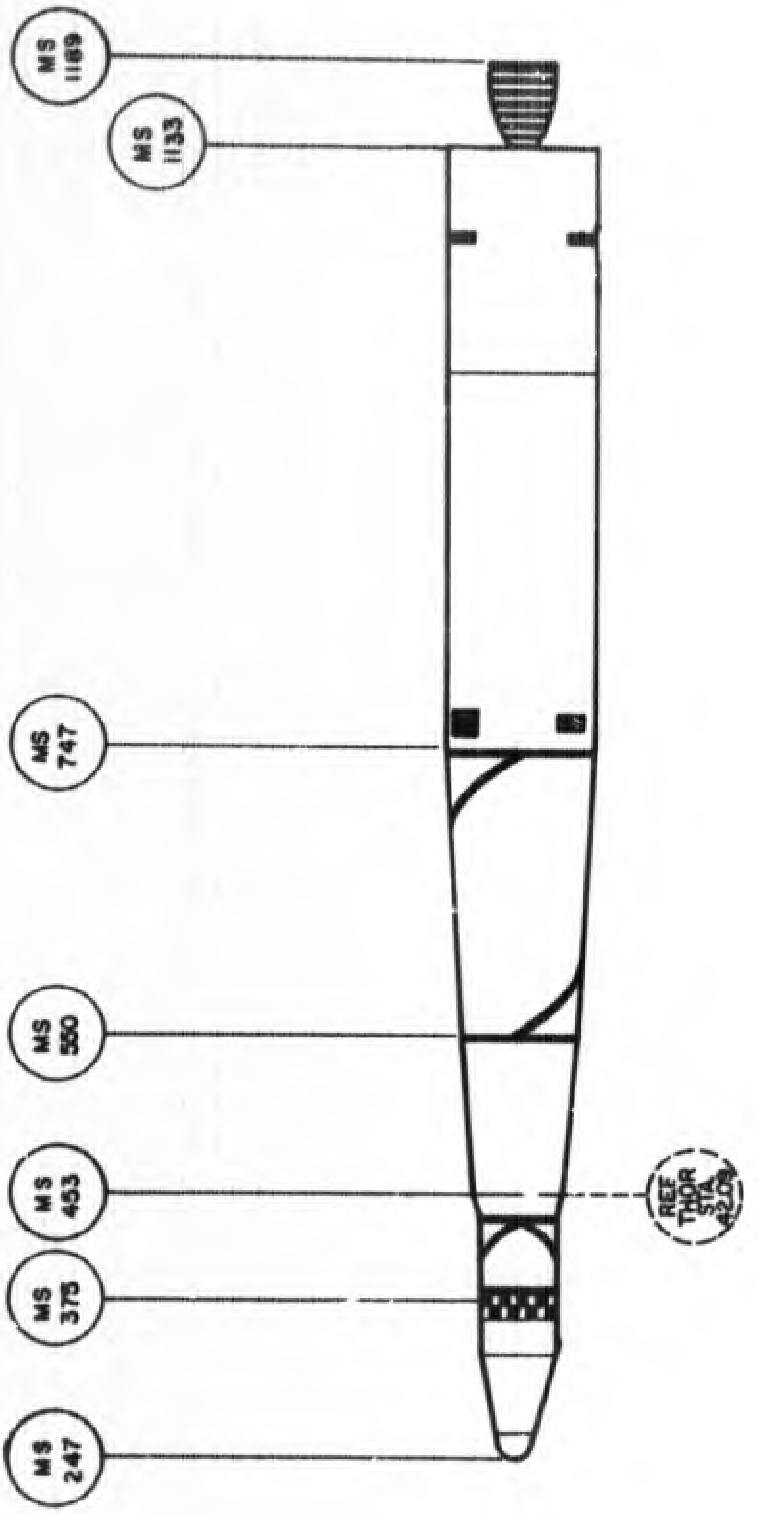


Fig. 1 Discoverer/Thor Configuration

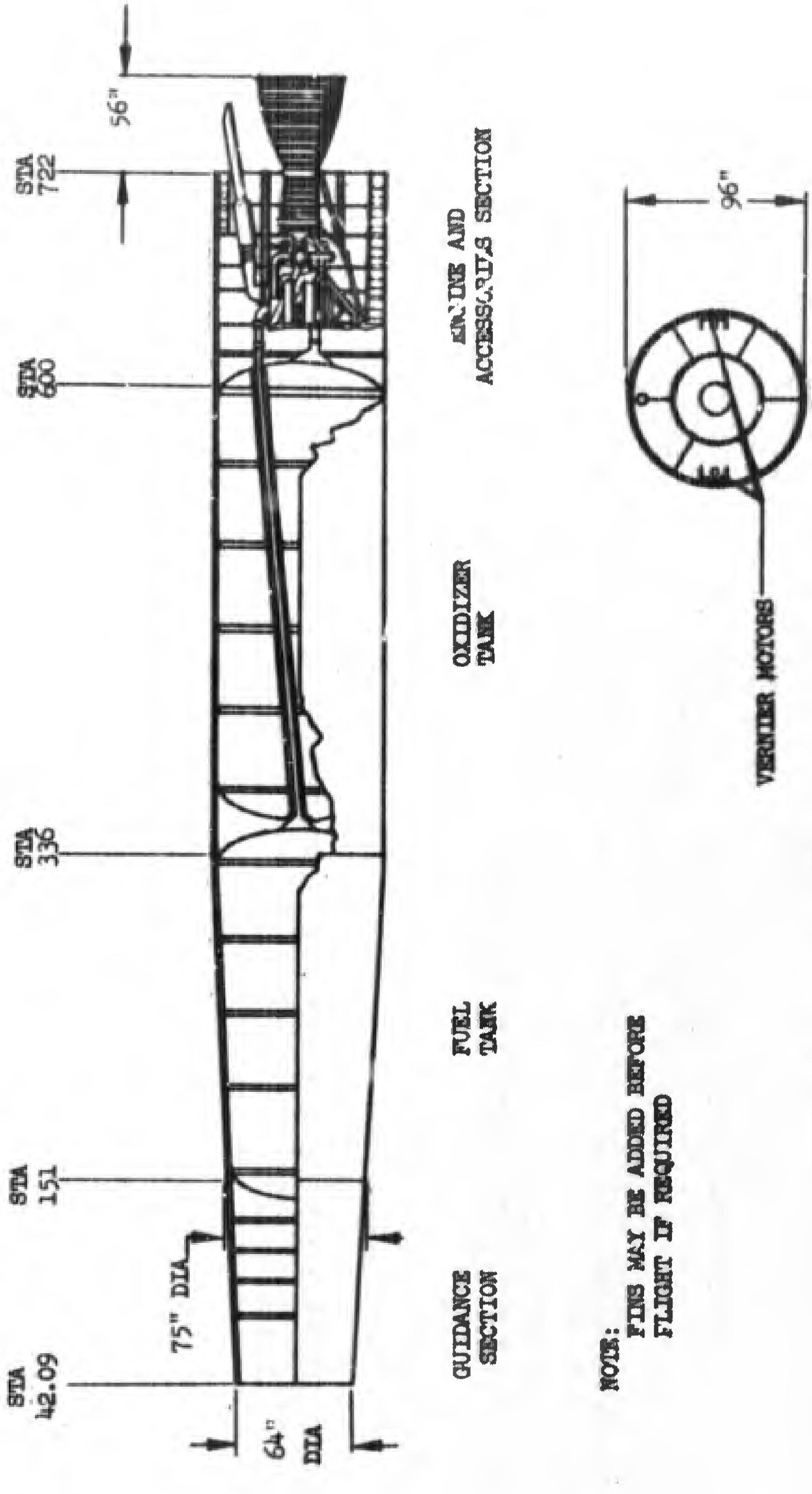
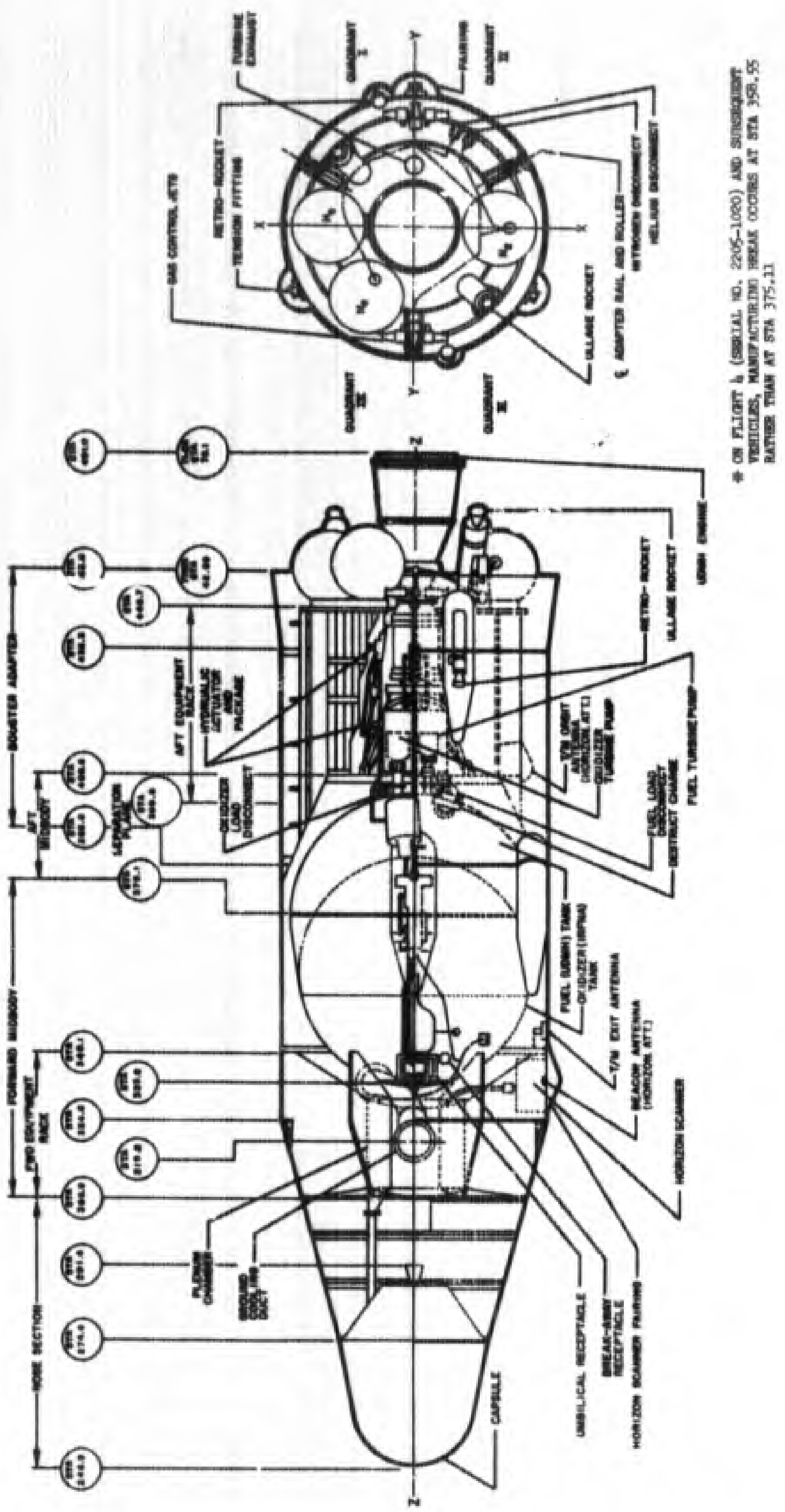


Fig. 2 Thor (SM-75) Booster, Inboard Profile



* ON FLIGHT 4 (SERIAL NO. 2205-1020) AND SUBSEQUENT VEHICLES, MANUFACTURING BREAK OCCURS AT STA 358.55 RATHER THAN AT STA 375.11

Fig. 3 Discoverer Satellite Vehicle, Inboard Profile

Two types of recovery capsule units will be utilized in the Discoverer Program. Both have an ablative re-entry shell, and contain a retro-rocket having a 10-second impulse equal to 7290 lb/sec (±3%). Weights of the capsules are 195 and 279 pounds.

Table I

DISCOVERER/THOR WEIGHT SUMMARY
(Discoverer Vehicle 1023)

| | |
|---|---|
| Discoverer Vehicle - Weight Empty | 2,010 lb |
| Propellants | 6,547 lb |
| IRFNA (4,705 lb) | |
| UDMH (1,842 lb) | |
| Discoverer Gross Weight at Launch (incl. Adapter) = Thor Payload | 8,557 lb |
| Thor Vehicle (incl. Lube Oil, Pressurizing Gas, Residual Propellants) | 9,324 lb |
| Thor Propellants (Impulse) | 96,515 lb |
| Liquid Oxygen (66,818 lb) | |
| RP-1 (29,697 lb) | |
| DISCOVERER/THOR GROSS WEIGHT AT LAUNCH | 114,396 lb |

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## SECTION 2
## FLIGHT TERMINATION SYSTEM

### DISCOVERER FLIGHT TERMINATION SYSTEM

The Discoverer flight termination system is designed to initiate vehicle destruction by either of two types of inputs: range safety command flight termination or automatic airborne flight termination.

Range safety command for flight termination will be given by the Range Safety Officer upon recognition of the need for such flight termination. The command flight termination signal will initiate a destruct command simultaneously in both the Thor booster and the Discoverer vehicle. The Thor 28-volt battery power supply is used for initiation of both the Discoverer and Thor command flight termination systems during the Thor-boost phase.

Within the Discoverer vehicle, a 1.2-pound shaped charge of composition "B" with a 25-grain RDX booster, when activated, will rupture the propellant tanks, dispersing the oxidizer and fuel overboard.

An MPS-19 range-safety radar is used to pulse the Discoverer S-band beacon for tracking data. This range safety radar tracking will stop at, or prior to, Thor burnout time (approximately 157 seconds from launch). This is to forestall the possibility of interference with the LMSD Mod II radar commands.

Operation of the Discoverer automatic flight termination system will be initiated by separation of the Discoverer vehicle from the Thor prior to programmed separation. (Approximately one and one-half inches of travel between the Discoverer and Thor vehicles is required to initiate destruct.)

For detailed flight termination system information, consult Reference 1. Included in that report is a wiring diagram of the Discoverer flight termination system which presents extensive detail on design, component use, system reliability, and test results.

## THOR FLIGHT TERMINATION SYSTEM

The Thor flight termination system is designed to operate on a range safety flight termination command signal. Upon receiving the command signal, primacord which is located longitudinally along the propellant tanks and circumferentially about the aft end of the oxidizer tank will be detonated. The primacord charges are designed to rip open the tanks and mix the fuel and oxidizer, reducing the Thor booster to a nonpropulsive condition. Simultaneously with initiation of the flight termination of the Thor booster, a voltage will be applied to the Discoverer vehicle, initiating flight termination of the vehicle. Reference 2 gives detailed information as to the operational characteristics of the Thor flight termination system.

## SECTION 3
## MALFUNCTIONS

Malfunctions during the Discoverer/Thor boost phase are separated for purposes of discussion into the categories of propulsion malfunction, flight control malfunction, structural failure, and beacon malfunction.

Recommendations appear in this section with regard to the requirement to terminate flight as the result of a stated malfunction. It is emphasized that the command function for flight termination exists only during the Thor boost phase.

### THOR BOOST PHASE

#### Propulsion System Malfunction

The propulsion system for the Thor booster utilizes a bipropellant-type rocket motor burning liquid oxygen and RP-1. Malfunctions of the propulsion system will be indicated by the failure of the Discoverer/Thor to attain the estimated velocity and altitude. This type of malfunction can be associated with a non-optimum fuel-oxidizer mixture, which in turn may be attributed to failures in the following functions and components: pressurization, valves, regulators, turbine pump, gas generator, or propellant-utilization sensing elements.

A malfunction of this nature, assuming sufficient thrust is supplied by the Thor rocket engine to establish the shaping phase of flight (from 10 seconds after launch), does not warrant missile destruction, as the vehicle would not be deviating in azimuth with the possible associated dangers to life and property. Further, valuable experimental flight subsystem data would be secured, enabling the Contractor to determine the cause of the particular failure.

Flight Control System Malfunction

With regard to range safety, skyscreen, or radar plotting board appearance, a flight control system malfunction will be similar to a rocket motor gimbal-type failure: namely, unprogrammed pitch and yaw or pitch and yaw oscillations.

This type of subsystem failure, if it is restricted to the pitch plane (from 10 seconds after launch), again does not warrant range safety destruction. Eccentric behavior in azimuth beyond the turning rate limitations (as established by the Vandenberg AFB Range Safety Officer) does require initiation of the destruct command.

**Structural Failure**

Structural failure of the Discoverer/Thor combination will be followed by vehicle flight path changes. The magnitude of these deviations will in turn depend on the type of structural failure, angle of attack, flight Mach number, and "q" (dynamic pressure). The most likely causes of a structural failure would be excessively high wind shears at altitude or a propulsion or flight control malfunction.

The critical (minimum safety margin) structural sections are at the tank support ring (Missile Station 375) on the Discoverer vehicle, and the forward propellant-guidance section joint (Missile Station 550) on the Thor booster. These critical stations are shown in Figure 1.

This type of mishap would probably occur in the area of 60 seconds ($\alpha$ q maximum) of the Discoverer/Thor boost phase. The physical breakup of the vehicle will probably precede the human reaction time (which is about four seconds when using radar plots) so that the Range Safety Officer would initiate vehicle flight termination as a matter of standard operational procedure.

### Beacon Malfunction

The Discoverer vehicle carries an S-band pulsed beacon transponder, transmitting on 2850 mc and receiving on 2920 mc. The S-band beacon is used for tracking the Discoverer vehicle throughout flight. In addition, a received command signal will be used to command the Discoverer rocket motor ignition. If this command is not transmitted to the vehicle, a programmer will initiate rocket engine ignition.

Failure or intermittent operation of the S-band beacon does not imply the loss of the mission; as mentioned above, the beacon is used during the Discoverer coast phase as an orbit-engine ignition control. Therefore, its non-operation, even though it removes the range safety tracking function, does not warrant the commanded destruction of the vehicle (if skin tracking is maintained). However, space-position data for range safety purposes can be obtained from the COTAR system that is to be employed by the range.

In reference to radars, it is desirable that the range safety radar used in conjunction with the airborne beacon be shut down at or prior to the Thor thrust termination, which occurs at approximately 157 seconds from launch. This is to preclude any possibility of an LMSD-transmitted command being "dropped out" due to interference from the range safety radar.

## DISCOVERER (POST-SEPARATION) FLIGHT PHASE

Malfunctions that may be encountered during the Discoverer flight phase in respect to range safety effects are limited to the point of orbit injection (powered Discoverer flight).

Once the orbit velocity and attitude have been established, prediction of the re-entry of the Discoverer flight into the earth's atmosphere can be made only after verification of the orbit and its decay characteristics.

Whether due to a malfunction or the normal orbital decay, the Discoverer will eventually start into a re-entry phase. During re-entry the vehicle will tumble because of its aerodynamic instability. The tumbling moments produced will probably cause breakup of the vehicle at Station 375 (tank support ring).

The velocity of each piece at impact is dependent on the drag imposed (drag in turn being a function of angle of attack, Mach number, and dynamic pressure) and the weight of each piece.

The total weight of the Discoverer orbital vehicle, without propellants, is approximately 1818 pounds with a projected area of 20 to 90 square feet, depending on the vehicle attitude. The impact velocity can range from 100 to 300 ft/sec depending on the type of motion encountered during the re-entry phase.

In summary, these measures and velocities are analogous to those encountered in a light-aircraft-type of accident. Actually, the surface impact damage for the Discoverer would be less, inasmuch as the glide angle is close to 90 degrees while that of a light plane in a glide approach is 10 to 30 degrees.

## SECTION 4
## GENERAL RANGE SAFETY PROBLEMS

The Discoverer/Thor missile, being aerodynamically unstable, can be expected to tumble for most conceivable control system malfunctions, thereby causing a dangerous condition during the burning phases. If tumbling occurs between 40 and 100 seconds from launch, the combined configuration will most certainly break up at Missile Station 453 (the interconnect between the first and second stages) and at Missile Station 747 (the junction of the oxidizer and fuel tanks of the first stage) due to the high aerodynamic forces experienced in this period.

For times prior to 40 seconds or after 100 seconds the vehicle will not break up in a tumbling condition, because of the low aerodynamic forces. In addition, because tumbling is a cyclical phenomenon, no large lateral deviations will be experienced.

Because of the aerodynamic instability of the Discoverer/Thor configuration at low angles-of-attack, a trimmed turn in the usual sense is impossible during powered flight. However, turning rates have been computed from the following general expression assuming that the aerodynamic moment is balanced by the thrust moment:

$$mV\dot{\gamma} = T \sin(\delta + \alpha) + F_n \cos\alpha - F_x \sin\alpha - mg\cos\gamma$$

where:

$\dot{\gamma}$ = turning rate, rad/sec
$T$ = thrust, lb
$\alpha$ = angle of attack, deg
$\delta$ = nozzle gimbal angle, deg
$F_n$ = aerodynamic normal force, lb
$F_x$ = aerodynamic axial force, lb

$m$ = vehicle mass, slugs
$V$ = vehicle velocity, ft/sec
$\gamma$ = flight path angle, deg

(This expression describes rocket motion in the vertical plane. The symbols employed are conventional NASA symbols for motion in the x-y plane. The above expression is similar to the equation used to describe motion in the horizontal plane, with differences being in the gravity term and symbols.)

It is realized that this rate is an instantaneous rate only and would require a peculiar malfunction in order to be attained; however, it is believed to represent an outer limit on the rates that can be expected from the vehicle.

## SECTION 5

## TRAJECTORY AND AERODYNAMIC DATA PRESENTATION

The basic information given in this report was computed on the Remington Rand 1103AF high speed digital computer at the LMSD Computer Center facility, using input data as given in Appendix A of this report. The data that follow satisfy the major requirements of Appendixes C and D and are discussed in the same order as requested (i.e., by paragraph and item). The following material must be read in conjunction with Appendixes C and D.

### PARAGRAPH 3

Item 3a. X, Y, and Z, the trajectory coordinates in an orthogonal earth-fixed coordinate system as defined in Paragraph 4b of Appendix C of this report, are tabulated in Appendix B as functions of time.

Item 3b. $\dot{X}$, $\dot{Y}$, and $\dot{Z}$, the component velocities along the specified coordinate system, are tabulated in Appendix B as functions of time.

Item 3c. The maximum trimmed turning rate of the velocity vector as qualified by Paragraph 4d of Appendix C is discussed briefly in Section 4, "General Range Safety Problems." Appendix C of Reference 3 contains a more complete discussion and the method of calculation. The results of the calculations are shown in Figures 4 through 7 both as turning rate and angle turned through for times of two, four, and six seconds after initiation of malfunction. The rates were computed in the lateral plane; however, the change in $\gamma$ due to gravity was estimated from the nominal trajectory and the appropriate corrections made to obtain rates in the vertical plane. The gravitational correction is shown in Figure 8.

