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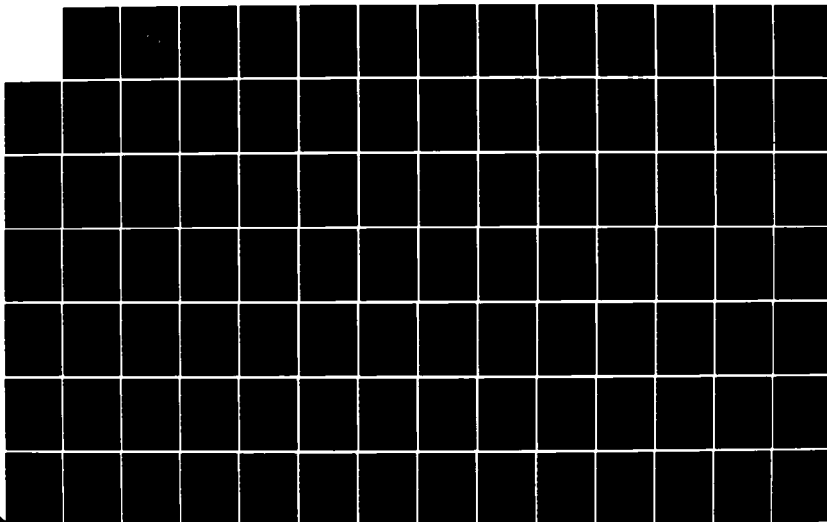
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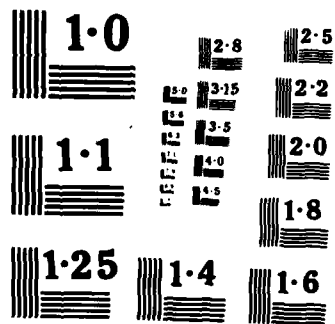
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THESIS

DISPERSION SENSITIVITY OF THE EIGHT INCH
ADVANCED RAMJET MUNITIONS TECHNOLOGY
PROJECTILE DUE TO WIND
AND MINOR THRUST ERRORS

by

Steven Ronald Poole

September 1984

Thesis Advisor:

A. E. Fuhs

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Prepared for: Colonel R. Larriva
Defence Advanced Research
Projects Agency
Arlington, VA 22209

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Dispersion Sensitivity of the Eight Inch
Advanced Ramjet Munitions Technology Projectile
Due to Wind and Minor Thrust Errors

by

Steven Ronald Poole
Major, Canadian Forces
B Sc., College Militaire Royale De Saint Jean, 1975

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ENGINEERING SCIENCE

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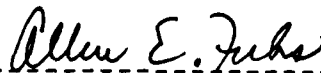
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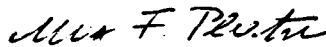


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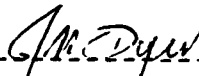
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A.E. Fuhs, Thesis Advisor



M.F. Platzter, Chairman, Department of Aeronautics



J.N. Dyer, Dean of Science and Engineering

ABSTRACT

Advanced Ramjet Munitions Technology (ARMT) is an ongoing project within the Defence Advanced Research Projects Agency (DARPA) to research ramjet munitions. The ARMT eight inch projectile uses ramjet thrust for a boosted trajectory, but operates on a thrust drag balance concept to create a pseudo vacuum trajectory during powered flight. The trajectory was analyzed using an IBM 370 computer simulation for three and five degrees of freedom. Work was also done to adapt the Ballistics Research Laboratories six degrees of freedom program to the IBM system. Projectile aerodynamic and mass properties were obtained from the Norden Systems Wind Tunnel Data. Dispersion from the vacuum trajectory due to wind prior to ramjet burnout proved minor. Dispersion due to constant thrust errors under 5% was within a 600 foot radius at terminal guidance over a range of 33 miles.