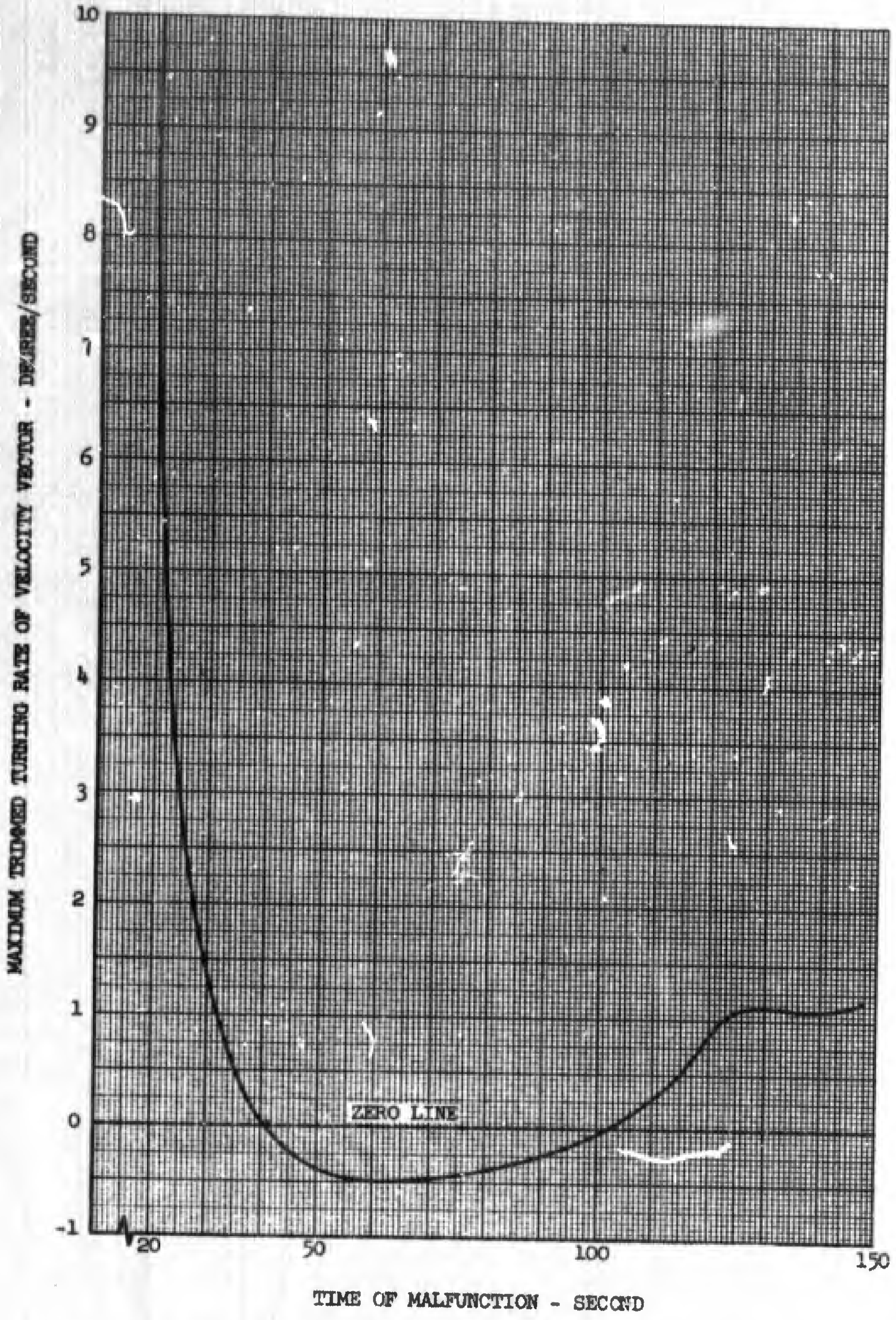

Fig. 4 Maximum Trimmed Turning Rate of Velocity Vector, vs Time of Malfunction - Vertical Plane

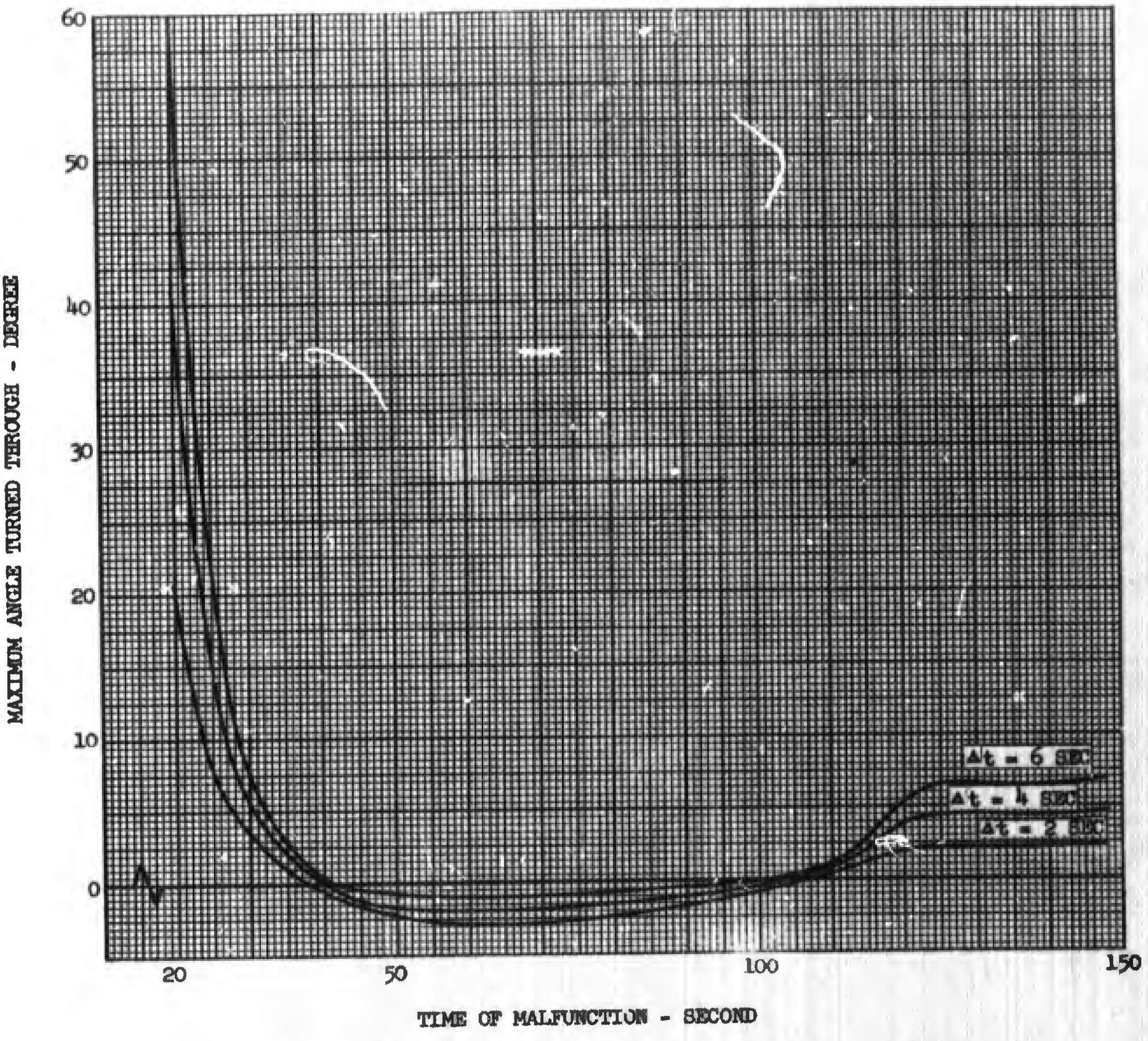

Fig. 5 Maximum Angle Turned Through by Velocity Vector for 2, 4, 6 Seconds of Maximum Rate Trimmed Turn, vs Time of Malfunction - Vertical Plane

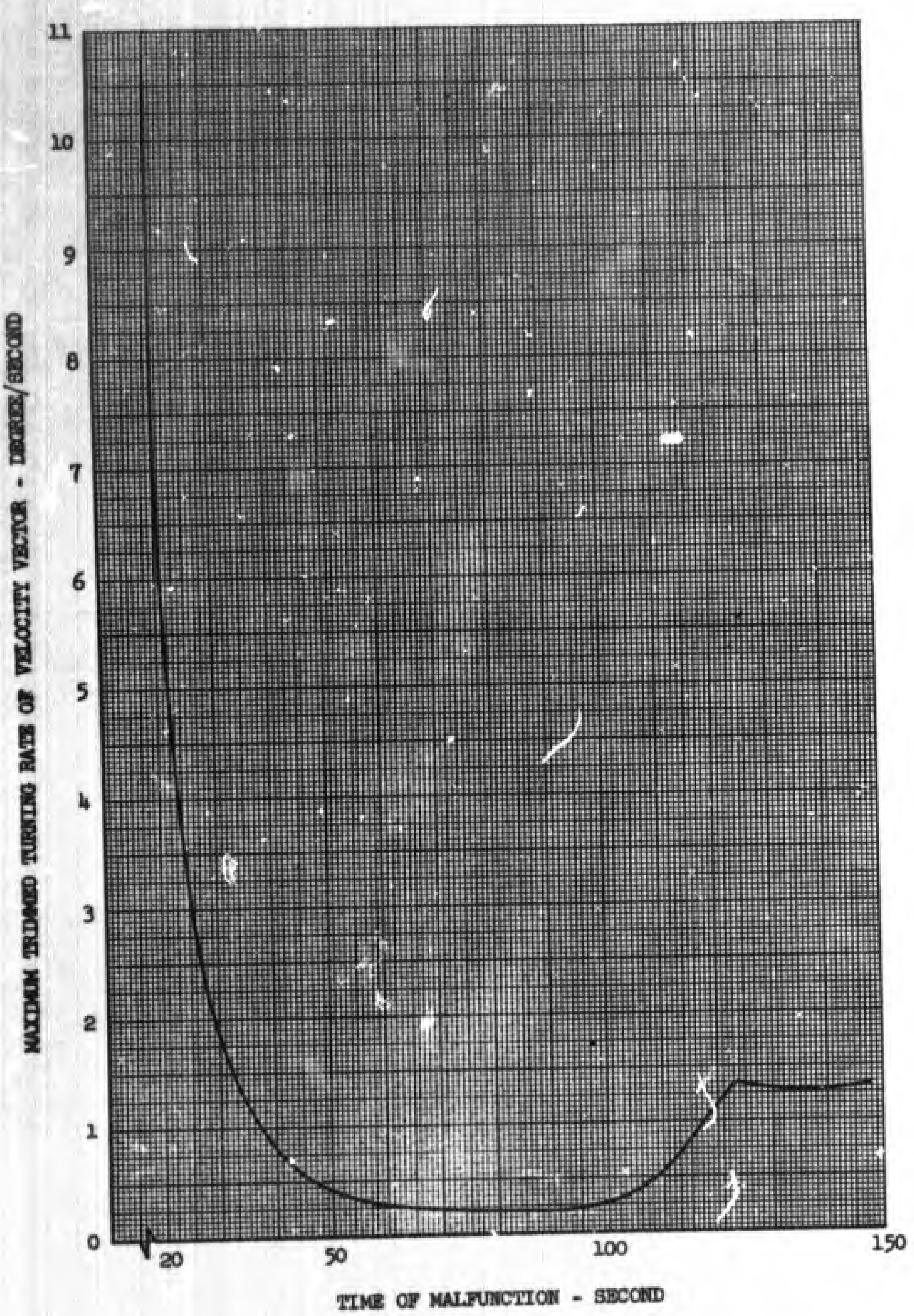

Fig. 6 Maximum Trimmed Turning Rate of Velocity Vector, vs Time of Malfunction - Horizontal Plane

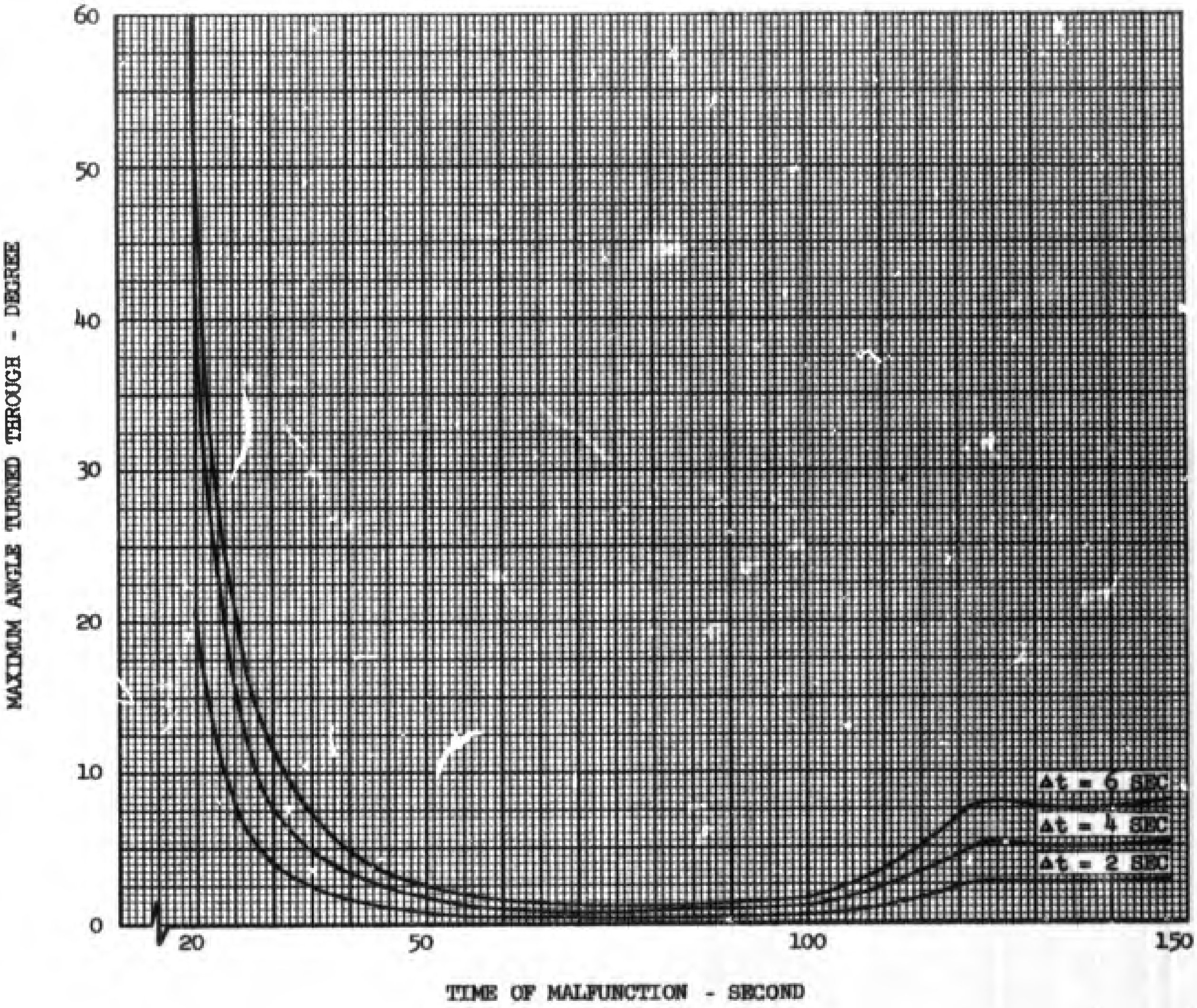

Fig. 7 Maximum Angle Turned Through by Velocity Vector for 2, 4, 6 Seconds of Maximum Trimmed Turn, vs Time of Malfunction - Horizontal Plane

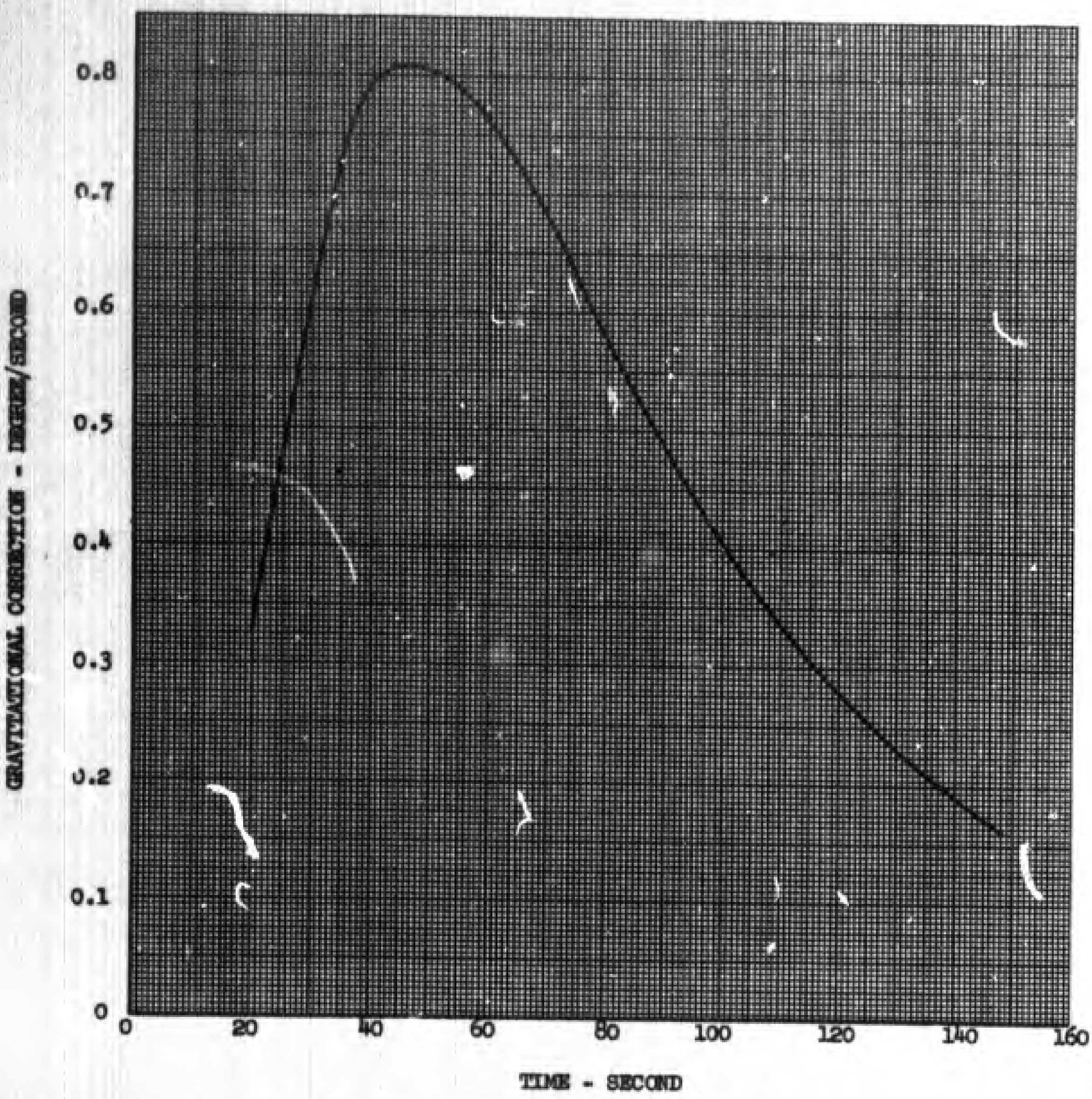

Fig. 8 Gravitational Correction vs Time

Tumbling turns were computed in the vertical plane for locked motor gimbal angles of two, four, and six degrees. The six-degree gimbal angle represents the five-degree mechanical stage plus a one-degree override for a total of six degrees maximum travel. From the machine printouts, time to tumble, and flight path angle turned through, and average turning rate, all for a tumble half-cycle, were obtained for flight in the vertical plane. The results of the calculations are shown in Figures 9, 10, and 11. Similar plots for tumbling in the lateral plane, using the gravity correction in Figure 8, are shown in Figures 12 and 13. It should be noted that the average turning rates (Figures 10 and 12) were obtained by dividing the total angle turned through by the time to turn through one half-cycle of tumbling. Average turning rates for gimbal angles of two, four, and six degrees were found to be essentially the same.

Item 3d. Speed, V, as a function of time is tabulated in Appendix B and plotted in Figures 14 and 15.

Item 3e. Flight path angle, $\gamma$, of the velocity vector as a function of time is tabulated in Appendix B (for inertial space axes as defined in Appendix C, Paragraph 4b) and plotted in Figure 16.

Item 3f. Three-sigma maximum expected deviations in the azimuth plane from the intended flight azimuth are shown in Figure 17. Impact points for various cutoff times are shown in Table II.

PARAGRAPH 4

Paragraph 4 is an explanation of the requirements of Paragraph 3.

PARAGRAPH 5

Item 5a. Altitude, h, in feet, is plotted as a function of time in Figures 14 and 15, and is tabulated in Appendix B. (Altitude is the distance of a

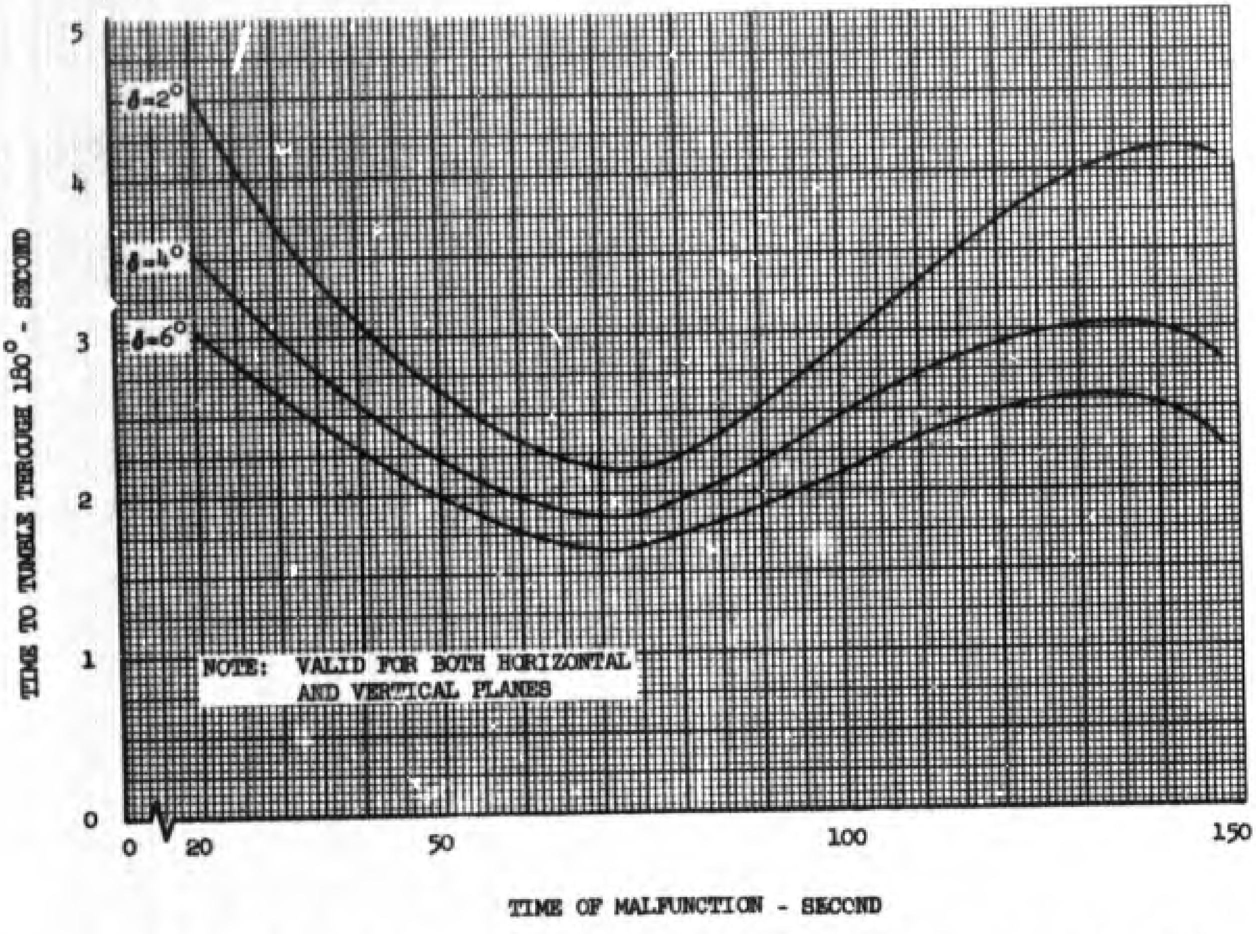

Fig. 9 Time to Tumble 180° vs Time of Malfunction, for Several Nozzle Deflection Angles

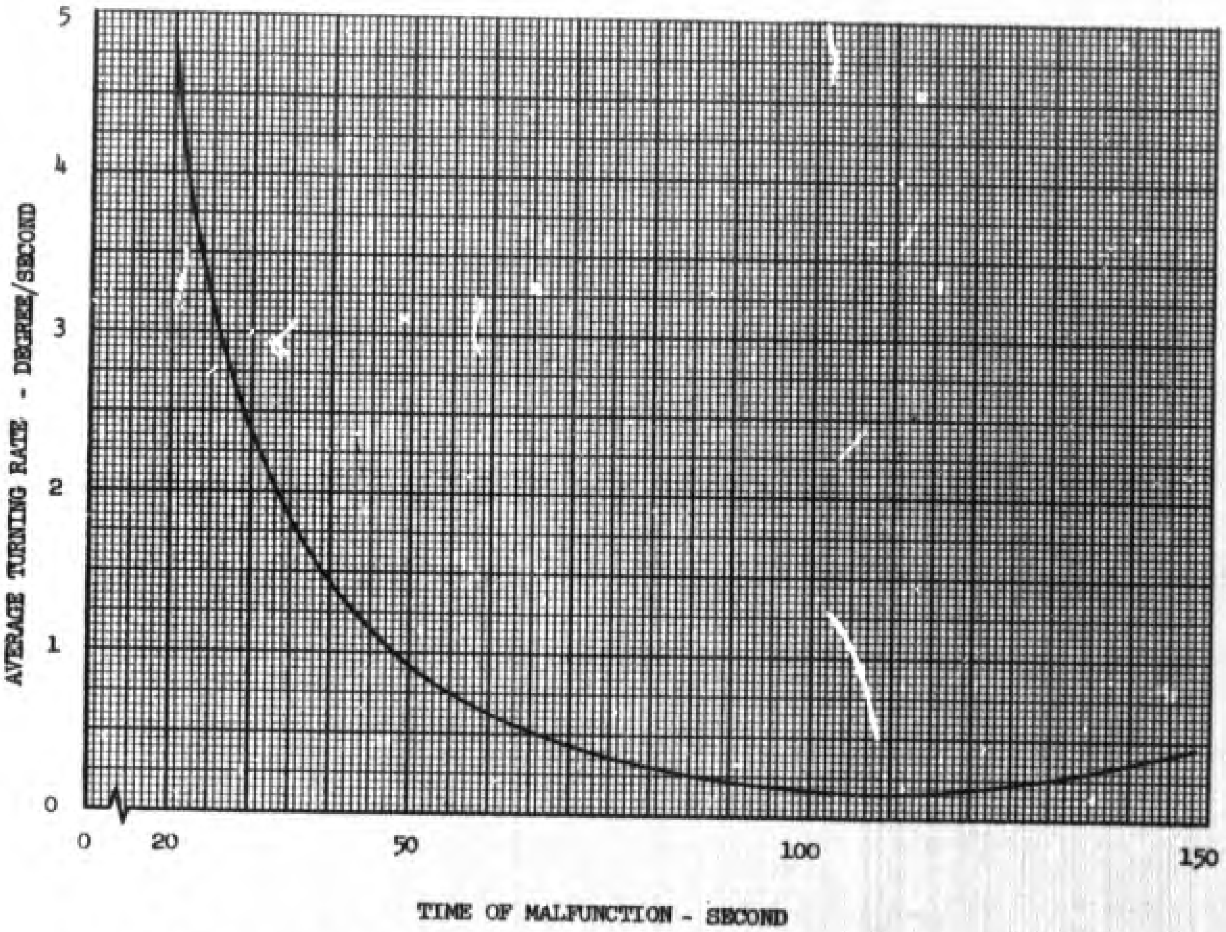

Fig. 10 Average Turning Rate of Velocity Vector Through 180° Tumble, vs Time of Malfunction - Vertical Plane

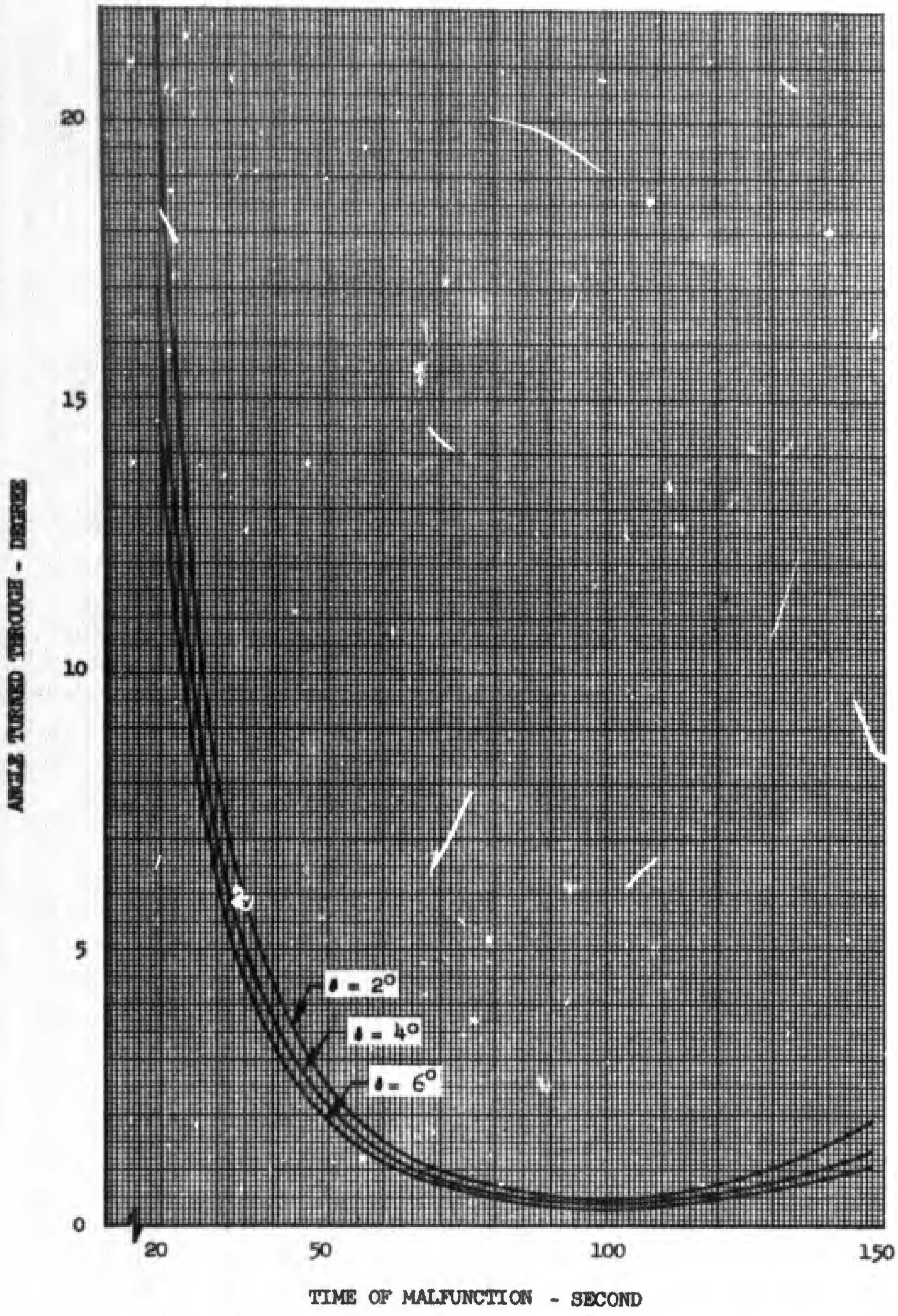

Fig. 11 Angle Turned Through by Velocity Vector During 180° Tumble, vs Time of Malfunction, for Several Nozzle Angles - Vertical Plane

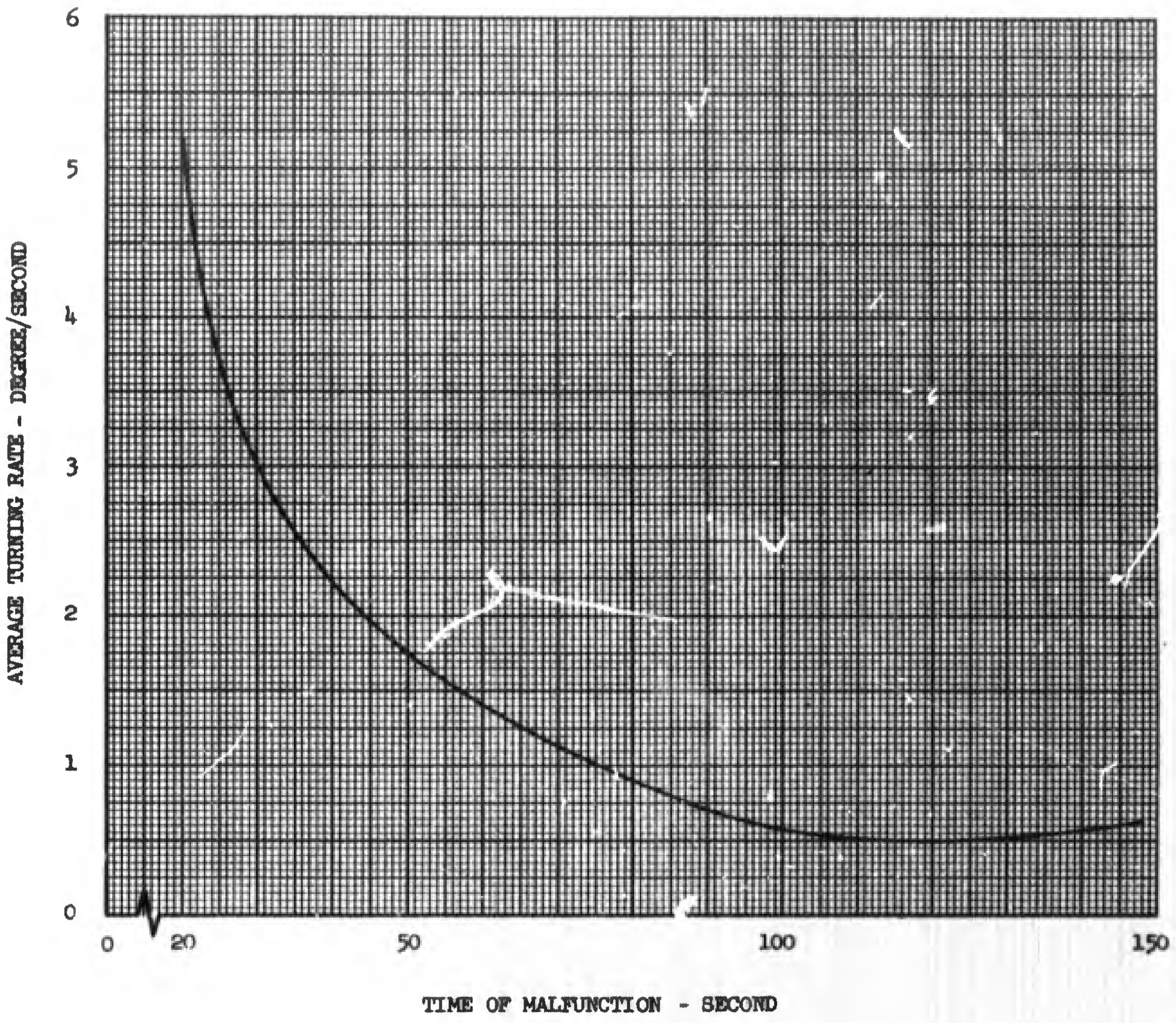

Fig. 12 Average Turning Rate of Velocity Vector Through 180° Tumble, vs Time of Malfunction - Horizontal Plane

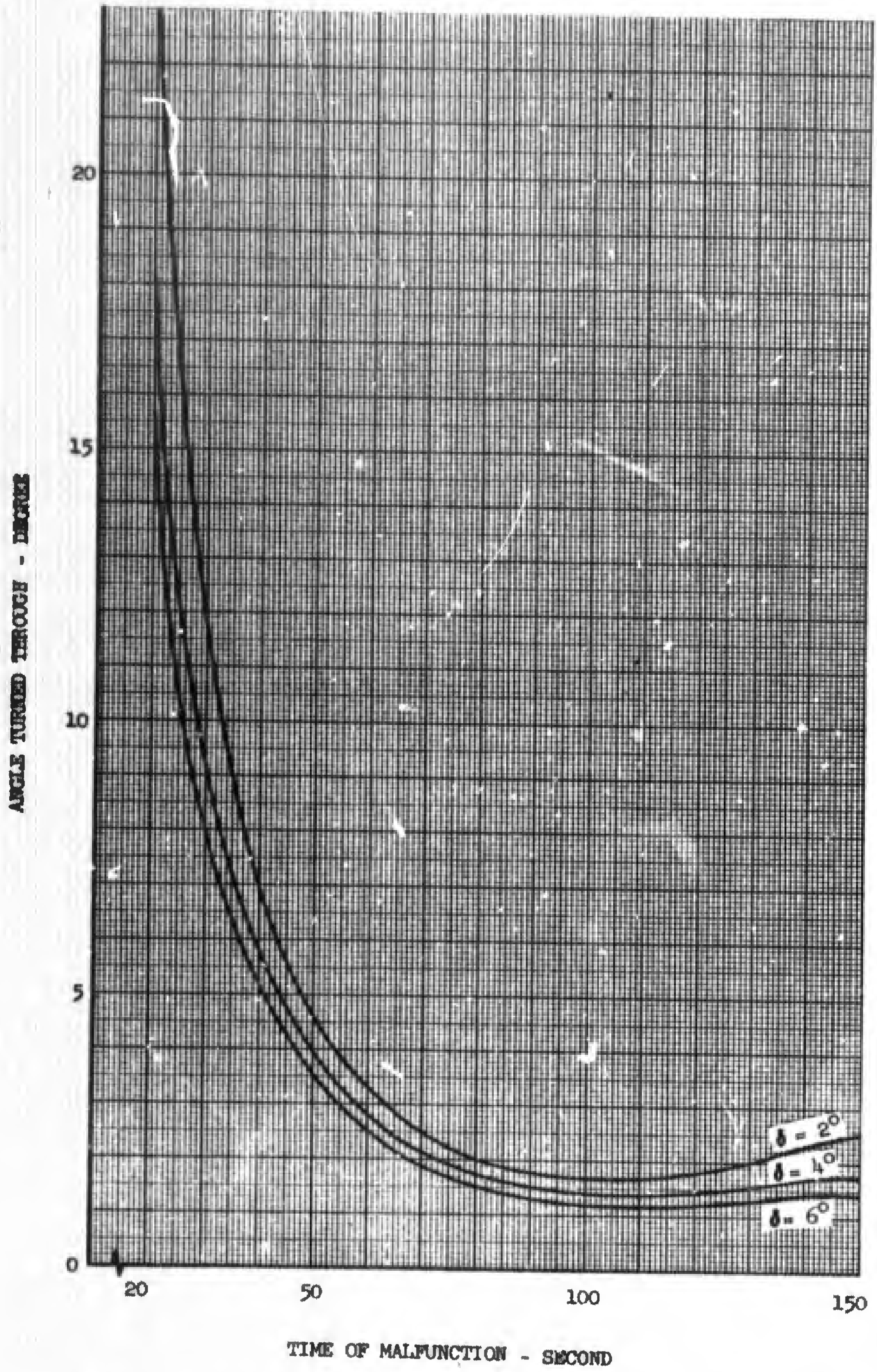

Fig. 13 Angle Turned Through by Velocity Vector During 180° Tumble, vs Time of Malfunction, for Several Nozzle Angles - Horizontal Plane

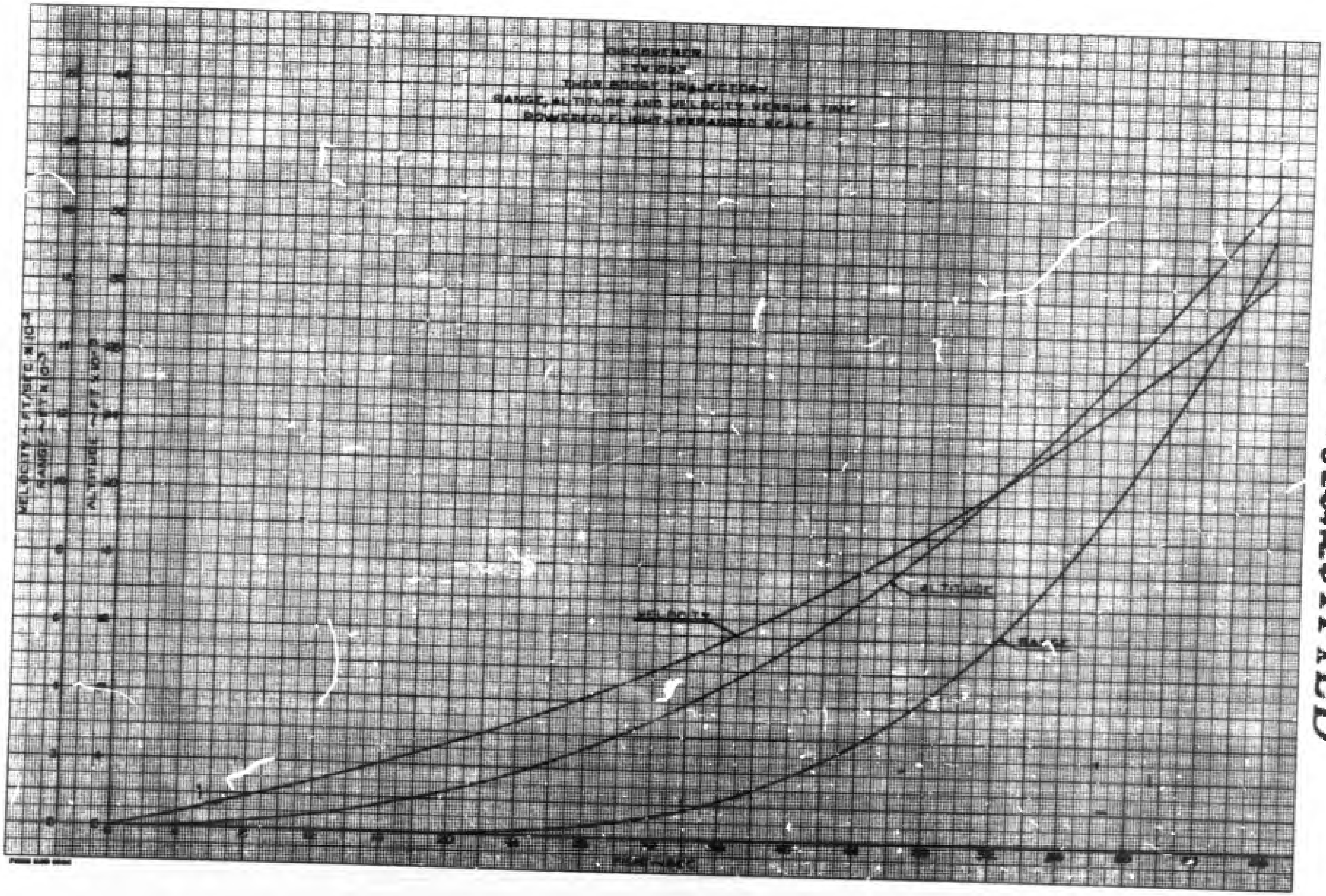

Fig. 14 Thor Boost Phase Trajectory - Range, Altitude, and Velocity vs Time (Expanded Scale)

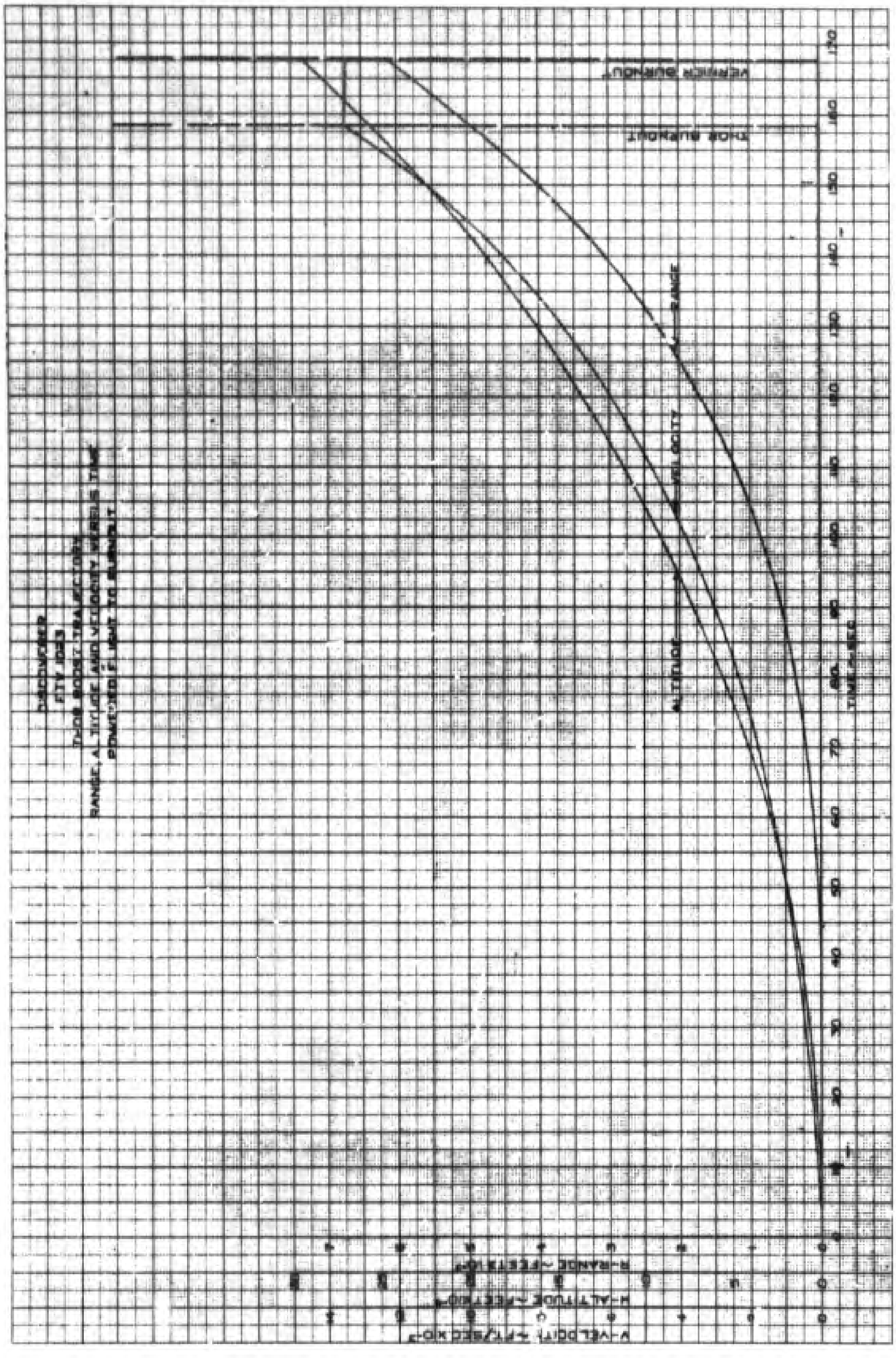

Fig. 15 Thor Boost Phase Trajectory - Range, Altitude, and Velocity vs Time (Launch to Burnout)