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TABLE OF SYMBOLS AND ABBREVIATIONS

ABBREVIATIONS:

AIFS -ADVANCED INDIRECT FIRE SYSTEM

ARMT -ADVANCED RAMJET MUNITIONS TECHNOLOGY

BRL -BALLISTICS RESEARCH LABORATORY

IODE -INTERACTIVE ORDINARY DIFFERENTIAL EQUATION
SOLVER

NPGS -NAVAL POSTGRADUATE SCHOOL

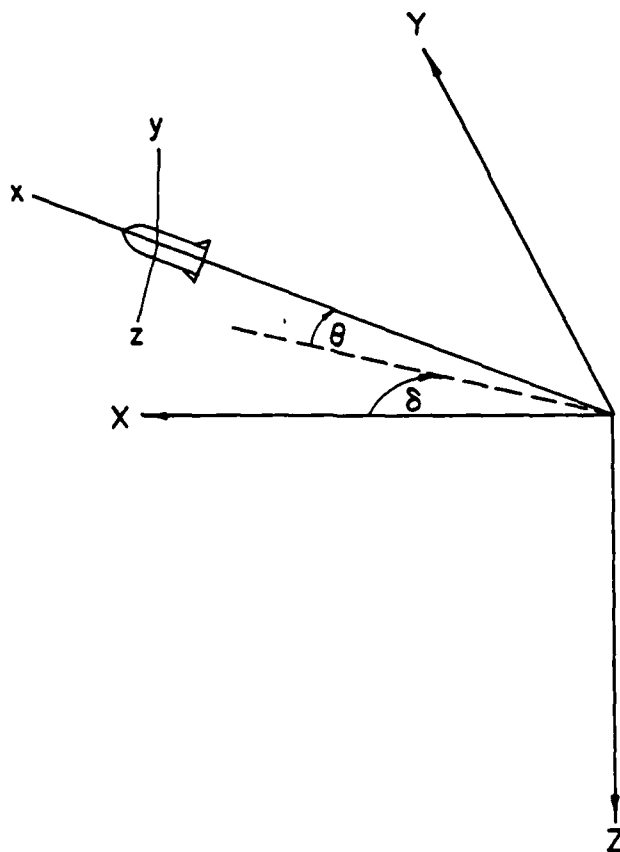
SYMBOLS:

FORMULA	PROGRAMS	DESCRIPTION	UNITS
α	A	angle of attack	radians
β	B	sideslip angle	radians
δ	DE	angle between body axis and inertial axis (yaw plane)	radians
γ	GA	angle between inertial axis and relative wind,yaw plane	radians
λ	LAMBDA	wavelength	feet
ρ	RO	air density	lbf-s ² /ft ⁴
ω	-	angular velocity	rads/sec
Ω	O	angle between relative wind and inertial axis (pitch plane)	radians
θ	THE	angle between body axis and inertial axis(yaw)	radians
C_d	CD	drag coefficient	

C _{do}	CDO	zero lift drag coefficient	
C _l	CL	lift coefficient	
C _{l_α}		slope lift coefficient	
C _m	CM	moment coefficient	
C _{m_α}	CMA	slope moment coefficient	
C _{m_q}	CMT	damping coefficient	
X _{cp}		centre of pressure location(from spike)	inches
X _{cg}		centre of gravity location(from spike)	inches
C	C	thrust error coefficient	
d	DI	projectile diameter	inches
D	DRAG	Drag	lbf
D _w		Drag due to wind	lbf
f		frequency	Hz
g	G	gravity	ft/sec
I	I	moment of inertia	slug-ft
I _{sp}	ISP	specific impulse	"sec"
L	L	lift	lbf
L _w		net lift due to transients	lbf
m	M	mass	lbm
q	Q	dynamic pressure	lbf/ft ² -s ²
U	V	relative wind	ft/sec
V		initial velocity projectile	ft/sec

Vcg	VCG	centre of gravity velocity	ft/sec
Vw	VW (3 deg) VWXY(5 deg) VWXZ(5deg)	wind velocity	ft/sec
Vwo		initial wind speed	ft/sec
X	X	range	ft
Y	Y	crossrange	ft
Z	Z	height	ft

GEOMETRIC NOMENCLATURE:



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I would be remiss if I did not thank my wife, Marie Josee, and my two children,Crista and Eric, for helping create the atmosphere I needed to succeed in the academic environment.