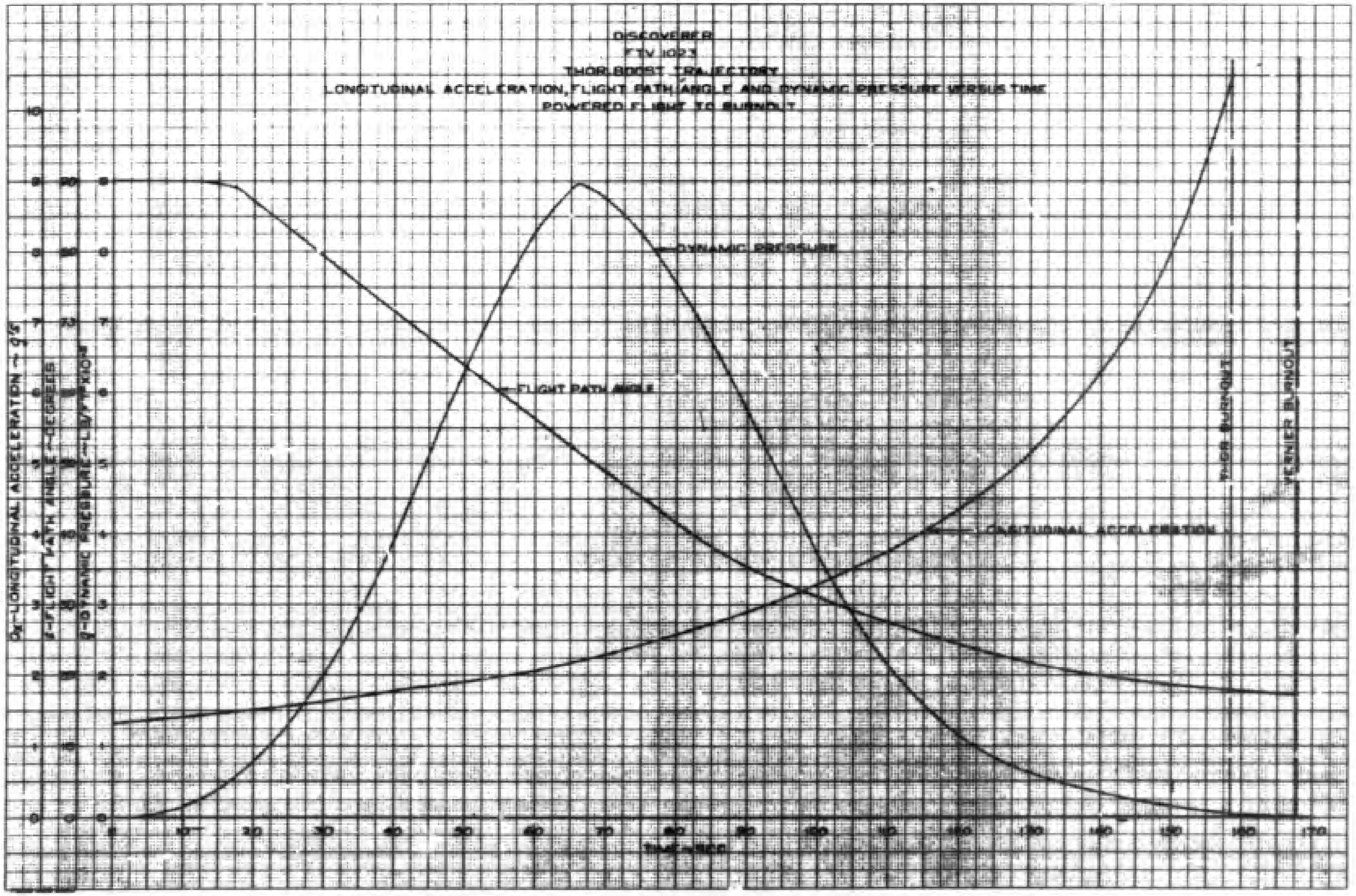

Fig. 16 Thor Boost Phase Trajectory - Dynamic Pressure, Longitudinal Acceleration, and Flight Path Angle vs Time

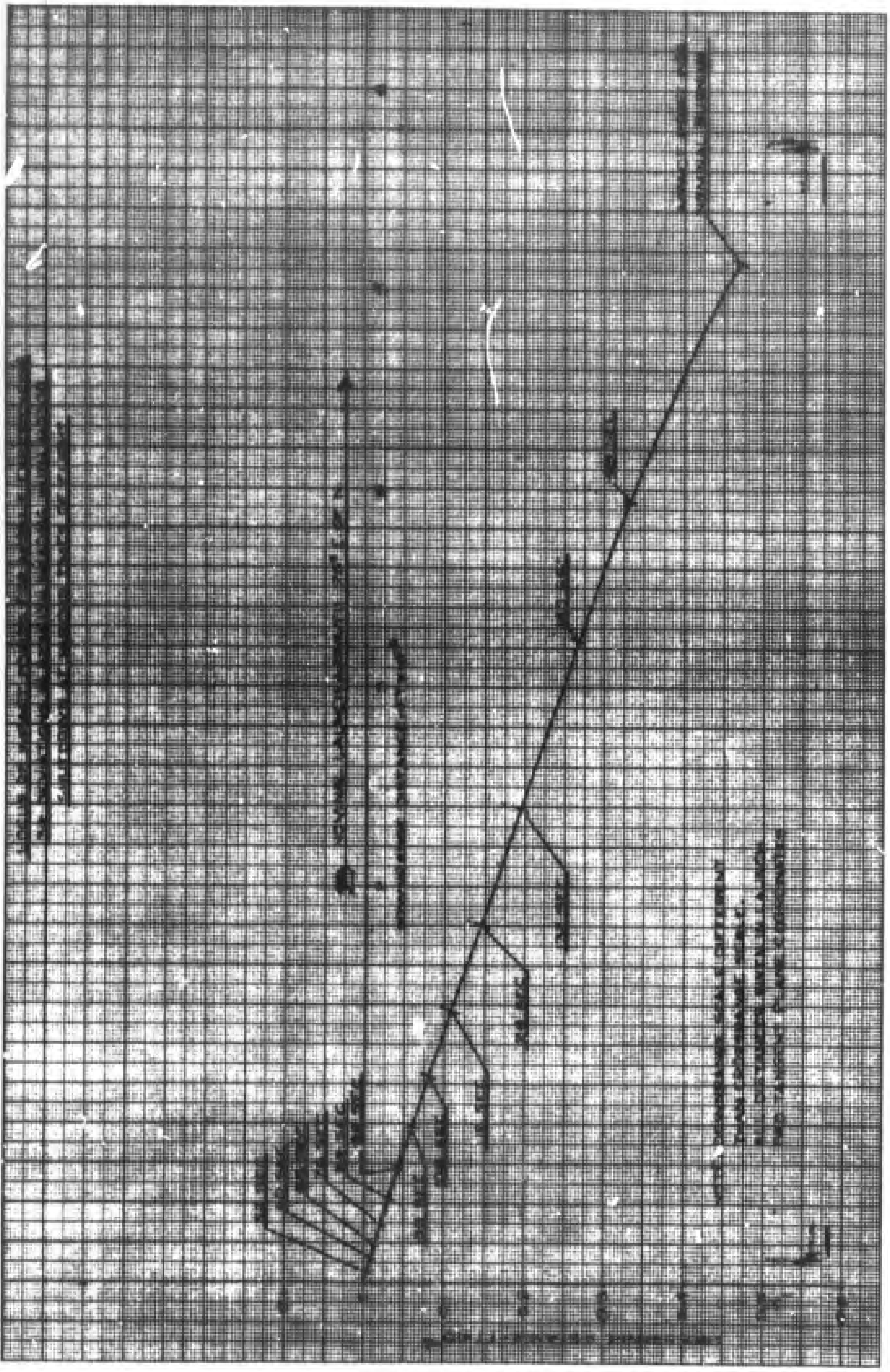

Fig. 17 Locus of Impact Points for Three-Sigma Azimuth Deviation

point above the surface of the earth measured along a line from the point to the earth's center.)

Item 5b. Fuel weight and gross weight are plotted as functions of time in Figure 18.

Item 5c. Acceleration, Ax, is plotted in terms of load factor in Figure 16 and tabulated (in ft/sec$^2$) in Appendix B.

Item 5d. Range, R, in feet is plotted as a function of time in Figures 14 and 15, and tabulated in Appendix B. (Range is the distance traveled, measured along the surface of the earth.)

PARAGRAPH 6

Item 6a. The approximate time delay between activation of firing circuits and first motion is 4 seconds.

Item 6b. The expected impact dispersion contours were determined by root sum squaring the individual range errors incurred by each of the sources of error listed below. The error sources were assumed to be normally distributed and independent. The specific values for a three-sigma level are as follows:

1. gyro drift - ±2.7°
2. inverter voltage change - ±3.5%
3. p.u. penalty - ±0.5%
4. thrust variation - ±3%
5. specific impulse variation - ±2%

A plot of the booster dispersion contour is shown in Figure 19.

Item 6c. The following discussion of possible failures of the Discoverer/Thor configuration is included for satisfaction of Appendix C requirements.

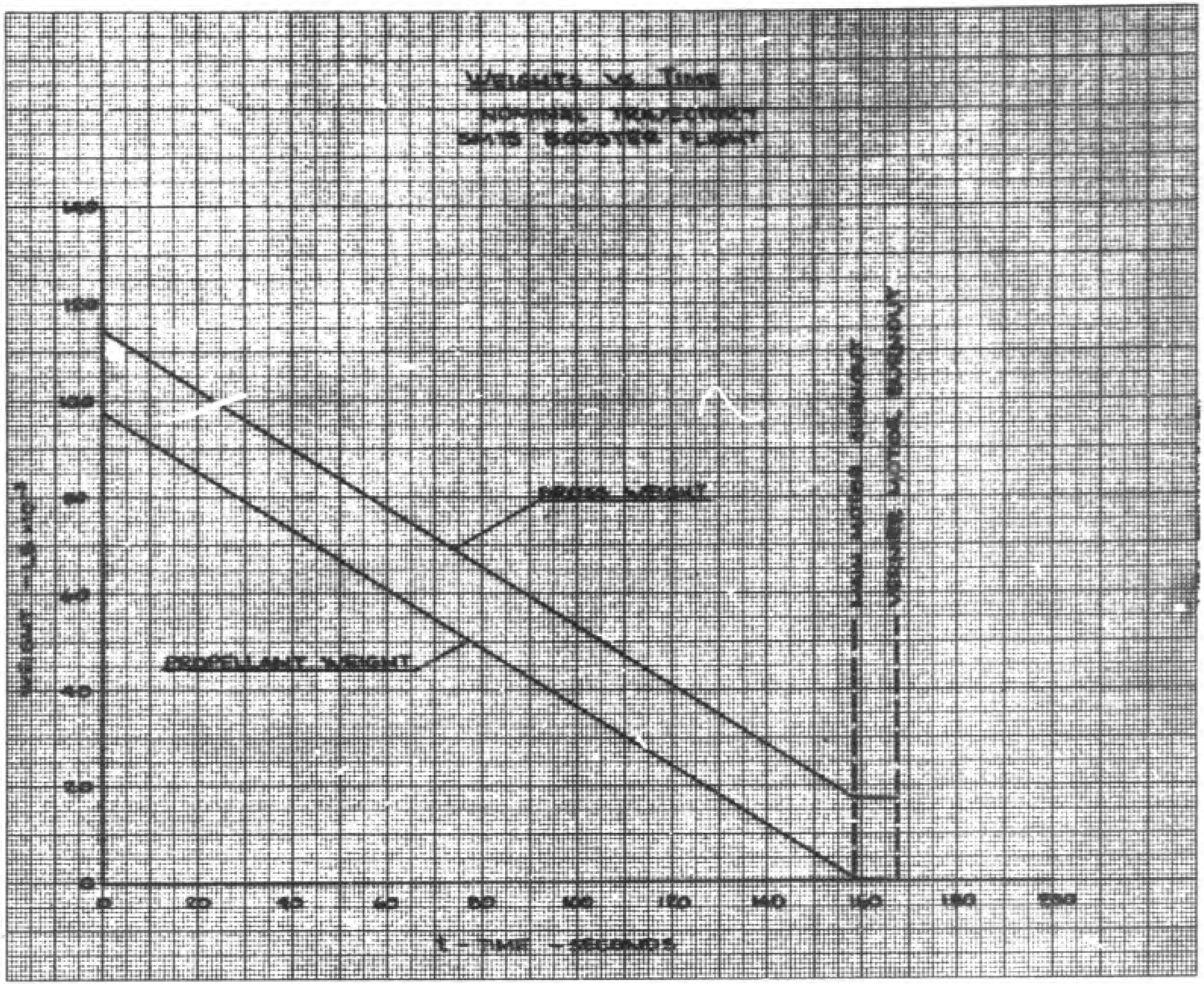

Fig. 18 Thor Boost Phase Trajectory - Weight vs Time

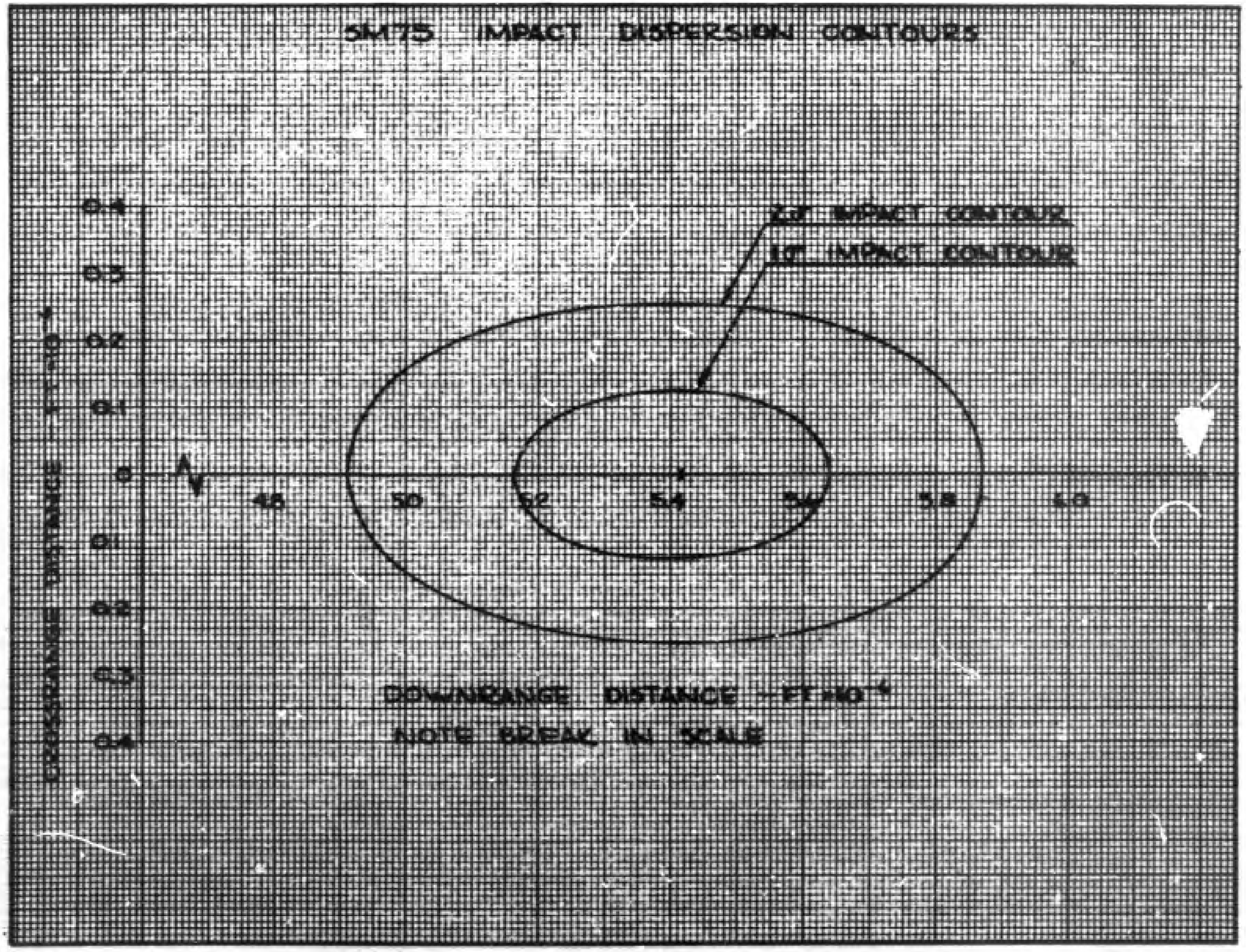

Fig. 19 SM-75 Impact Dispersion Contours

__Thor Booster Propulsion System__. The propulsion system for the Thor booster is composed of the following subsystems: Rocketdyne S-3 engine, two vernier engines (1000-pound thrust each), turbine pump (an integral part of the engine assembly), gimbal mount, mixture ratio control, and engine mount. Each subsystem could result in failure of the flight. The following possibilities were reviewed:

a. __Shutdown of Burning.__ The Thor propulsion system utilizes a liquid propellant combination of liquid oxygen and JP-4 pump-fed into the combustion chamber of the S-3 engine. The following are the most likely failures resulting in engine shutdown:

   (1) Pump cavitation, resulting either from vortexing at the pump inlet or vapor bubbles in the fuel or oxidizer lines (geysering) due to insufficient pressure head at the pump inlet

   (2) Pump failure

   (3) Severe shift or failure of the mixture ratio control, resulting in quenching of the flame

   (4) Failure of the engine mount, resulting in rupture of inlet lines.

b. __Gimbal Mount Malfunction__. The gimbal mount consists of a pivoted ring attached to the engine mount with the aft end of the engine chamber attached to the ring and pivoted in a direction perpendicular to that of the ring. The following are considered to be the most likely failures:

   (1) Freezing of the gimbal due to bearing failure

   (2) Structural failure of the pivots or the ring.

c. __Vernier Engine Malfunction__. The vernier engines provide roll control during main motor burning. Should the verniers shut down during powered flight the vehicle could roll, resulting in a loss of pitch/yaw resolution and producing an erratic flight.

__Structure__. The over-all airframe of the Discoverer/Thor missile provides aerodynamic and structural continuity between the Thor booster and the Discoverer vehicle. Failure of the structure would result primarily from excessive aerodynamic loading. Such loading would normally be from external environment exceeding the design limits or from control system malfunctions inducing a large angle of attack. As mentioned previously, the vehicle would break up at the interconnect section between the Thor and the Discoverer, and at the junction of the fuel and oxidizer tanks of the Thor.

Flight Control System. The flight control system of the Thor booster consists of two major subsystems: The autopilot and the hydraulic system.

a. Autopilot. Failures in the autopilot can be grouped into three main categories:

(1) Failure of the reference gyros
(2) Failure of the pitch rate programmer
(3) Failure of the gain system.

Failure of the pitch reference during booster flight would result in a hard-over nozzle deflection, tumbling the vehicle (during the pitch-over program only). Loss of yaw reference would result in drift of the missile yaw attitude and eventual loss of control of the vehicle. Loss of roll reference would result in slow roll rates and subsequent loss of pitch/yaw resolution, producing an erratic flight path.

Failure of the rate programmer would cause the vehicle to try to fly a constant attitude orientation. If this occurred prior to 100 seconds, it would result in tumbling the vehicle, due to large aerodynamic forces. After 100 seconds, this failure would result in the vehicle flying to excessive altitudes. If the rate programmer malfunctions by commanding high rates, the nozzle will gimbal to a hard-over position, resulting in eventual tumbling of the vehicle. Although there is no programming in yaw or roll, if the autopilot failed to sense a yaw rate the vehicle would eventually tumble: Failure to sense a roll rate would have the same effect as loss of roll reference.

Complete failure of the gain systems would result in the rocket engine not gimbaling and a subsequent drifting and tumbling of the vehicle due to its aerodynamic instability.

b. Hydraulic System. The types of failure that could occur in the hydraulic system are classified in three main groups:

(1) DC position pickoff failure

(2) DC power amplifier failure

(3) Hydraulic and actuators system failure.

Loss of either the dc position pickoff or the dc power amplifier would result in a hard-over nozzle and tumbling of the vehicle.

Item 6d. The expected behavior of the missile after a flight termination command is as follows:

a. The Thor propellant tanks will be split longitudinally by primacord. In addition, a circumferential line of primacord at the aft end of the oxidizer tank will separate the tank bulkhead from the tank.

b. The destruct charge at the base of the Discoverer propellant tanks will be ignited from the Thor destruct system. Since the tanks will be filled, the hydrodynamic shock through the liquid will in all probability rupture the tanks.

c. The vehicle will, therefore, be separated into the following major pieces:

| | |
|---|---|
| Thor engine assembly | 3500 lb |
| Thor oxidizer tank sections | 900 lb |
| Four helium tanks, 62 pounds each | 248 lb |
| Thor fuel tank sections | 700 lb |
| Adapter and interconnect assembly | 140 lb |
| Discoverer propulsion and control assembly | 700 lb |
| Recovery capsule | 195 lb |

The principal effect of the flight termination explosion is the breaking open of the propellant tanks to permit rapid dumping of their contents. Cutting of the aft bulkhead of the Thor permits the liquid oxygen to dump through the motor section. Also, the longitudinal splitting of the tanks permits some discharge through the gaps. The rupturing of the Discoverer tanks permits the propellants to dump through the engine section of that stage.

The flight termination explosion will have a negligible effect on the velocity of the heavy pieces of the exploded vehicle. The heavy fragments (1/2 to 5 pounds) will acquire a velocity normal to the flight path of approximately 100 ft/sec. The lighter fragments (less than 1/2 pound) will acquire velocities up to approximately 1000 ft/sec also normal to the flight path.

Estimates of drag coefficient of the pieces going the minimum and maximum distances are given in Figures 20 and 21. It should be noted that these estimates are merely approximations; however, they are believed to be conservative.

Item 6e. The Thor airframe will most certainly break up in the reentry environment, probably somewhere between 200,000 and 100,000 feet altitude. First breakup should occur at the junction of the fuel and oxidizer tanks (MS 747), with additional breakups between the engine section and the oxidizer tank, and between the fuel tank and the adapter section. It is possible that these four sections will maintain their structural integrity until impact, although the tank and adapter sections will flatten out.

Item 6f. Drag coefficient, $C_D$, for the satellite vehicle is plotted versus Mach number in Figure 22.

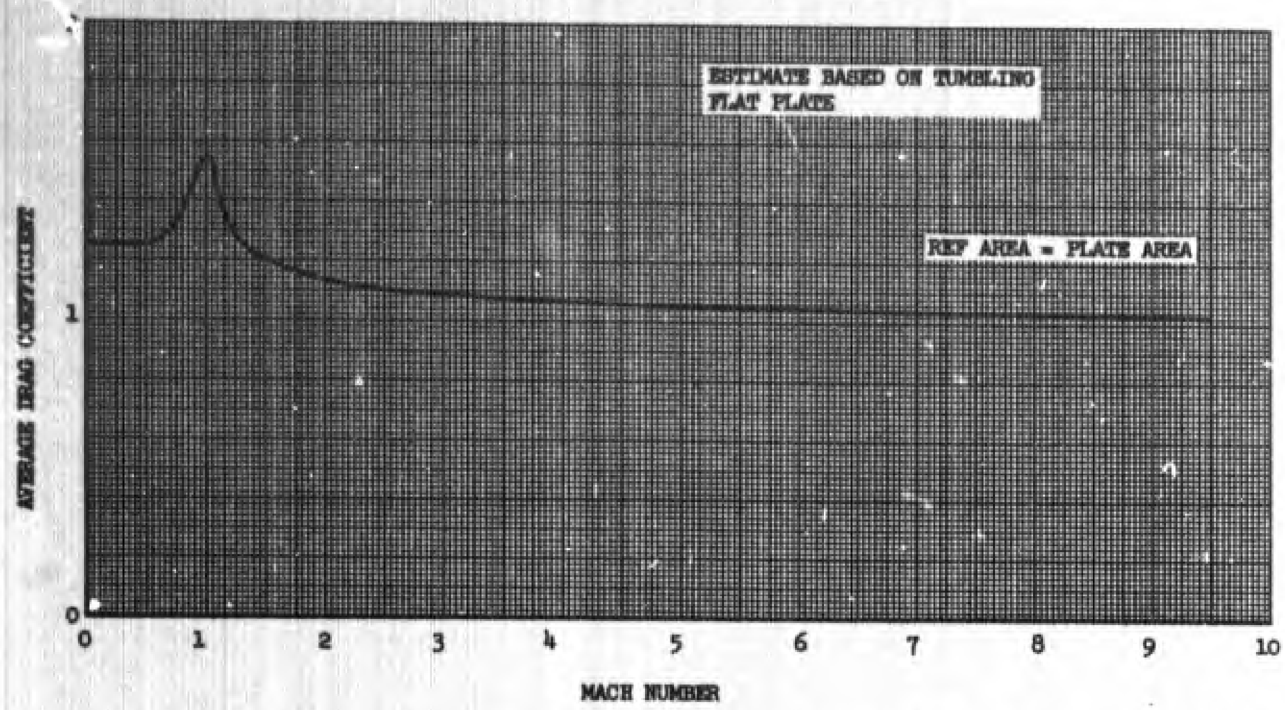

Fig. 20 Two-Sigma Upper Estimate of Drag Coefficient for Piece of Vehicle Going Shortest Distance

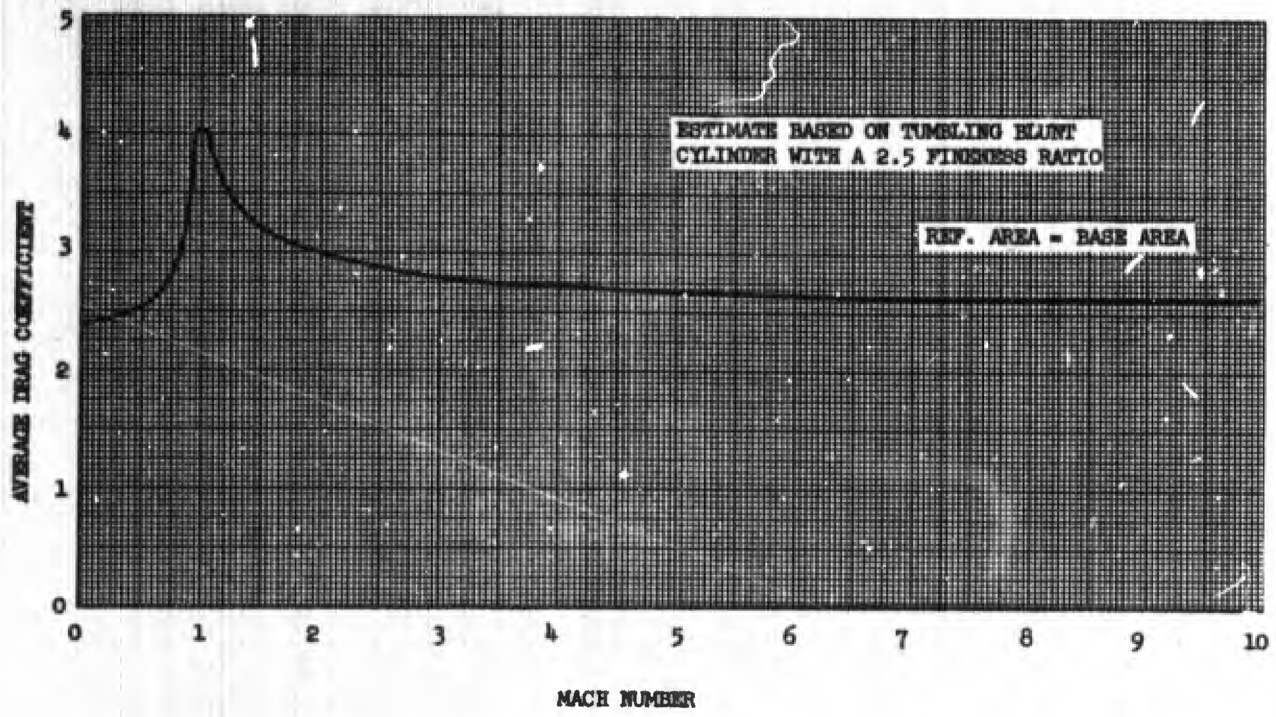

Fig. 21 Two-Sigma Lower Estimate of Drag Coefficient for Piece of Vehicle Going Maximum Distance

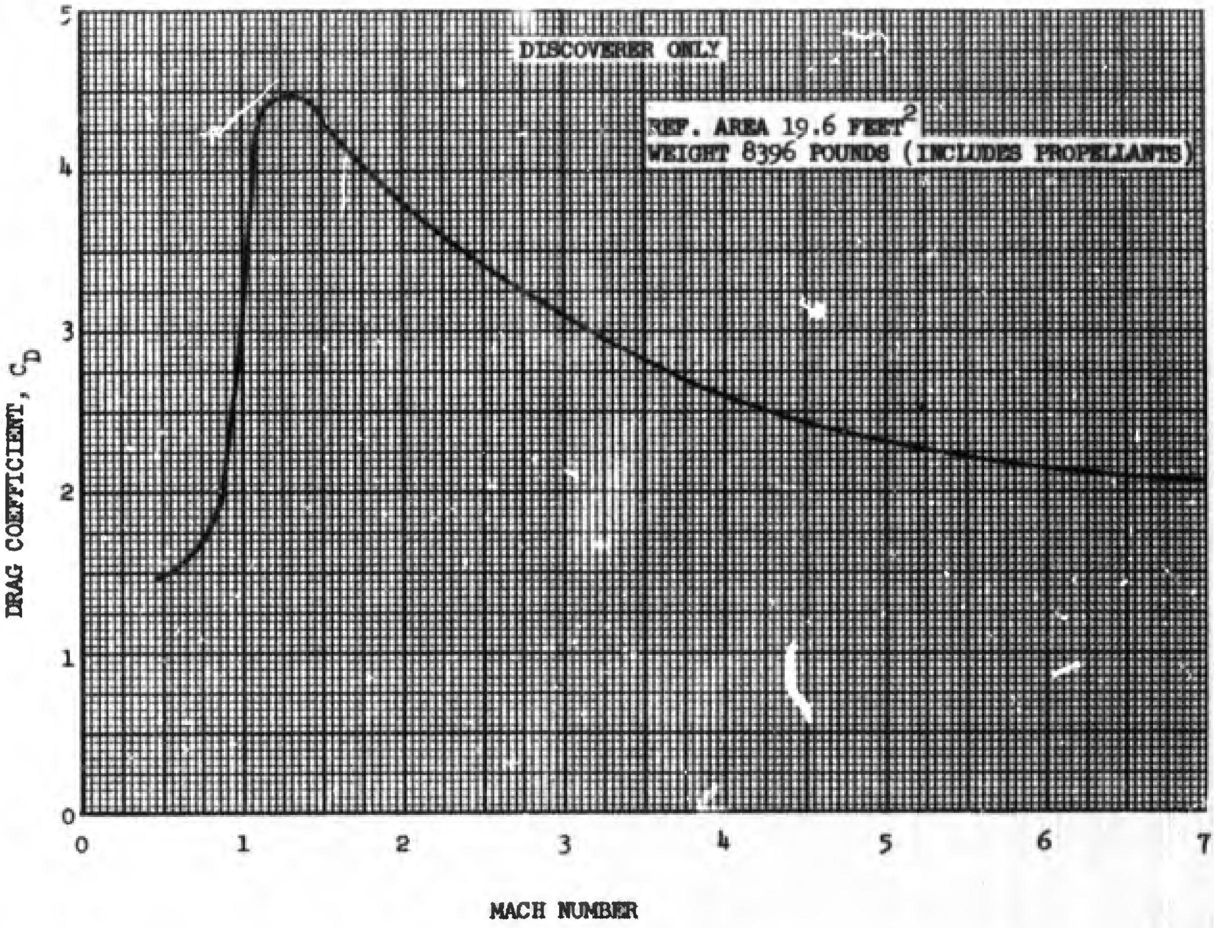

Fig. 22 Drag Coefficient vs Mach Number

Item 6g. Table II gives the geodetic longitude and latitude, downrange distance, X and Z coordinates, and time of impact for premature thrust termination of the Thor booster.

The calculations (which include drag force, using the drag coefficient for the total configuration) assume the vehicle to remain intact after engine shutdown. The launch pad was assumed to be located at 34° 45' 21.84" North latitude and 120° 37' 36.46" West longitude. An initial launch azimuth of 175° East of North was assumed.

The Discoverer satellite vehicle does not carry a command flight termination system; however, estimates of lateral dispersion were made assuming the following initial conditions:

| | |
|---|---|
| Ignition time from launch | 167, 279 seconds |
| Vehicle pitch attitude | 20°, 40°, 60° |
| Vehicle yaw attitude | 10°, 45°, 90°, 135° |
| Vehicle burning time | 119 seconds |

The vehicle was assumed to maintain a constant attitude during burning. Table II shows the impact points.

It should be noted that since the Discoverer vehicle is a satellite it is potentially capable of impacting almost anywhere on the surface of the earth. This, of course, arises from the fact that the vehicle has only a finite lifetime, even on orbit. Accurate predictions of impact zones for deorbiting vehicles are impossible due to the extreme uncertainty of the values of air density at very high altitudes.

Item 6h. Discoverer vehicle 1023 will not be launched under the wind conditions described in Appendix C, Paragraph 6h.

Item 6i. Based on a minimum propellant-utilization penalty, the maximum possible burning time is 159.261 seconds, with a corresponding maximum range of 5,665,000 feet.

## Table II

## IMPACT POINTS FOR PREMATURE BOOSTER MOTOR SHUTDOWN

| Booster Shutdown Time (sec) | Flight Time From Launch (sec) | Total Range (ft) | Impact Latitude (°N) | Impact Longitude (°W) | X (ft) | Z (ft) |
|---|---|---|---|---|---|---|
| 20 | 42.2 | 352 | 34.755 | 120.625 | 352 | 0 |
| 28 | 63.3 | 2,511 | 34.749 | 120.624 | 2,511 | 0 |
| 36 | 82.9 | 8,404 | 34.733 | 120.623 | 8,275 | 0 |
| 44 | 105.7 | 21,134 | 34.698 | 120.619 | 20,860 | 0 |
| 52 | 126.9 | 41,963 | 34.641 | 120.614 | 41,720 | 219 |
| 60 | 149.8 | 75,034 | 34.551 | 120.605 | 74,089 | 467 |
| 68 | 171.4 | 125,015 | 34.414 | 120.592 | 123,359 | 886 |
| 76 | 194.1 | 200,924 | 34.206 | 120.572 | 198,165 | 1,591 |
| 84 | 215.8 | 304,660 | 33.922 | 120.547 | 300,657 | 2,690 |
| 92 | 238.2 | 436,921 | 33.560 | 120.513 | 431,191 | 4,252 |
| 100 | 262.7 | 609,648 | 33.087 | 120.472 | 601,611 | 6,474 |
| 108 | 286.6 | 822,760 | 32.504 | 120.422 | 811,882 | 9,504 |
| 116 | 312.5 | 1,100,882 | 31.743 | 120.359 | 1,086,005 | 13,715 |
| 124 | 341.1 | 1,461,370 | 30.756 | 120.281 | 1,441,026 | 19,615 |
| 132 | 373.1 | 1,921,543 | 29.496 | 120.185 | 1,893,767 | 27,744 |
| 140 | 411.7 | 2,555,373 | 27.760 | 120.058 | 2,515,942 | 39,655 |
| 148 | 462.2 | 3,465,756 | 25.267 | 119.888 | 3,405,313 | 58,210 |

**PARAGRAPH 7**

The Thor boosters utilized in the Discoverer program are programmed for operation to fuel exhaustion; therefore, a programmed fuel cutoff will not occur in advance of fuel exhaustion.

**PARAGRAPH 8**

A tabulation of range, altitude, and velocity as functions of time, from launch to booster impact, is presented in Appendix B.

## REFERENCES

1. "WS-117L Flight Termination System," September 1958, LMSD-6258
2. "WS-315A Range Safety Destruct System," 1956 Douglas Thor Destruct System, SM-27100, Rev. No. 1.
3. "WS-117L Range Safety Report, Program IIA Flight No. One," LMSD-6104-1, 22 September 1958

# APPENDIX A

# APPENDIX A

## INPUT DATA USED FOR CALCULATION OF DISCOVERER/THOR RANGE SAFETY TRAJECTORIES

This appendix gives the input data used in the RR1103AF digital computer for trajectory calculations.

The aerodynamic coefficients used in the calculations for the nominal trajectory were obtained from wind tunnel tests conducted at the NASA Ames Unitary wind tunnel facility and are shown graphically in Figures A-1 through A-6. A check of the normal force coefficient, $C_N$, indicated that it was reasonably linear over angles of attack up to about eight degrees. Therefore, $C_N$ was computed from the following equation:

$$C_N = C_{N_\alpha} \cdot \alpha$$

where

$C_N$ = normal force coefficient

$C_{N_\alpha}$ = normal force coefficient slope

$\alpha$ = angle of attack

Tumbling turns were computed using high angle-of-attack data. The equations used are as follows:

$$X_{CP} = \frac{C_{N_B} \cdot X_{CP_o} + C_{N_C} + X_{CP_C}}{C_{N_B} + C_{N_C}}$$