I. INTRODUCTION

A. ARMT OPERATIONAL CONCEPT

Conventional artillery uses unguided projectiles to destroy a variety of targets including armored vehicles. Ballistic information and professional experience are used to direct fire onto a target with little chance of a direct hit in the first few rounds. A forward observer provides feedback to the guns for correction until the target is destroyed with subsequent rounds. Generally this approach is limited to the 30 kilometer range and often point target locations are not known.

The ARMT projectile, formerly called AIFS, changes the conventional concept by providing a fire and forget, boosted and terminally guided projectile with a highly predictable trajectory. Conventional heat seekers and target identification systems are short range and require a blunt nose which has high drag. Active radar is not practical. Long ranges of 60 kilometers are achieved by using solid fuel ramjet propulsion with an axisymmetric air inlet spike. An accurately predicted trajectory is achieved by ensuring thrust equals drag to produce zero axial acceleration and create a pseudo-vacuum trajectory during powered flight. At a preset time (near ideal condition ramjet burnout) the inlet spike is discarded and canards are deployed for

terminal guidance control. A passive or reflected target energy system will be used for terminal guidance. Research is ongoing and sponsored by DARPA. Projectile characteristics are at Appendix A.

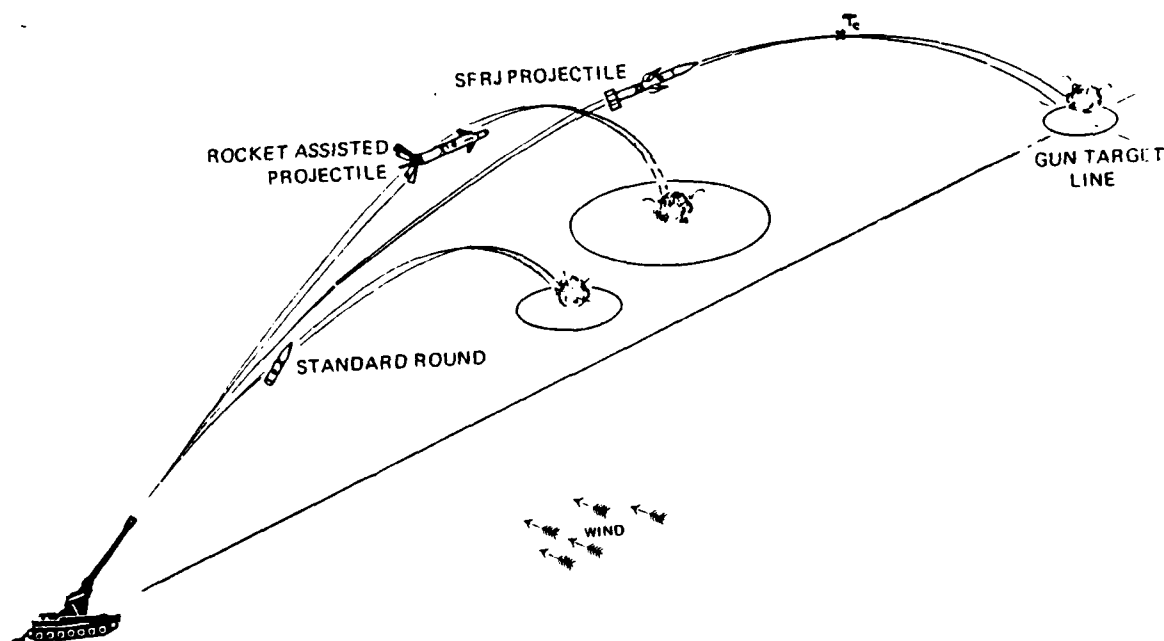


Figure 1-1 ARMT Trajectory Concept

B. THRUST DRAG BALANCE CONCEPT