$$C_N = C_{N_B} + C_{N_C}$$

$$F_x = q\, S_R\, C_{D_o} \cos \alpha$$

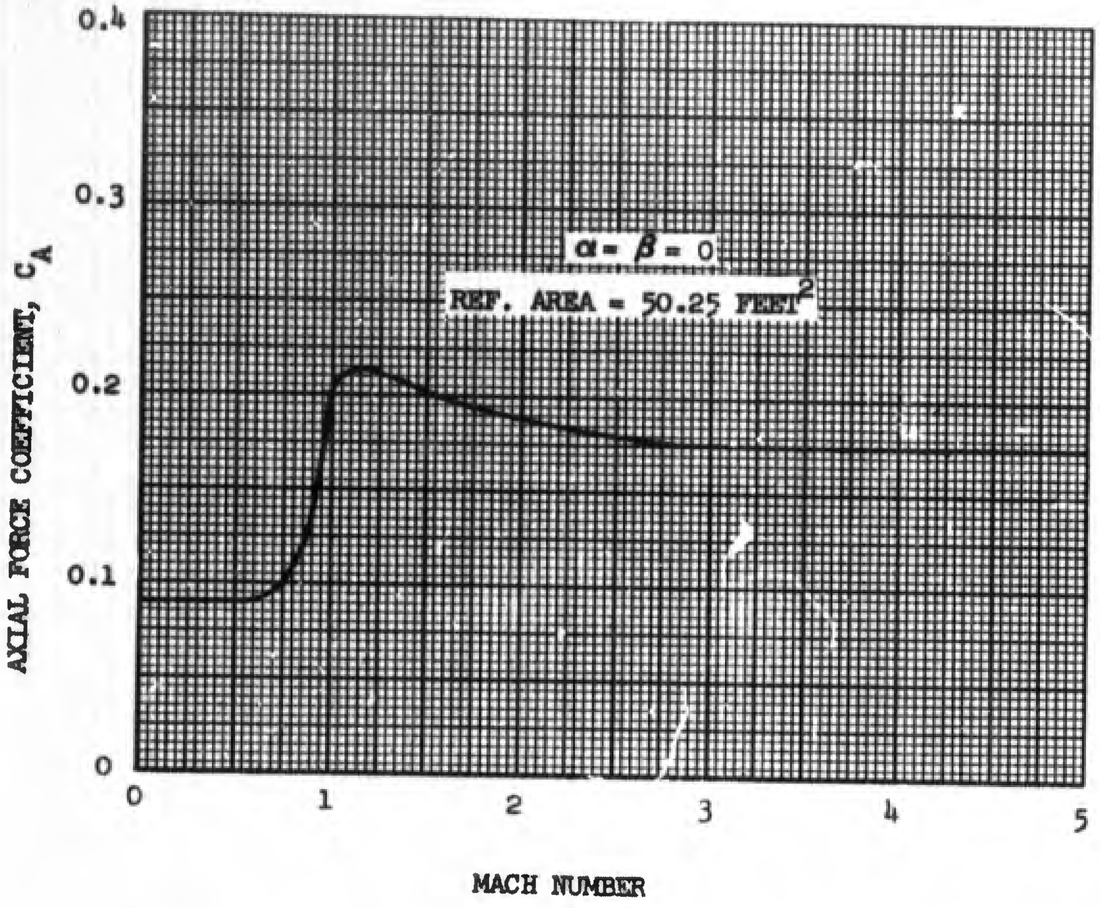

Fig. A- Axial Force Coefficient vs Mach Number - Discoverer/Thor

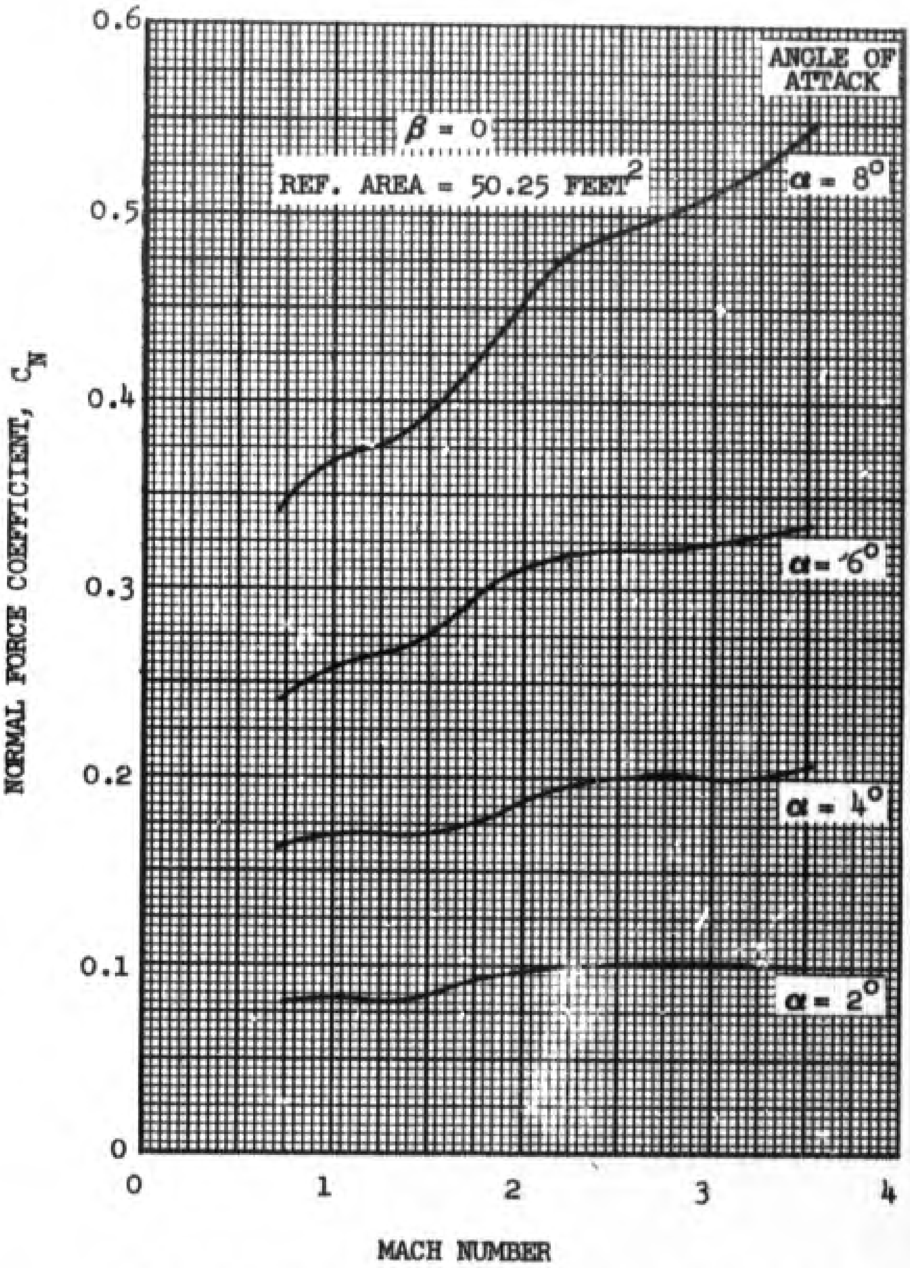

Fig. A-2 Normal Force Coefficient vs Mach Number - Discoverer/Thor

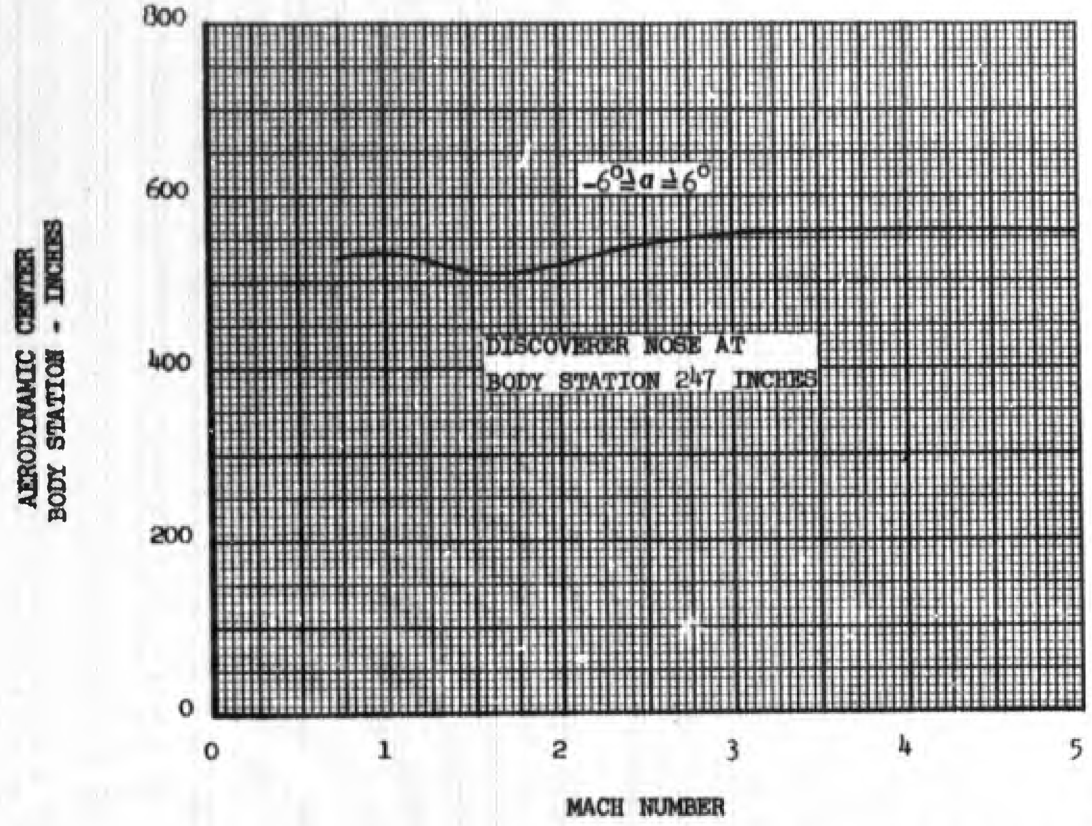

Fig. A-3 Aerodynamic Center vs Mach Number - Discoverer/Thor

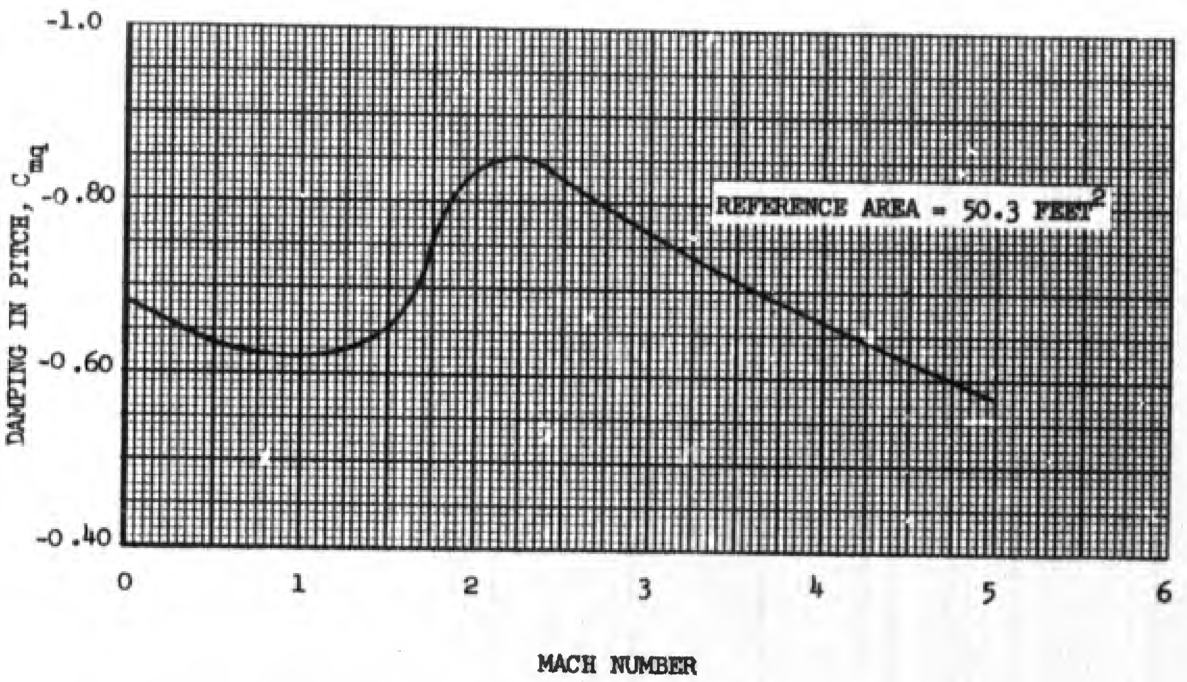

Fig. A-4 Damping in Pitch vs Mach Number - Discoverer/Thor

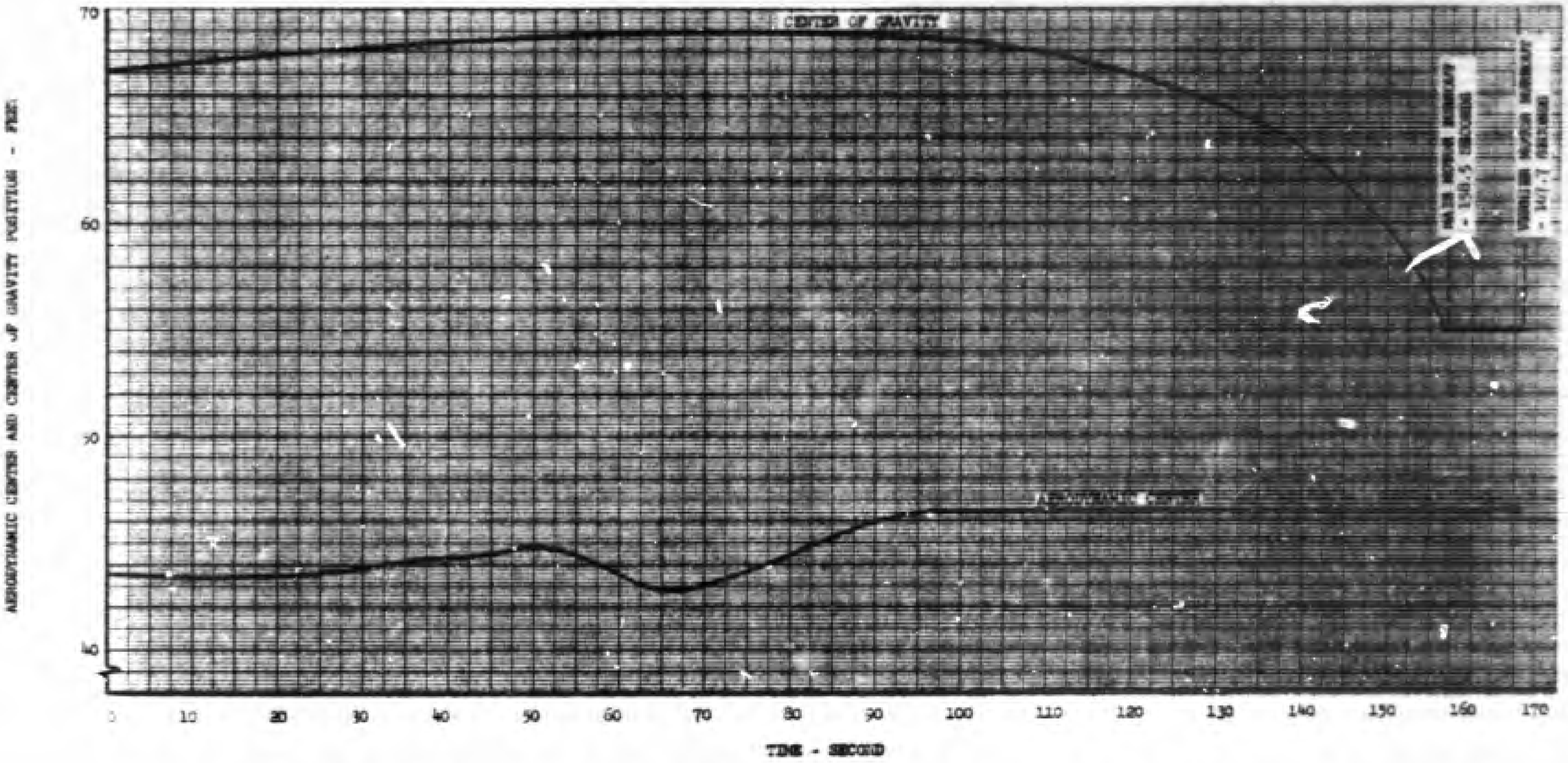

Fig. A-5 Aerodynamic Center and Center of Gravity vs Time - Discoverer/Thor

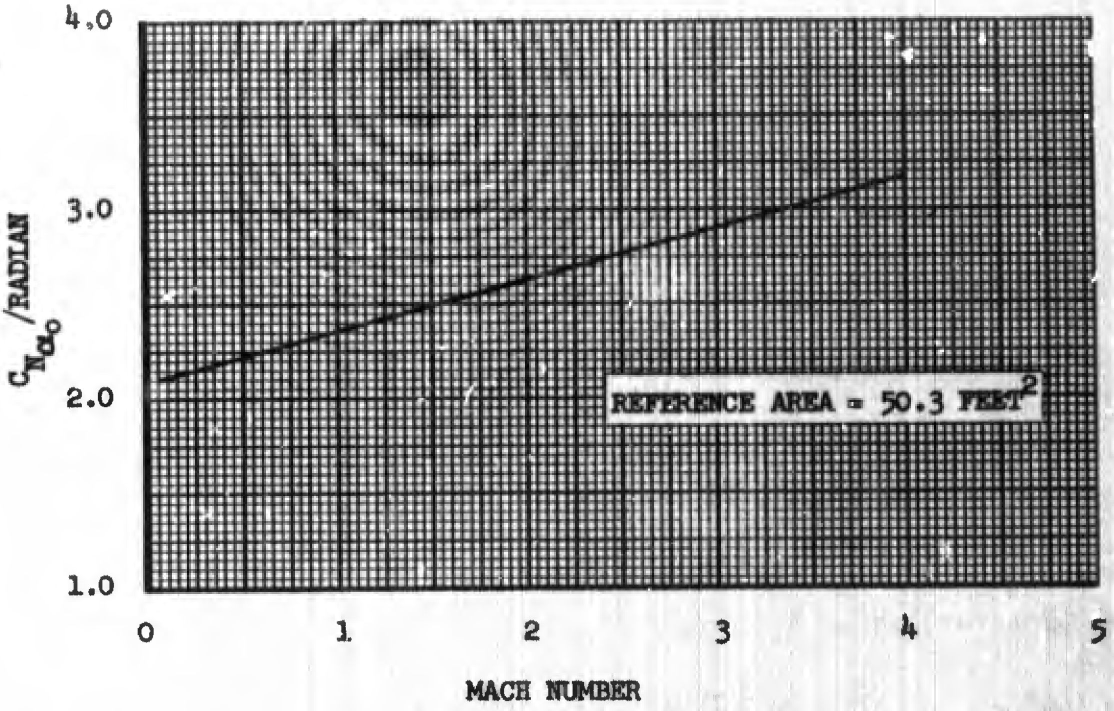

Fig. A-6 Normal Force Coefficient per Redian vs Mach Number where

$C_{N_x}$ = f(M) See Figure A-6

$X_{CP_o}$ = f(M) See Figure A-2

$$C_{N_C} = \frac{S_B}{S_R} \sin^2 \alpha \; C_{D_{cr}}$$

$\frac{S_B}{S_R}$ = 9.77 = Ratio of projected body area to reference area

$C_{D_{co}}$ = Cross flow drag coefficients; see Figure A-7

$X_{CP_C}$ = 751.1 = Body station where cross-flow drag acts

$F_x$ = Axial force

$S_R$ = Reference area

$\alpha$ = Angle of attack

The Thor thrust curve is presented both as a function of time for this particular flight and as a function of altitude in Figures A-8 and A-9.

The control gains and pitch rate are given in Table A-I, and the pitch program is shown in Figure A-10.

Weight plotted as a function of time is shown on Figure 18 in the main body of the text. Center of gravity and moments of inertia as a function of time are shown on Figures A-5 and A-11.

Table A-I lists the basic parameters used in the calculations.

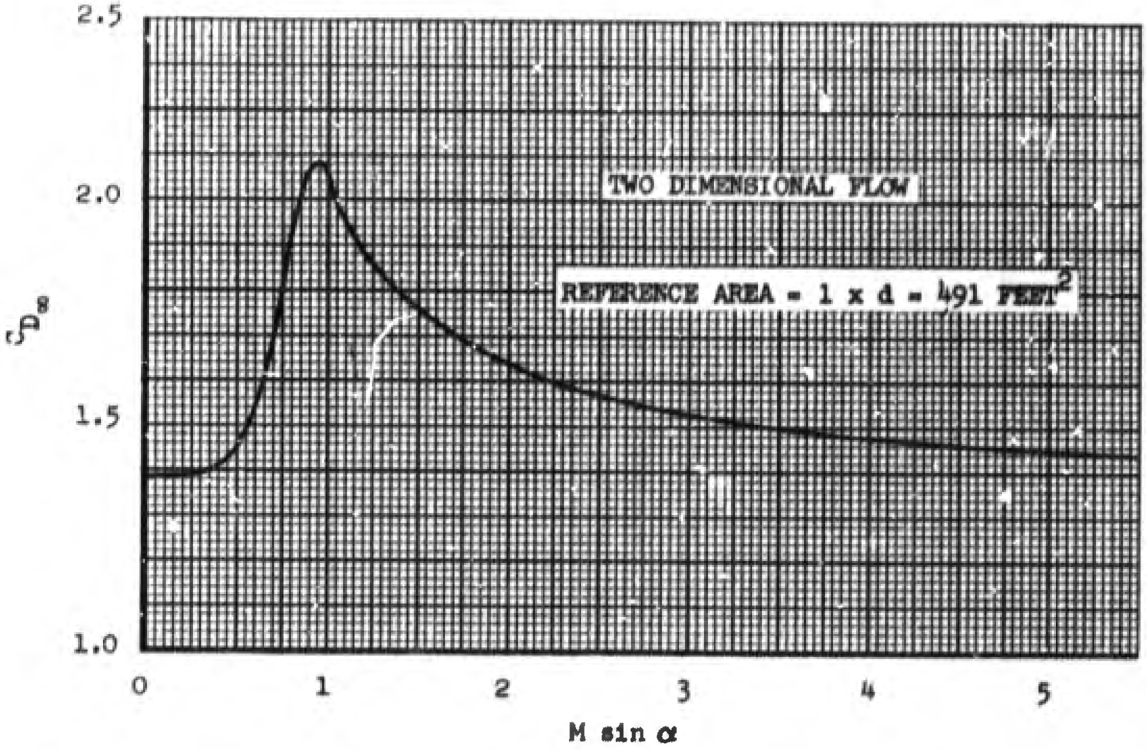

Fig. A-7 Cross-Flow Drag Coefficient

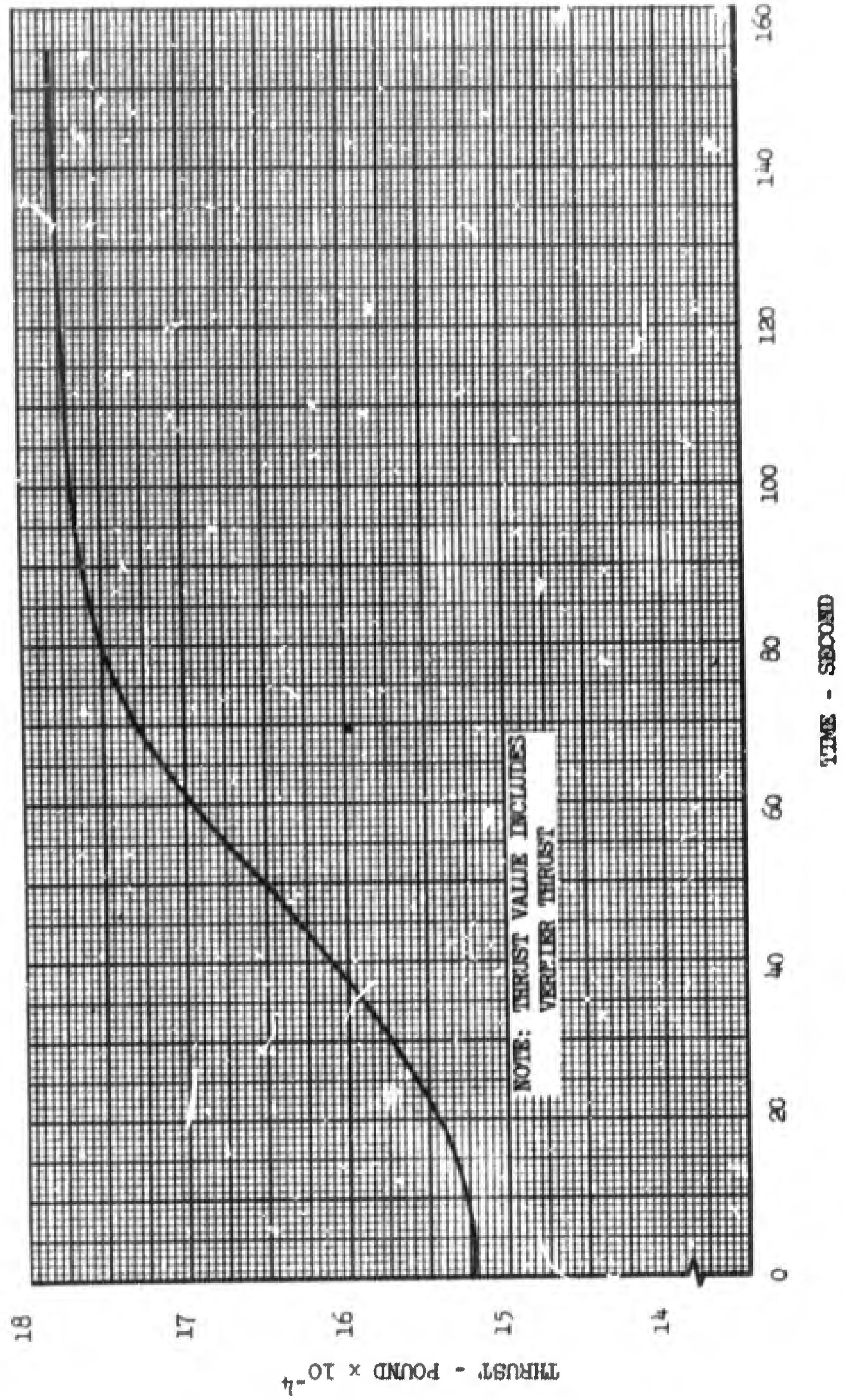

Fig. A-8 Thrust vs Time

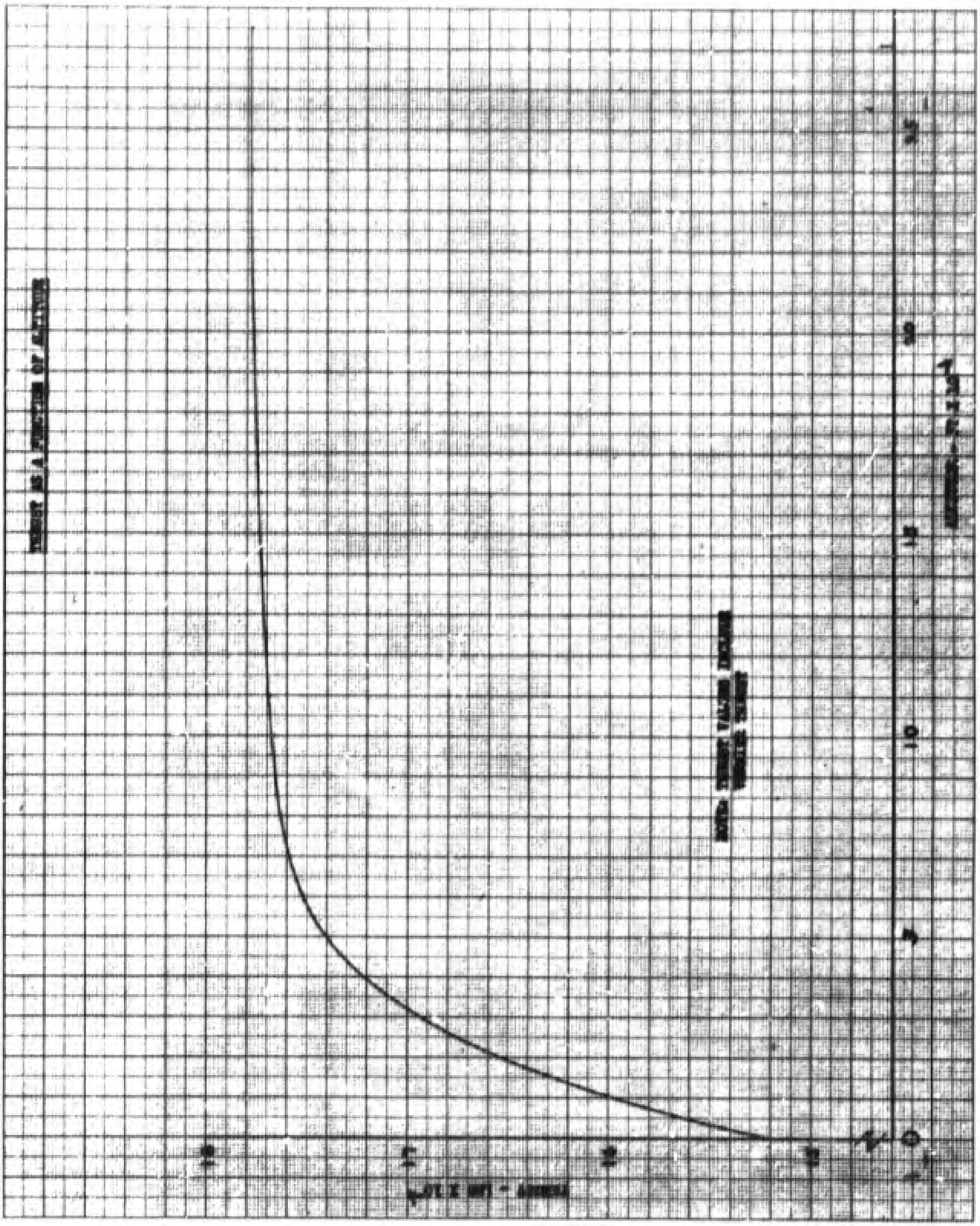

Fig. A-9 Thrust vs Altitude

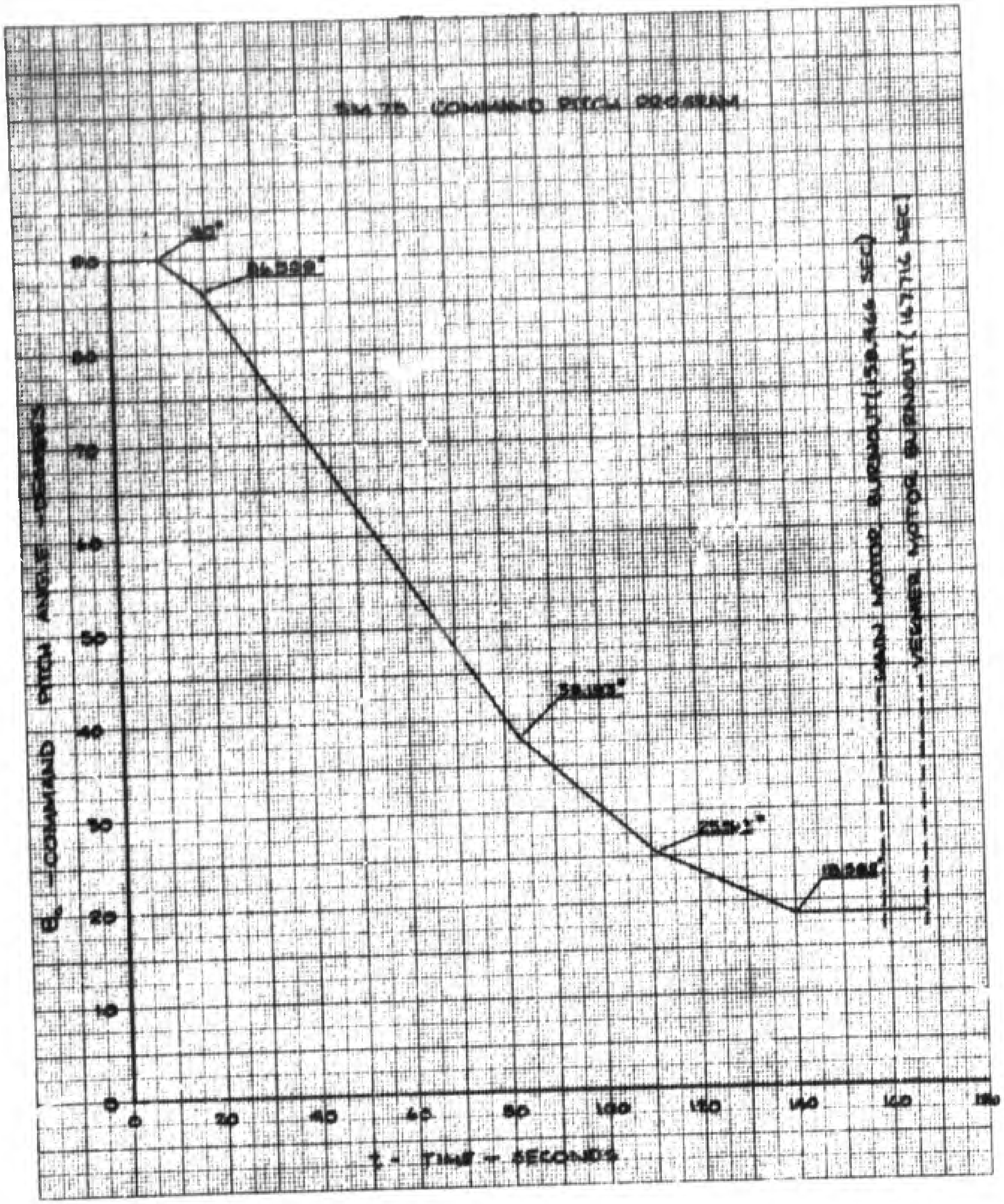

Fig. A-10 SM-75 Command Pitch Program

## Table A-I

## DISCOVERER/THOR BASIC PARAMETERS

| | | |
|---|---|---|
| Gross weight | 114,462 | lb |
| Thor main motor burnout weight | 17,381 | lb |
| Thor vernier motor burnout weight | 17,307 | lb |
| Reference area, $S_R$ | 50.25 | $ft^2$ |
| Reference length, d | 8 | ft |
| Initial c.g. position* | 803 | in. |
| Main motor burnout c.g. position* | 654 | in. |
| Vernier motor burnout c.g. position* | 653 | in. |
| Exit plane position* | 1,169 | in. |
| Main motor throat position* | 1,090 | in. |
| Projected Body Area, $S_B$ | 491 | $in^2$ |
| Body length, l | 78.2 | ft |
| Cross-flow center-of-pressure position* | 751 | in. |
| Initial pitch moment of inertia | 782,000 | $slug\text{-}ft^2$ |
| Final pitch moment of inertia | 394,000 | $slug\text{-}ft^2$ |
| Initial yaw moment of inertia | 782,000 | $slug\text{-}ft^2$ |
| Final yaw moment of inertia | 394,000 | $slug\text{-}ft^2$ |
| Sea-level specific impulse | 249 | sec |
| Vacuum specific impulse | 289 | sec |
| Maximum gimbal deflection angle | + 5 | deg |
| Maximum gimbal deflection rate | 30 | deg/sec |
| Autopilot pitch attitude gain | 2.25 | |
| Autopilot pitch rate gain | 0.75 | |
| Autopilot yaw attitude gain | 2.25 | |
| Autopilot yaw rate gain | 0.75 | |