Balanced thrust drag implies that the thrust equals the drag vectors during powered flight. The aim of the balance is to negate meteorological variations throughout the trajectory by reducing all force vectors to zero except gravity. The resulting pseudo-vacuum trajectory is highly predictable. The balance is accomplished by measuring axial acceleration and maintaining it at zero. Appendix B explores this concept in detail. The potential errors include transients due to wind induced reactions and measurement errors in the technical application of the balance in flight. Further, any asymmetries such as aerodynamic misalignment or thrust will produce a lateral force which must be offset by a small roll rate (sixth degree of freedom). This allows longitudinal forces to be the significant forces.

The concept of thrust drag balance is best demonstrated in Figures 1-2 and 1-3. In Figure 1-2 the centre of gravity of the projectile is flying at an angle of attack (α) with a velocity vector (V_{cg}) relative to a fixed earth reference frame. The aerodynamic forces are lift (L) and drag (D). Assuming static stability and neglecting transient dynamics, the angle of attack becomes zero, which

reduces lift to zero. If thrust equals drag then only the gravitational force exists.

If a crosswind (V_w) is applied, the projectile corks into the wind because of the aerodynamic force acting on the centre of pressure. Adjusting the thrust and again assuming static stability the drag can be offset as shown in Figure 1-3 by applying the correct thrust. For future reference the component of drag normal to the plane containing V_{cg} is D_w .

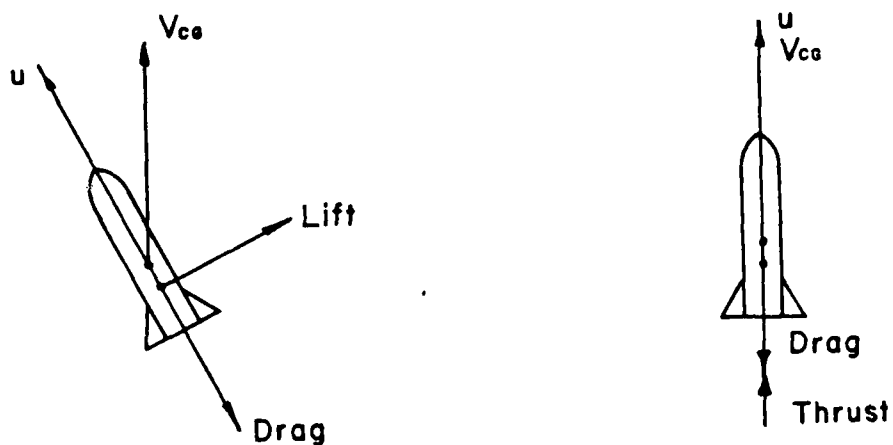


Figure 1-2 Projectile Dynamics Thrust Equals Drag

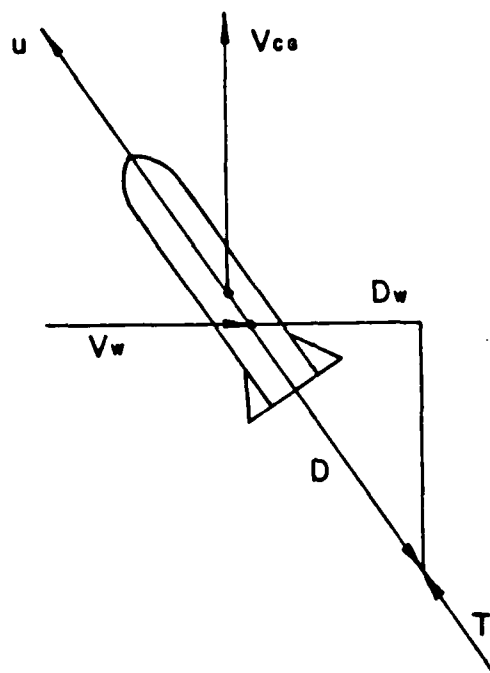


Figure 1-3 Projectile Dynamics With Crosswind

If a tailwind or headwind is applied, thrust is adjusted to compensate in the same manner.

The dynamics or transient effects due to wind which create damped oscillatory motion have a cumulative net lift effect(as shown in Figure 1-4) as angle of attack is proportional to lift. The area under the curve in Figure 1-4

does not average to zero due to the damping. For future reference this lift due to wind will be referred to as L_w .

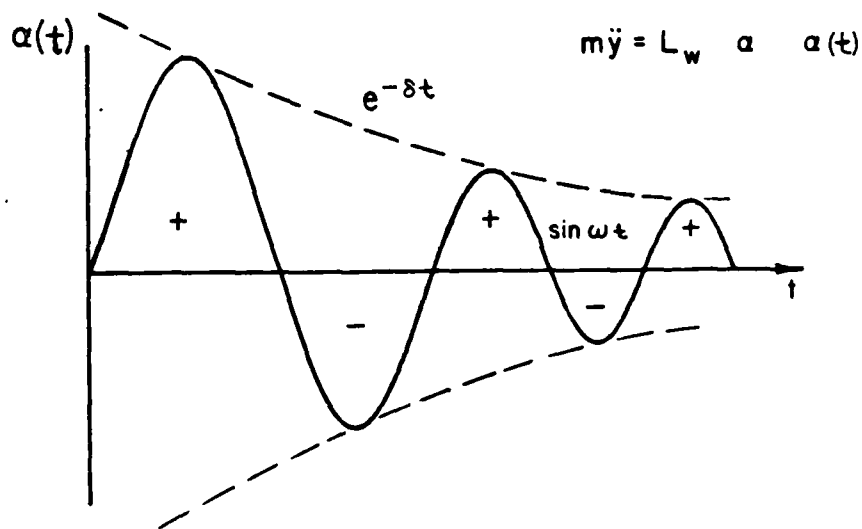


Figure 1-4 Angle Of Attack Versus Time

Calculations integrating $\alpha(t)$ twice to demonstrate the above in the yaw or pitch plane are at Appendix B.

C. THESIS SCOPE

It is emphasized that the scope of this thesis is to analyze dispersion from the pseudo-vacuum trajectory at terminal guidance time for the eight inch ARMT projectile. In colloquial terms the "basket" from which the projectile will be guided to target was determined. Further, this basket is based on thrust errors and wind effects for a

launch angle of 45 degrees and muzzle velocity of MACH 2.2 at sea level. Linearized aerodynamics were used in all calculations. No attempt was made to establish a "footprint" for projectile impact.

II. TRAJECTORY ANALYSIS METHODOLOGY

A. VACUUM TRAJECTORY ANALYSIS

A short and simple BASIC program was written to establish the vacuum trajectory and fuel burn time of the projectile in a two dimensional scenario where thrust exactly equaled drag. The Standard U.S. Atmosphere was used and the drag coefficient linearized [Reference 1]. The program listing and baseline data are at Appendix D. The key parameters and equations used are listed at Appendices A and D. The baseline pseudo-vacuum trajectory is shown in Figure 2-1.

B. THREE-DEGREES-OF-FREEDOM MODEL

The computer simulation was established using the Interactive Ordinary Differential Equation (IODE) library program at NPGS. A listing of the three degrees of freedom equations is in the IODE specifications at Appendix E. The simulation is based on wind tunnel results from Norden Systems [References 2 and 3] and assumes a horizontal plane at 30000 feet altitude. This height was chosen as significant flight time is at altitude and the time of flight in this plane was near actual flight time. Primarily the model was used to study crosswind effects but resonance with the projectile short period was simulated. Different thrust

scenarios were also used. Figure 2-2 depicts the model in the X-Y plane.