* Discoverer nose at Missile Station 247 (inches)

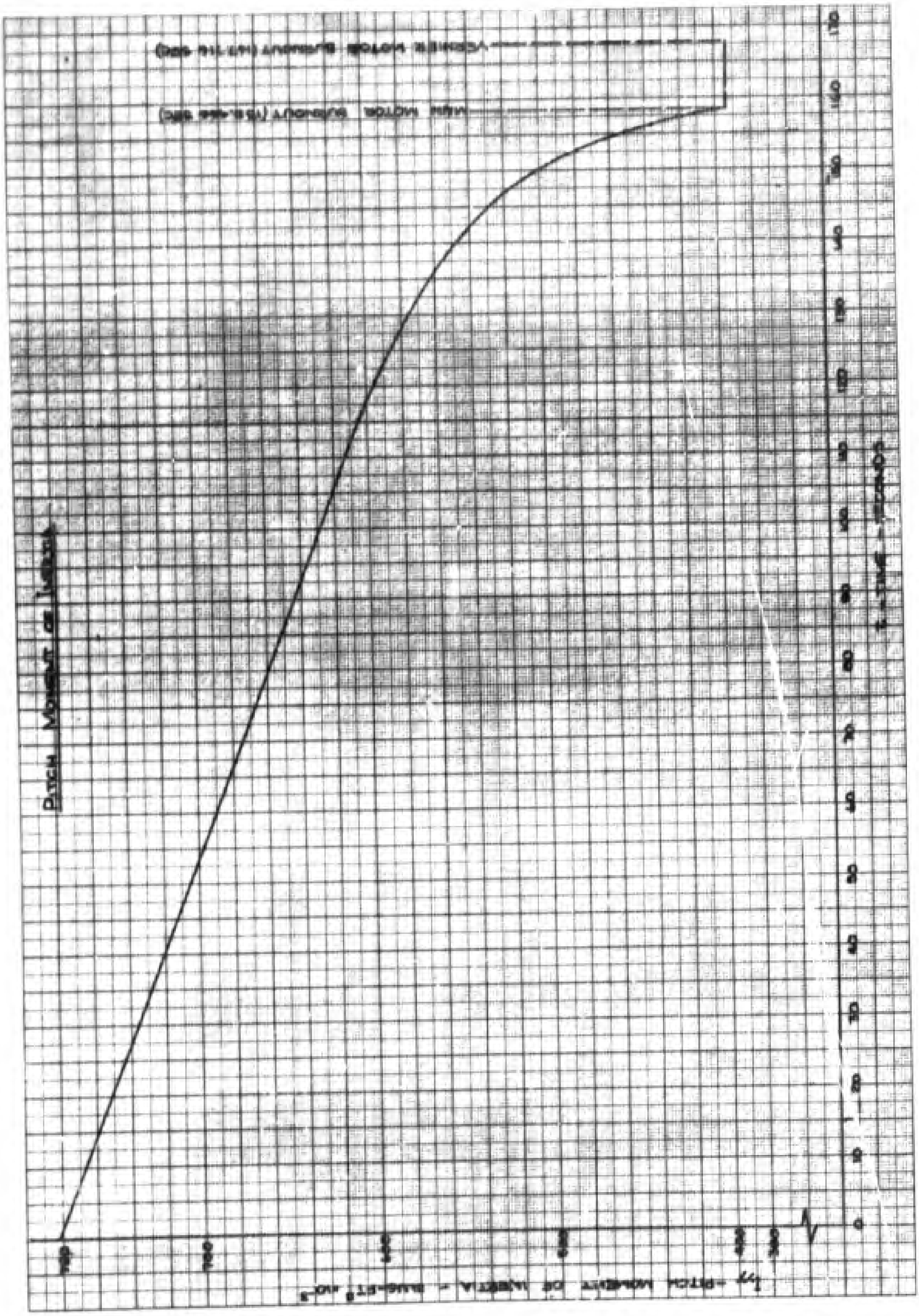

Fig. A-11 Pitch Moment of Inertia

# APPENDIX B

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### * ACTUAL TRAJECTORY TABULATION
### DISCOVERER 1023 FLIGHT

Azimuth Launch Angle 182.8° E of N

| Time (sec) | R (ft) | h (ft) | V (ft/sec) | $\gamma$ (deg) | $A_x$ (ft/sec$^2$) | X (ft) | $\dot{X}$ (ft/sec) | Y (ft) | $\dot{Y}$ (ft/sec) | Z (ft) | $\dot{Z}$ (ft/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 90.00 | 42.753 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.0000 | 0 | 23.00000 | 22.0000 | 90.00 | 43.220 | 0 | 0 | 23.000000 | 22.0000 | 0 | 0 |
| 4.0000 | 0 | 92.00000 | 46.0000 | 90.00 | 43.720 | 0 | 0 | 92.000000 | 46.0000 | 0 | 0 |
| 6.0000 | 0 | 203.0000 | 69.0000 | 90.00 | 44.220 | 0 | 0 | 203.00000 | 69.0000 | 0 | 0 |
| 8.0000 | 0 | 361.0000 | 93.0000 | 90.00 | 44.740 | 0 | 0 | 361.00000 | 93.0000 | 0 | 0 |
| 10.000 | 0 | 575.0000 | 119.000 | 90.00 | 45.289 | 0 | 0 | 575.00000 | 119.000 | 0 | 0 |
| 12.000 | 0 | 839.0000 | 145.000 | 89.88 | 45.860 | 0 | 0 | 839.00000 | 145.000 | 0 | 0 |
| 14.000 | 2.244620 | 1158.022 | 174.061 | 89.34 | 46.455 | 2.2447451 | 2.00674 | 1158.0000 | 174.049 | 0 | 0 |
| 15.000 | 4.889257 | 1339.[illegible] | 188.559 | 88.99 | 46.762 | 4.8895709 | 3.33822 | 1339.2500 | 188.559 | 0 | 0 |
| 16.000 | 9.031500 | 1535.242 | 203.432 | 88.59 | 47.077 | 9.0321645 | 5.00312 | 1535.2500 | 203.370 | 0 | 0 |
| 17.000 | 15.00679 | 1746.145 | 218.599 | 88.17 | 47.397 | 15.008047 | 7.00504 | 1746.2500 | 218.486 | 0 | 0 |
| 18.000 | 23.15308 | 1972.319 | 234.098 | 87.71 | 47.724 | 23.155275 | 9.34616 | 1972.2500 | 233.912 | 0 | 0 |
| 19.000 | 33.81053 | 2214.074 | 249.940 | 87.24 | 48.059 | 33.814119 | 12.0285 | 2214.0000 | 249.651 | 0 | 0 |
| 20.000 | 47.29967 | 2471.729 | 266.134 | 86.76 | 48.399 | 47.305275 | 15.0429 | 2471.7500 | 265.709 | 0 | 0 |
| 21.000 | 64.14730 | 2745.590 | 282.687 | 86.19 | 48.747 | 64.155744 | 18.7827 | 2745.5000 | 282.062 | 0 | 0 |
| 22.000 | 85.09486 | 3035.951 | 299.611 | 85.55 | 49.103 | 85.107249 | 23.2359 | 3036.0000 | 298.709 | 0 | 0 |
| 23.000 | 110.8445 | 3343.106 | 316.923 | 84.86 | 49.465 | 110.86227 | 28.3926 | 3343.0000 | 315.649 | 0 | 0 |
| 24.000 | 142.1053 | 3667.346 | 334.636 | 84.12 | 49.835 | 142.13029 | 34.2627 | 3667.2500 | 332.878 | 0 | 0 |
| 25.000 | 179.5922 | 4008.958 | 352.767 | 83.35 | 50.212 | 179.62552 | 40.8502 | 4009.0000 | 350.394 | 0 | 0 |
| 26.000 | 224.0242 | 4368.230 | 371.331 | 82.55 | 50.597 | 224.06992 | 48.1592 | 4368.2500 | 368.195 | 0 | 0 |
| 27.000 | 276.1240 | 4745.444 | 390.345 | 81.72 | 50.989 | 276.18535 | 56.1933 | 4745.5000 | 386.279 | 0 | 0 |
| 28.000 | 336.6177 | 5140.883 | 409.824 | 80.88 | 51.388 | 336.69907 | 64.9559 | 5141.0000 | 404.643 | 0 | 0 |
| 29.000 | 406.2343 | 5554.826 | 429.735 | 80.03 | 51.796 | 405.34223 | 74.4497 | 5554.7500 | 423.287 | 0 | 0 |
| 30.000 | 485.7054 | 5987.553 | 450.243 | 79.16 | 52.211 | 485.84423 | 84.6776 | 5987.5000 | 442.209 | 0 | 0 |
| 31.000 | 575.7654 | 6439.341 | 471.215 | 78.29 | 52.633 | 575.94215 | 95.6421 | 6439.2500 | 461.407 | 0 | 0 |

(Trajectory data continued on following pages)

NOTES:

1. X, Y, Z are earth-fixed, right-handed Cartesian coordinate system, with origin at the launch pad and with X positive downrange, Y positive upward, and Z positive to the right.
2. Flight path angle $\gamma$ is referenced to the X-Z plane described above.
3. Range R is distance along the surface of the earth.
4. Altitude h is altitude above the surface of the earth, along the local vertical at the point.

*** See page 1 for effect of azimuth change.**

| Time (sec) | R (ft) | h (ft) | V (ft/sec) | $\gamma$ (deg) | $A_x$ (ft/sec$^2$) | X (ft) | $\dot{X}$ (ft/sec) | Y (ft) | $\dot{Y}$ (ft/sec) | Z (ft) | $\dot{Z}$ (ft/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 32.000 | 677.1511 | 6910.465 | 492.716 | 77.42 | 53.064 | 677.37518 | 107.346 | 6910.5000 | 480.880 | 0 | 0 |
| 33.000 | 790.6020 | 7401.200 | 514.760 | 76.54 | 53.502 | 790.88256 | 119.792 | 7401.2500 | 500.627 | | |
| 34.000 | 916.8606 | 7911.820 | 537.363 | 75.67 | 53.948 | 917.20753 | 132.968 | 7911.7500 | 520.648 | 0 | 0 |
| 35.000 | 1056.672 | 8442.598 | 560.539 | 74.81 | 54.404 | 1057.0992 | 146.925 | 8442.5000 | 540.940 | | |
| 36.000 | 1210.788 | 8993.808 | 584.304 | 73.94 | 54.869 | 1211.3088 | 161.620 | 8993.7500 | 561.507 | 0 | 0 |
| 37.000 | 1379.961 | 9565.721 | 608.671 | 73.09 | 55.340 | 1380.5934 | 177.078 | 9565.7500 | 582.344 | | |
| 38.000 | 1564.951 | 10158.60 | 633.651 | 72.24 | 55.817 | 1565.7120 | 193.292 | 10158.500 | 603.450 | 0 | 0 |
| 39.000 | 1766.522 | 10772.73 | 659.256 | 71.40 | 56.300 | 1767.4338 | 210.279 | 10772.750 | 624.821 | | |
| 40.000 | 1985.445 | 11408.37 | 685.495 | 70.57 | 56.787 | 1986.5314 | 228.042 | 11408.250 | 646.452 | 0 | 0 |
| 41.000 | 2222.495 | 12065.77 | 712.377 | 69.75 | 57.278 | 2223.7799 | 246.568 | 12065.500 | 668.338 | | |
| 42.000 | 2478.457 | 12745.18 | 739.910 | 68.94 | 57.773 | 2479.9719 | 265.925 | 12745.000 | 690.471 | 0 | 0 |
| 43.000 | 2754.122 | 13446.85 | 768.10[illegible] | 68.14 | 58.269 | 2755.8959 | 284.060 | 13446.500 | 712.844 | | |
| 44.000 | 3050.290 | 14171.02 | 796.952 | 67.34 | 58.766 | 3052.3622 | 307.004 | 14170.750 | 735.446 | 0 | 0 |
| 45.000 | 3367.769 | 14917.91 | 826.465 | 66.56 | 59.251 | 3370.1773 | 328.764 | 14917.750 | 758.260 | | |
| 46.000 | 3707.377 | 15687.71 | 856.630 | 65.79 | 59.725 | 3710.1651 | 351.349 | 15687.500 | 781.261 | 0 | 0 |
| 47.000 | 4069.938 | 16480.61 | 887.440 | 65.02 | 60.187 | 4073.1535 | 374.766 | 16480.250 | 804.426 | | |
| 48.000 | 4456.282 | 17296.75 | 918.879 | 64.26 | 60.617 | 4459.9767 | 399.021 | 17296.250 | 827.720 | 0 | 0 |
| 49.000 | 4867.243 | 18136.25 | 950.912 | 63.51 | 61.012 | 4871.4745 | 424.113 | 18135.750 | 851.095 | | |
| 50.000 | 5303.651 | 18999.16 | 983.510 | 62.77 | 61.368 | 5308.4818 | 450.038 | 18998.750 | 874.504 | 0 | 0 |
| 51.000 | 5766.327 | 19885.48 | 1016.61 | 62.03 | 61.630 | 5771.8239 | 476.780 | 19884.750 | 897.877 | | |
| 52.000 | 6256.064 | 20795.13 | 1050.12 | 61.30 | 61.813 | 6262.3015 | 504.304 | 20794.250 | 921.108 | 0 | 0 |
| 53.000 | 6773.640 | 21727.94 | 1084.06 | 60.57 | 62.135 | 6780.6968 | 532.627 | 21727.000 | 944.193 | | |
| 54.000 | 7319.903 | 22683.87 | 1118.65 | 59.83 | 62.730 | 7327.8627 | 561.873 | 22682.500 | 967.314 | 0 | 0 |
| 55.000 | 7895.834 | 23663.03 | 1154.10 | 59.13 | 63.331 | 7904.7913 | 592.150 | 23661.500 | 990.613 | | |
| 56.000 | 8502.444 | 24665.57 | 1190.31 | 58.41 | 63.889 | 8512.4988 | 623.434 | 24663.750 | 1013.99 | 0 | 0 |
| 57.000 | 9140.745 | 25691.55 | 1227.30 | 57.70 | 64.465 | 9152.0036 | 655.752 | 25689.500 | 1037.43 | | |
| 58.000 | 9811.779 | 26741.03 | 1265.09 | 56.99 | 65.060 | 9824.3575 | 689.136 | 26738.750 | 1060.92 | 0 | 0 |
| 59.000 | 10516.61 | 27814.05 | 1303.70 | 56.28 | 65.663 | 10530.642 | 723.617 | 27811.250 | 1084.44 | | |
| 60.000 | 11256.36 | 28910.66 | 1343.15 | 55.58 | 66.287 | 11271.966 | 759.223 | 28907.750 | 1107.98 | 0 | 0 |
| 61.000 | 12032.15 | 30030.85 | 1383.46 | 54.87 | 66.943 | 12049.477 | 795.996 | 30027.250 | 1131.53 | | |
| 62.000 | 12845.16 | 31174.63 | 1424.67 | 54.17 | 67.618 | 12864.360 | 833.974 | 31170.750 | 1155.06 | 0 | 0 |
| 63.000 | 13696.60 | 32342.00 | 1466.80 | 53.46 | 68.312 | 13717.840 | 873.192 | 32337.500 | 1178.57 | | |
| 64.000 | 14587.71 | 33532.92 | 1509.86 | 52.76 | 69.011 | 14611.170 | 913.684 | 33527.750 | 1202.03 | 0 | 0 |
| 65.000 | 15519.78 | 34747.34 | 1553.87 | 52.05 | 69.719 | 15545.639 | 955.471 | 34741.500 | 1225.40 | | |
| 66.000 | 16494.09 | 35985.12 | 1598.84 | 51.35 | 70.439 | 16522.555 | 998.581 | 35978.500 | 1248.65 | 0 | 0 |
| 67.000 | 17511.98 | 37246.18 | 1644.80 | 50.64 | 71.204 | 17543.253 | 1043.04 | 37239.000 | 1271.78 | | |
| 68.000 | 18574.80 | 38530.39 | 1691.79 | 49.93 | 71.985 | 18609.116 | 1088.90 | 38522.250 | 1294.77 | 0 | 0 |
| 69.000 | 19683.94 | 39837.61 | 1739.81 | 49.23 | 72.774 | 19721.541 | 1136.17 | 39828.250 | 1317.59 | | |
| 70.000 | 20840.80 | 41167.67 | 1788.89 | 48.52 | 73.581 | 20881.936 | 1184.85 | 41157.250 | 1340.24 | 0 | 0 |
| 71.000 | 22046.78 | 42520.41 | 1839.05 | 47.81 | 74.411 | 22091.727 | 1234.97 | 42508.750 | 1362.70 | | |
| 72.000 | 23303.32 | 43895.62 | 1890.31 | 47.11 | 75.253 | 23352.361 | 1286.53 | 43882.500 | 1384.95 | 0 | 0 |
| 73.000 | 24611.84 | 45293.12 | 1942.68 | 46.40 | 76.108 | 24665.287 | 1339.56 | 45278.500 | 1406.97 | | |
| 74.000 | 25973.80 | 46712.66 | 1996.18 | 45.70 | 76.979 | 26031.978 | 1394.05 | 46698.500 | 1428.75 | 0 | 0 |
| 75.000 | 27390.66 | 48154.02 | 2050.83 | 45.00 | 77.863 | 27453.895 | 1450.03 | 48136.000 | 1450.27 | | |
| 76.000 | 28863.88 | 49616.93 | 2106.63 | 44.31 | 78.759 | 28932.544 | 1507.51 | 49597.000 | 1471.50 | 0 | 0 |
| 77.000 | 30394.95 | 51101.11 | 2163.62 | 43.61 | 79.667 | 30469.418 | 1566.49 | 51079.000 | 1492.43 | | |
| 78.000 | 31985.36 | 52606.26 | 2221.78 | 42.92 | 80.587 | 32066.030 | 1626.98 | 52581.750 | 1513.02 | 0 | 0 |
| 79.000 | 33638.61 | 54132.04 | 2281.15 | 42.23 | 81.518 | 33723.898 | 1689.00 | 54105.000 | 1533.27 | | |