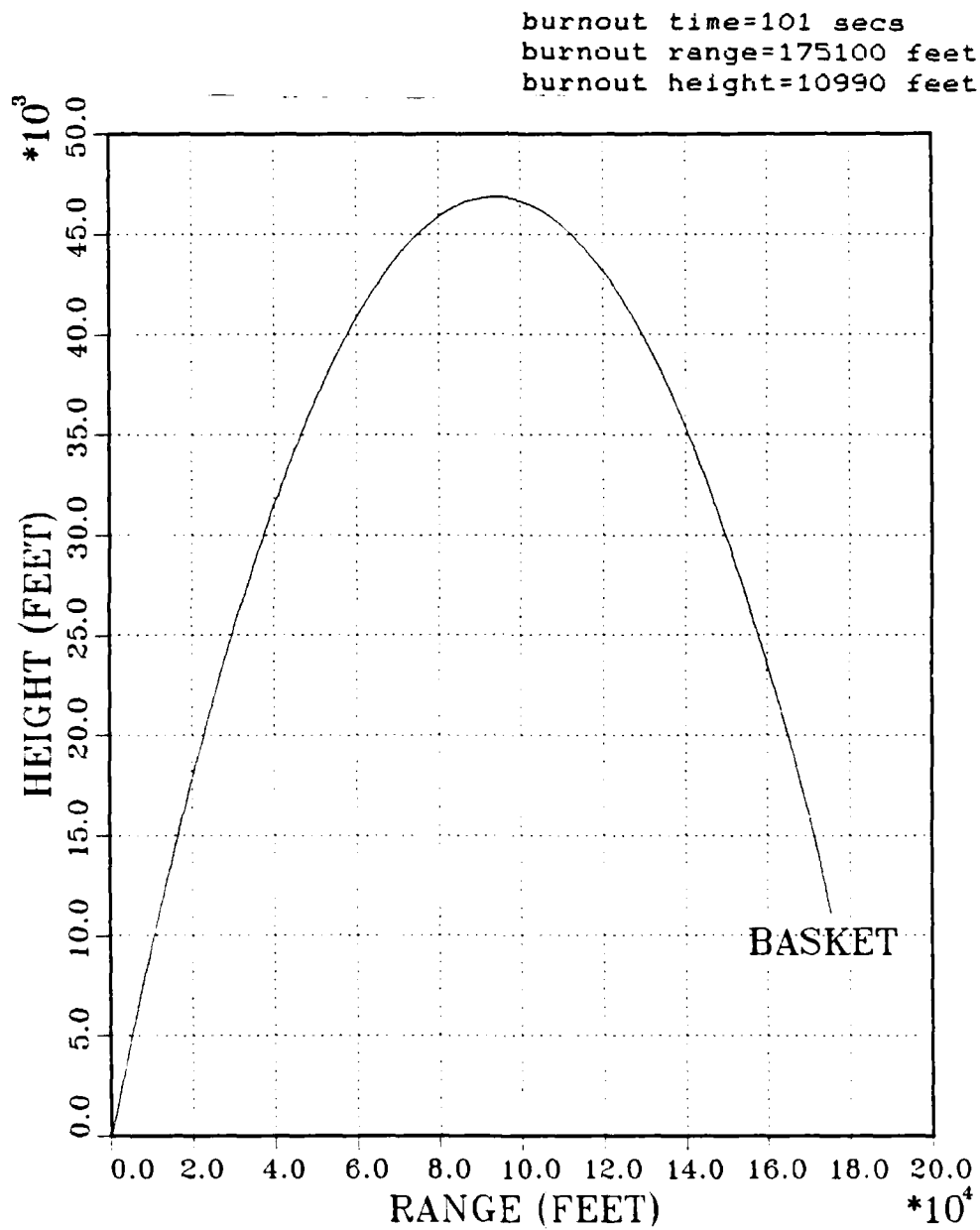


Figure 2-1 ARMT Pseudo-vacuum Trajectory

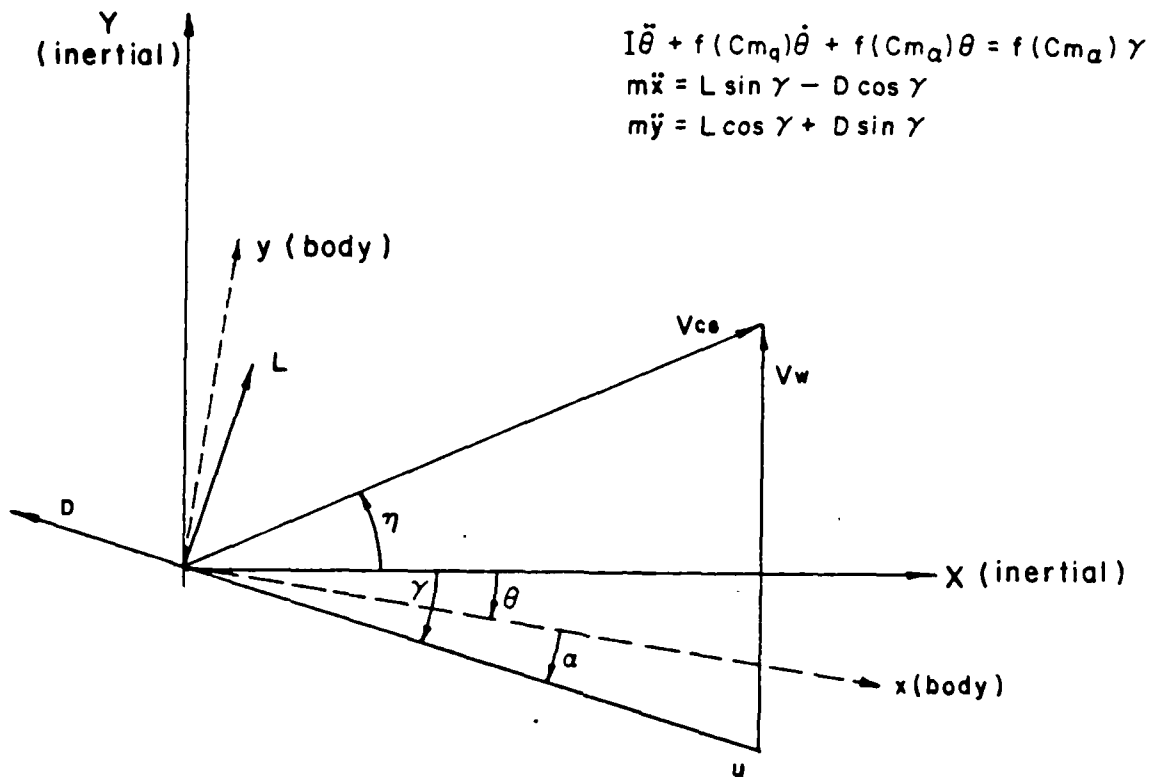


Figure 2-2 Three Degrees Freedom Model (Yaw Plane)

The crosswinds were varied in intensity and duration to analyze crossrange dispersion. As well thrust was varied as a function of drag by scaling the drag. Cm_q predictions were approximately -190 to -205 by Norden Systems [Reference 2] and an analysis was done to determine the effects of varying this damping coefficient. To further study the projectile characteristics, trajectories were simulated with no thrust or mass attenuation with varying wind profiles. Figure 2-3 ,

shows the baseline three-degrees-of-freedom trajectory of thrust equals drag with no wind.