| Time (sec) | R (ft) | h (ft) | V (ft/sec) | γ (deg) | $A_x$ (ft/sec$^2$) | X (ft) | X (ft/sec) | Y (ft) | Y (ft/sec) | Z (ft) | Z (ft/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 80.000 | 35350.20 | 55678.12 | 2341.73 | 41.55 | 82.460 | 35444.553 | 1752.55 | 55648.250 | 1553.13 | | |
| 81.000 | 37127.64 | 57244.13 | 2403.53 | 40.86 | 83.412 | 37229.531 | 1817.65 | 57211.000 | 1572.60 | 0 | 0 |
| 82.000 | 38970.47 | 58829.67 | 2466.56 | 40.19 | 84.374 | 39080.373 | 1884.29 | 58793.250 | 1591.65 | | |
| 83.000 | 40880.20 | 60434.34 | 2530.83 | 39.51 | 85.345 | 40998.629 | 1952.48 | 60394.000 | 1610.25 | 0 | 0 |
| 84.000 | 42858.36 | 62057.68 | 2596.36 | 38.84 | 86.327 | 42985.856 | 2022.16 | 62013.750 | 1628.47 | | |
| 85.000 | 44906.10 | 63699.79 | 2663.19 | 38.21 | 87.341 | 45043.220 | 2092.68 | 63651.250 | 1647.20 | 0 | 0 |
| 86.000 | 47024.13 | 65361.35 | 2731.37 | 37.60 | 88.384 | 47171.464 | 2163.93 | 65308.000 | 1666.66 | | |
| 87.000 | 49213.23 | 67043.06 | 2800.87 | 37.03 | 89.439 | 49371.382 | 2236.06 | 66984.750 | 1686.68 | 0 | 0 |
| 88.000 | 51474.31 | 68745.40 | 2871.69 | 36.[illegible]7 | 90.309 | 51643.932 | 2309.21 | 68681.750 | 1707.10 | | |
| 89.000 | 53808.41 | 70468.77 | 2943.85 | 35.98 | 91.594 | 53990.167 | 2383.44 | 70399.000 | 1727.84 | 20 | 25 |
| 90.000 | 56216.62 | 72213.48 | 3017.33 | 35.47 | 92.692 | 56411.205 | 2458.83 | 72137.500 | 1748.84 | | |
| 91.000 | 58700.08 | 73979.79 | 3092.15 | 34.97 | 93.805 | 58908.227 | 2535.42 | 73896.750 | 1770.05 | 100 | 50 |
| 92.000 | 61259.99 | 75767.91 | 3168.32 | 34.45 | 94.933 | 61482.463 | 2613.26 | 75677.750 | 1791.41 | | |
| 93.000 | 63897.60 | 77577.99 | 3245.85 | 33.95 | 96.076 | 64135.187 | 2692.40 | 77479.750 | 1812.87 | 200 | 80 |
| 94.000 | 66614.19 | 79410.18 | 3324.74 | 33.48 | 97.233 | 66867.721 | 2772.88 | 79303.500 | 1834.41 | | |
| 95.000 | 69411.08 | 81264.53 | 3405.02 | 33.03 | 98.418 | 69681.414 | 2854.73 | 81148.500 | 1855.97 | 349 | 125 |
| 96.000 | 72289.63 | 83141.14 | 3486.71 | 32.58 | 99.647 | 72577.671 | 2938.01 | 83015.500 | 1877.56 | | |
| 97.000 | 75251.26 | 85040.03 | 3569.86 | 32.14 | 100.90 | 75557.934 | 3022.76 | 84903.750 | 1899.16 | 605 | 132 |
| 98.000 | 78297.41 | 86[illegible]41.25 | 3654.48 | 31.70 | 102.18 | 78623.700 | 3109.02 | 86813.750 | 1920.74 | | |
| 99.000 | 81429.57 | 88904.83 | 3740.59 | 31.28 | 103.48 | 81776.485 | 3196.80 | 88745.000 | 1942.28 | 890 | 135 |
| 100.00 | 84649.24 | 90870.76 | 3828.22 | 30.86 | 104.81 | 85017.836 | 3286.15 | 90698.250 | 1963.78 | | |
| 101.00 | 87957.96 | 92859.03 | 3917.37 | 30.45 | 106.15 | 88349.331 | 3377.09 | 92672.750 | 1985.20 | 1147 | 145 |
| 102.00 | 91357.29 | 94869.61 | 4008.08 | 30.04 | 107.52 | 91772.565 | 3469.64 | 94668.500 | 2006.55 | | |
| 103.00 | 94848.80 | 96902.48 | 4100.36 | 29.64 | 108.92 | 95289.167 | 3563.83 | 96685.750 | 2027.81 | 1432 | 151 |
| 104.00 | 98434.11 | 98957.59 | 4194.23 | 29.24 | 110.34 | 98900.795 | 3659.69 | 98724.000 | 2048.96 | | |
| 105.00 | 102114.2 | 101034.5 | 4289.71 | 28.85 | 111.79 | 102608.56 | 3757.22 | 100783.25 | 2069.99 | 1718 | 156 |
| 106.00 | 105892.1 | 103134.0 | 4386.86 | 28.44 | 113.28 | 106415.29 | 3856.51 | 102863.75 | 2090.90 | | |
| 107.00 | 109768.7 | 105255.5 | 4485.71 | 28.08 | 114.81 | 110322.19 | 3957.56 | 104965.25 | 2111.69 | 2036 | 161 |
| 108.00 | 113745.8 | 107398.9 | 4586.27 | 27.70 | 116.36 | 114331.05 | 4060.41 | 107087.25 | 2132.35 | | |
| 109.00 | 117825.3 | 109564.4 | 4688.59 | 27.33 | 117.96 | 118443.67 | 4165.10 | 109230.00 | 2152.86 | 2345 | 166 |
| 110.00 | 122008.8 | 111751.7 | 4792.70 | 26.96 | 119.59 | 122661.91 | 4271.66 | 111393.00 | 2173.22 | | |
| 111.00 | 126298.3 | 113960.7 | 4898.63 | 26.60 | 121.26 | 126987.65 | 4380.12 | 113576.25 | 2193.42 | 2667 | 170 |
| 112.00 | 130495.5 | 116191.5 | 5006.42 | 26.24 | 122.97 | 131422.88 | 4490.51 | 115779.50 | 2213.50 | | |
| 113.00 | 135202.3 | 118444.1 | 5116.12 | 25.89 | 124.72 | 135969.27 | 4602.60 | 118003.50 | 2234.00 | 3012 | 174 |
| 114.00 | 139820.4 | 120719.2 | 5227.77 | 25.55 | 126.51 | 140628.67 | 4716.46 | 120248.00 | 2254.90 | | |
| 115.00 | 144551.3 | 123017.2 | 5341.40 | 25.22 | 128.35 | 145402.83 | 4832.13 | 122513.25 | 2276.20 | 3370 | 179 |
| 116.00 | 149397.0 | 125338.7 | 5457.06 | 24.90 | 130.24 | 150293.60 | 4949.67 | 124800.50 | 2297.88 | | |
| 117.00 | 154359.2 | 127684.0 | 5574.78 | 24.59 | 132.18 | 155302.85 | 5069.13 | 127109.25 | 2319.93 | 3721 | 185 |
| 118.00 | 159439.8 | 130053.6 | 5694.62 | 24.28 | 134.16 | 160432.56 | 5190.58 | 129440.50 | 2342.35 | | |
| 119.00 | 164640.8 | 132448.1 | 5816.62 | 23.99 | 136.21 | 165684.73 | 5314.06 | 131794.25 | 2365.14 | 4125 | 190 |
| 120.00 | 169964.2 | 134867.9 | 5940.84 | 23.70 | 138.31 | 171061.42 | 5439.64 | 134171.00 | 2388.29 | | |
| 121.00 | [illegible] | 137313.4 | 6067.32 | 23.42 | 140.46 | 176564.77 | 5567.37 | 136570.75 | 2411.79 | 4466 | 196 |
| 122.00 | 180986.1 | 139785.1 | 6196.13 | 23.14 | 142.68 | 182196.96 | 5697.33 | 138994.75 | 2435.66 | | |
| 123.00 | 186689.1 | 142283.6 | 6327.33 | 22.87 | 144.97 | 187960.24 | 5829.58 | 141442.25 | 2459.89 | 4872 | 202 |
| 124.00 | 192522.9 | 144809.2 | 6[illegible]0.97 | 22.61 | 147.32 | 193856.95 | 5964.19 | 143914.50 | 2484.48 | | |
| 125.00 | 198490.0 | 147362.6 | 6597.14 | 22.35 | 149.76 | 199889.48 | 6101.22 | 146411.50 | 2509.44 | 5136 | 209 |
| 126.00 | 204592.6 | 149944.2 | 6735.91 | 22.10 | 152.29 | 206060.29 | 6240.78 | 148933.50 | 2534.79 | | |
| 127.00 | 210833.3 | 152554.6 | 6877.38 | 21.85 | 154.91 | 212371.96 | 6382.95 | 151481.25 | 2560.52 | 5641 | 216 |

| Time (sec) | R (ft) | h (ft) | V (ft/sec) | $\gamma$ (deg) | $A_x$ (ft/sec$^2$) | X (ft) | $\dot{X}$ (ft/sec) | Y (ft) | $\dot{Y}$ (ft/sec) | Z (ft) | $\dot{Z}$ (ft/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 128.00 | 217214.7 | 155194.3 | 7021.63 | 21.61 | 157.61 | 218827.14 | 6527.82 | 154058.50 | 2586.66 | 6065 | 223 |
| 129.00 | 223739.3 | 157863.8 | 7168.74 | 21.38 | 160.40 | 225428.58 | 6675.48 | 156654.50 | 2613.20 | | |
| 130.00 | 230409.9 | 160563.8 | 7318.80 | 21.14 | 163.29 | 232179.11 | 6826.01 | 159281.25 | 2640.15 | 6501 | 232 |
| 131.00 | 237229.3 | 163294.9 | 7471.92 | 20.91 | 166.29 | 239081.65 | 6979.53 | 161935.25 | 2667.54 | | |
| 132.00 | 244200.8 | 166057.6 | 7628.20 | 20.69 | 169.39 | 246134.24 | 7136.15 | 164613.50 | 2695.36 | 6965 | 240 |
| 133.00 | 251326.3 | 168852.6 | 7787.74 | 20.47 | 172.61 | 253355.03 | 7295.94 | 167325.75 | 2723.63 | | |
| 134.00 | 258610.1 | 171680.5 | 7950.67 | 20.25 | 175.95 | 260732.28 | 7459.07 | 170063.75 | 2752.37 | 7464 | 249 |
| 135.00 | 266055.0 | 174542.1 | 8117.12 | 20.04 | 179.42 | 268274.38 | 7625.64 | 172831.00 | 2781.59 | | |
| 136.00 | 273664.8 | 177438.1 | 8287.19 | 19.83 | 183.01 | 275984.80 | 7795.77 | 175627.25 | 2811.30 | 7976 | 259 |
| 137.00 | 281441.8 | 180369.1 | 8461.01 | 19.62 | 186.74 | 283867.21 | 7969.60 | 178453.75 | 2841.51 | | |
| 138.00 | 289390.7 | 183335.9 | 8638.73 | 19.42 | 190.61 | 291925.33 | 8147.26 | 181310.50 | 2872.24 | 8511 | 270 |
| 139.00 | 297515.1 | 186339.4 | 8820.51 | 19.22 | 194.65 | 300163.12 | 8328.93 | 184198.50 | 2903.51 | | |
| 140.00 | 305818.7 | 189380.3 | 9006.50 | 19.02 | 198.86 | 308584.63 | 8514.73 | 187117.75 | 2935.33 | 9071 | 280 |
| 141.00 | 314305.6 | 192459.5 | 9196.88 | 18.82 | 203.25 | 317194.11 | 8704.86 | 190069.25 | 2967.83 | | |
| 142.00 | 322980.0 | 195578.3 | 9391.84 | 18.64 | 207.83 | 325995.81 | 8899.21 | 193053.75 | 3001.80 | 9664 | 290 |
| 143.00 | 331845.9 | 198738.6 | 9591.57 | 18.46 | 212.62 | 334994.06 | 9097.96 | 196073.50 | 3037.31 | | |
| 144.00 | 340907.7 | 201942.3 | 9796.27 | 18.29 | 217.63 | 344193.35 | 9301.33 | 199129.00 | 3074.44 | 10,240 | 301 |
| 145.00 | 350169.8 | 205191.4 | 10006.1 | 18.12 | 222.87 | 353598.40 | 9509.74 | 202222.75 | 3113.23 | | |
| 146.00 | 359636.9 | 208488.0 | 10221.5 | 17.97 | 228.37 | 363214.16 | 9727.81 | 205356.00 | 3153.78 | 10,890 | 312 |
| 147.00 | 369314.1 | 211834.1 | 10442.5 | 17.82 | 234.14 | 373045.85 | 9951.39 | 208531.00 | 3196.15 | | |
| 148.00 | 379206.5 | 215232.1 | 10669.5 | 17.68 | 240.20 | 383098.88 | 10165.5 | 211749.75 | 3240.43 | 11,550 | 322 |
| 149.00 | 389319.5 | 218684.4 | 10902.8 | 17.54 | 246.58 | 393378.99 | 10395.6 | 215012.50 | 3286.71 | | |
| 150.00 | 399659.0 | 222193.4 | 11142.6 | 17.41 | 253.29 | 403892.22 | 10631.8 | 218323.25 | 3335.11 | 12,130 | 332 |
| 151.00 | 410230.9 | 225761.8 | 11389.4 | 17.29 | 260.38 | 414644.92 | 10874.6 | 221683.50 | 3385.71 | | |
| 152.00 | 421041.6 | 229392.3 | 11643.5 | 17.17 | 267.87 | 425643.79 | 11124.7 | 225095.50 | 3438.65 | 12,960 | 342 |
| 153.00 | 432097.9 | 233087.8 | 11905.4 | 17.04 | 275.80 | 436895.92 | 11381.1 | 228561.50 | 3494.04 | | |
| 154.00 | 443406.9 | 236851.5 | 12175.5 | 16.96 | 284.20 | 448408.82 | 11645.8 | 232084.50 | 3552.04 | 13,723 | 353 |
| 156.00 | 466810.0 | 244600.0 | 12742.0 | 16.77 | 302.69 | 472250.00 | 12200.0 | 239310.00 | 3677.00 | 14,450 | 364 |
| 158.46 | 497200.0 | 254580.0 | 13496.0 | 16.56 | 3.61 | 503230.00 | 12936.0 | 248580.00 | 3847.00 | 15,400 | 378 |
| 160.00 | 516600.0 | 260900.0 | 13486.0 | 16.33 | 3.63 | 523100.00 | 12940.0 | 254400.00 | 3800.00 | 16,000 | 388 |
| 162.00 | 541900.0 | 269100.0 | 13475.0 | 16.11 | 3.66 | 548900.00 | 12945.0 | 262000.00 | 3741.00 | 16,780 | 397 |
| 164.00 | 567400.0 | 277200.0 | 13463.0 | 15.87 | 3.68 | 574400.00 | 12950.0 | 269300.00 | 3680.00 | 17,510 | 405 |
| 166.00 | 592700.0 | 285200.0 | 13452.0 | 15.61 | 3.70 | 600000.00 | 12955.0 | 276700.00 | 3620.00 | 18,306 | 413 |
| 167.71 | 614500.0 | 292100.0 | 13443.0 | 15.39 | 3.70 | 623000.00 | 12960.0 | 282900.00 | 3569.00 | 19,100 | 420 |
| 200.00 | 972600.0 | 400000.0 | 13228.0 | | | | | | | | |
| 230.00 | 1400000 | 497500.0 | 12958.0 | | | | | | | | |
| 260.00 | 1768300 | 560100.0 | 12807.0 | | | | | | | | |
| 290.00 | 2140000 | 604500.0 | 12701.0 | | | | | | | | |
| 320.00 | 2510000 | 628800.0 | 12645.0 | | | | | | | | |
| 350.00 | 2875600 | 631000.0 | 12637.0 | | | | | | | | |
| 380.00 | 3240000 | 613300.0 | 12679.0 | | | | | | | | |
| 410.00 | 3617000 | 574000.0 | 12772.0 | | | | | | | | |
| 440.00 | 3985000 | 516000.0 | 12911.0 | | | | | | | | |
| 470.00 | 4355000 | 438000.0 | 13100.0 | | | | | | | | |
| 500.00 | 4726000 | 367000.0 | 13326.0 | | | | | | | | |
| 530.00 | 5110000 | 215800.0 | 13759.0 | | | | | | | | |
| 578.00 | 5500000 | 0 | 1000 | | | | | | | | |

COAST PHASE

# APPENDIX C

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D1 20 Nov 58

SUBJECT: Trajectory and Aerodynamic Data

TO: Commander in Chief
Strategic Air Command
Offutt Air Force Base, Nebraska

1. The trajectory and aerodynamic data listed in this letter are required to provide missile flight safety criteria for all peacetime launches from this base. This letter is intended to be a complete statement of such data requirements, however additional information may be required from time to time. It is necessary that upon request, the Director of Intelligence, 1st Missile Division, be provided their data for specific missile trajectories.

2. The information itemized below is required for each missile flight or group of similar flights. A lead time of 30 days is desired. If this information is not provided at least three weeks prior to a proposed missile launching, the range safety calculations cannot be made in time to meet the scheduled launch date. Much of the information requested below, particularly in paragraph 6, will not change from missile to missile. In these cases, this information need not be resupplied provided reference is made to this fact.

3. From launch through shutdown (or burnout) of the final stage (including vernier stage), the following are required: (See paragraph 4 for details)

a. X, Y, Z, vs time

b. X, Y, Z, vs time

c. Maximum turning rate of velocity vector vs time

d. Speed vs time

e. Path angle of velocity vector vs time

f. Maximum expected lateral deviations from the intended flight direction.

4. This paragraph gives additional details relative to the requirements of paragraph 3 above:

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a. Items 3a through 3f are required for the nominal trajectory only.

b. Items 3a, 3b, and 3e must be referenced to an orthogonal, earth-fixed, coordinate system with origin at the launching pad, the X and Z axis lying in the plane tangent to the ellipsoid at the launching pad, and the Y axis perpendicular to the tangent plane. The azimuth of the positive X axis should coincide with the launch azimuth, the azimuth of the positive Z axis should be 90° greater than the azimuth of the positive X axis, and the positive Y axis should be up.

c. Three copies of the tabulated printout containing Items 3a, 3b, 3d, and 3e are required. Values must be printed out at even one or two second intervals and also at the time corresponding to termination of thrust for each stage. Time "0.0 sec" must correspond to first motion of the first stage and all times in the printout must be referenced to this.

d. Item 3e is required in order to provide a means of determining at any time during powered flight the maximum angle through which the velocity vector can turn in various time intervals at two, four, and six seconds. It should be assumed that the missile has behaved normally up to the point of the malfunction which produces the maximum rate turn. Turning rate data are required at two second intervals beginning at twenty seconds. From twenty seconds to 110 seconds both pitch turn rates and lateral turn rates are desired. After 110 seconds until the end of powered flight, only lateral turn rates are required. They should be provided in one of the two following forms: (1) tabulated data which give the maximum total angle through which the velocity vector can turn in two, four, and six second intervals. (If supplied in this form the times at which data are supplied must coincide with times at which the trajectory data (Items 3a and 3b) are printed out.) (2) turning rate graphs which give directly the total angle during the specified time intervals or which can be integrated under to give these values. In arriving at maximum turning rates, both trimmed turns and tumbling turns which can result from erratic gimballing of the rocket engine(s) should be considered up to the point of a structural failure which would impose a condition of zero thrust. It is believed that the turning rates used may be a compromise between the trimmed turn rates and the mean turning rates achieved during the time for the missile to tumble through 180°. However, if the maximum rate trimmed turn for a period of four or six seconds is virtually impossible, turning rates for these cases may be based on some more likely type malfunction. Maximum turning rate information is required during the latter part of powered flight which will

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be applicable for time delays up to ten or twenty seconds. This is required to estimate the time beyond which no destruct action need be taken by the Range Safety Officer provided the missile has behaved normally up to this point. A complete explanation of how maximum turning rates were calculated including all assumptions made is also required.

e. The information requested in paragraph 3f is to provide the capability of ascertaining whether a normal missile experiencing a three sigma deviation will violate Range Safety destruct criteria. For comparison with impact prediction destruct criteria, a locus of predicted impact points (specifying latitude and longitude for premature cut-off times) at four to eight second intervals beginning at thirty seconds after liftoff is necessary.

5. The following additional items are required to cover the period from launch through shutdown of the final stage. For item 5b relatively crude information is adequate, and may be furnished in graph form if more convenient. Item 5d is range along the earth's surface from the pad to a point directly beneath the missile. Item 5a is altitude above the earth's surface. Items 5a, 5c, and 5d below, should be included in the computer printout described in paragraph 4c.

a. Altitude vs time

b. Fuel weights vs time and gross weight vs time

c. Acceleration vs time

d. Range vs time

6. The following data are also required for each missile flight or group of similar flights:

a. Approximate time delay between activation of firing circuits and first motion.

b. For a normal missile flight, estimate of impact dispersion for each re-entry body giving range standard deviation, deflection standard deviation (or probable errors), and mean point of impact. Assumptions made relative to the factors causing the deviations should be stated.

c. Brief, general discussion of typical failures which may occur during flight such as a hard over rocket engine(s), failures which lead to premature shutdown of booster or missile engine, failure of the programmer, shifting of platform reference, structural failures, expected or possible missile behavior for those failures, and an estimate of the probability of their occurrences. Any other information considered pertinent with respect to critical portions of flight, missile stability characteristics, structural and/or g limits.

d. Expected effect of destruct explosion including engineering estimates of number and approximate weights of pieces, effects of explosion on remaining fuel, effects of explosion on velocity of pieces, two sigma lower estimate of $C_d$ vs Mach no. (specifying reference area and weight) for pieces going the maximum distance, two sigma upper estimate of $C_d$ vs Mach no. for pieces going minimum distance. (If maximum distance piece can possibly be stable, drag coefficient curve is desired for alpha = 0.) If obtained by taking the mean of the lower two sigma drag coefficients obtained by observing the piece from four orthogonal directions in a plane containing the longitudinal axis. The difficulty in estimating drag coefficients and then placing a statistical interpretation on these estimates is fully realized. If this cannot be done, some method for obtaining an absolute maximum and minimum should be suggested, e.g. using a value of $C_d$ $A/W = 0.2m^2/kg$. In addition, drag information is desired for the minimum distance piece exclusive of sheet metal and skin.

e. Will the airframe break up upon re-entry into atmosphere? If so, give estimate of number of pieces and impact weights. How much lateral variation of warhead can be brought about after re-entry by wind and aerodynamic effects: Maximum expected duration of vernier stage beyond cutoff of final booster stage. Estimate of lateral deviation of warhead (or nose cone) and booster that can be brought about during this period by malfunctioning of vernier rockets.

f. $C_d$ vs Mach no. (specifying reference area and weight) for separated warhead or nose cone.

g. Tabulation of geodetic latitude and longitude and downrange distance of impact points on a rotating earth for various premature destruct (or cutoff) times beginning about thirty seconds after first motion. Points are required at four to eight second intervals and at the times corresponding to termination of thrust for each stage. The computation of thrust for each stage. The computation times must coincide with times at which trajectory data (items 3a and 3b) are printed out. Also required for each computation point are (1) the remaining flight time to impact, (2) range from pad to impact, (3) and the following:

(1) X & Z coordinates of the impact point or

(2) Distance from pad to impact measured along earth's surface in the X direction and the Z direction. It is desired that the computations take into account the effects of atmospheric drag, but if the differences between the maximum distance drag calculations and vacuum calculations are insignificant, vacuum calculations will be considered acceptable. If drag computations are made, they should be based on the same drag information used for the maximum distance pieces (see paragraph 6a). Drag assumptions made, spheroid used, pad location, and normal nose cone separation time should be specified.

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h. Maximum expected trajectory deviations during the first fifty to seventy seconds of flight due to effects of (1) a thirty, forty-five and sixty knot head wind and (2) a thirty, forty-five and sixty knot side wind. If other factors (e.g. gyro drift) add significantly to the deviations caused by wind, the effects of these factors should be included also. This information is required in order to determine whether a normal missile experiencing a severe wind condition will violate Range Safety destruct criteria in the launch area. It is required in the form of tabulated X, Y, Z position information using the same reference system described in paragraph 4b. It is quite likely that this information need be provided for only one typical trajectory for each missile.

i. Maximum possible burning time and the maximum possible range of nose cone and tankage if all fuel is expended.

7. For some flights a programmed fuel cutoff may be scheduled well in advance of fuel exhaustion. In such cases, if the cutoff mechanism fails to function at the normal cutoff time, the Range Safety Officer may be unable to allow the flight to continue unless the proper destruct criteria have been provided beyond the normal cutoff point. Any such destruct criteria must be based primarily on items 3a through 3c and 6g.

8. A tabulation of down range distance, altitude and velocity versus time, from first missile motion to nose cone impact, is required. In the event the computer printout outlined in paragraph 4c above continues to impact time, this tabulation is not required. If tabular data is provided, intervals of thirty seconds of time are adequate.

FOR THE COMMANDER:

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Letter, 392 ABC, DI, dated 20 Nov 58, Subj: Trajectory and Aerodynamic Data.

The expected effects of destruct explosion should also include the following lethal areas for both a "dry", i.e. missile intact with zero fuel, and a "wet", i.e. full fuel load and 10 percent mixing efficiency:

a. To persons standing in open

b. Collapse 13" brick wall

c. Derail a railroad car

d. Capsize or rupture the sides of a ship of "Liberty" specifications.

Maximum impact velocity should be assumed in determining the above lethal areas.

Incl 1

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Letter, 392 ABC, D1, dated 20 Nov 58, Subj: Trajectory and Aerodynamic Data, added paragraph 6j.

6j. During the early part of the launch a total failure, that is, failure of the guidance system and/or the propulsion system, may occur such that the missile may impact at any of the 360 degrees about the launch pad. An estimate is required of the impact distribution about the launch pad if such a failure occurs within the first 40 seconds after lift off. This information is necessary in determining hit probabilities and the area about the pad which must be cleared of ships, railroad cars, working groups, etc. The assumptions, method and data used to determine the impact distribution should be provided also.

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# APPENDIX D

## APPENDIX D

## RESULTS OF RANGE SAFETY MEETING HELD AT VANDENBERG AFB ON 3 FEBRUARY 1959

With the concurrence of the WS-117L Project Office AFBMD, a meeting was held at the Vandenberg AFB Instrumentation Control Center between LMSD and the cognizant SAC Range Safety personnel for the purpose of clarifying questions concerning the LMSD Report 6104-1, "WS-117L Range Safety Report, Program IIA Flight Number One." In addition, a discussion was held regarding the requirements outlined in AFR 190-16 (DI to Commander in Chief, Strategic Air Command, Offutt Air Force Base, Nebraska, entitled, "Trajectory and Aerodynamic Data," dated 20 November 1958).

It was resolved that the requirements outlined in AFR 190-16 (included in this report as Appendic C) did not significantly differ from criteria previously used by LMSD and, therefore, would be used in the future with the following exceptions:

1. Item 6d. It was agreed that the Range Safety personnel would determine the points of impact of fragments due to destruct (0 + 40 seconds of flight) from data and formulas supplied by LMSD. Also, LMSD is to supply information concerning fragment weight, size, and velocity.

2. Item 6j. This item was resolved so that LMSD would provide the Range Safety group with data or formulas to enable them to estimate the impact distribution about the launch pad for failures occurring within the first 40 seconds after liftoff.

3. Enclosure 1. To comply with the agreement made with the Range Safety personnel, LMSD would provide the necessary formulas to enable the Range Safety group to determine the lethality of various missile fragments (resulting from a command destruct of "wet" and "dry" missiles).