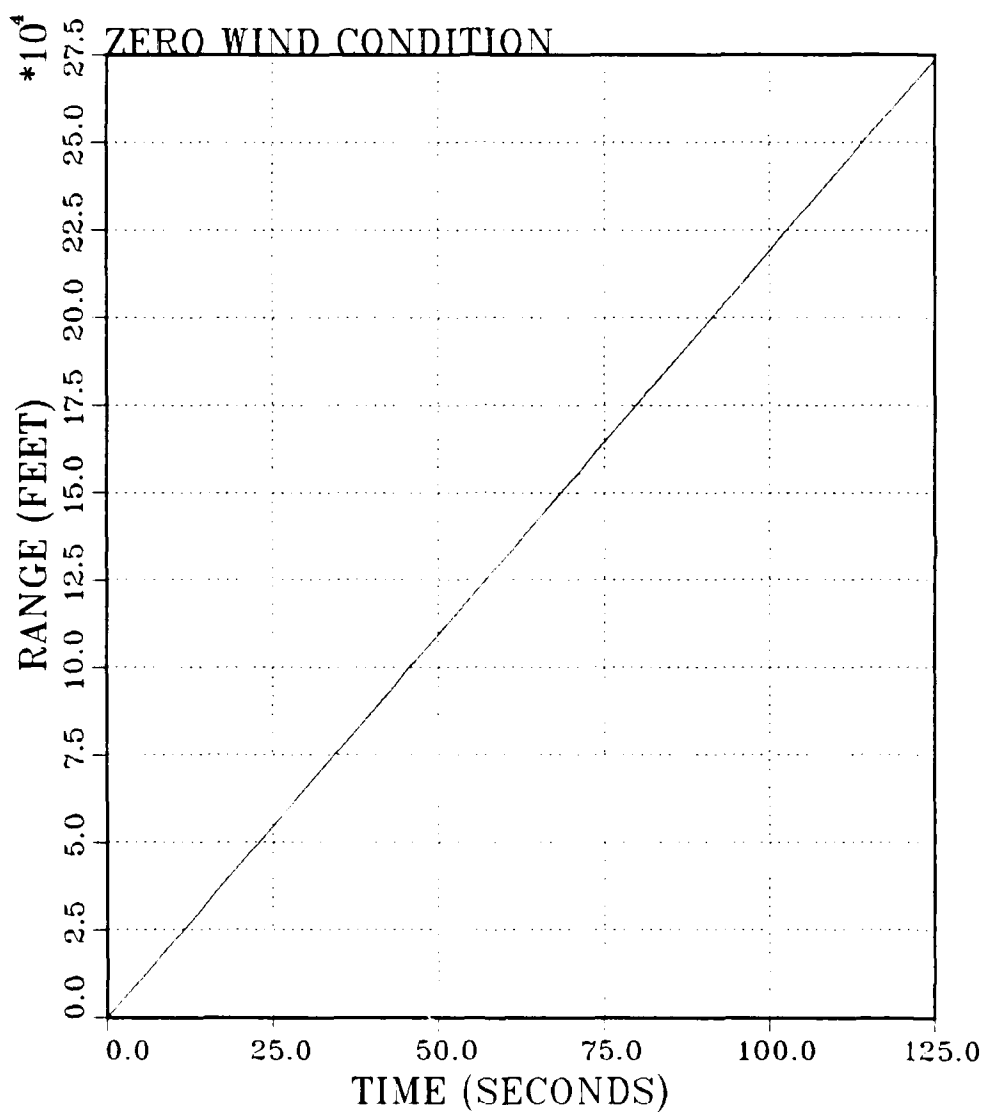


Figure 2-3 Baseline Three-Degrees-Of-Freedom Trajectory

C. FIVE-DEGREES-OF-FREEDOM MODEL

Again the IODE program was used to solve a five degrees of freedom system of equations. The roll plane was neglected for the following reasons:

- the program could not accept sufficient functions to define six degrees of freedom.

- the fins are expected to damp out initial spin due to gun rifling (900 RPM) in the first few seconds of flight. Sufficient spin to average projectile asymmetry errors to zero but not enough to significantly affect dynamics will remain.(ie. gyroscopic effects and Magnus effects)

- the initial spin damping dynamics are beyond the scope of this thesis.

The projectile was assumed to be axisymmetric allowing for ease of calculations in the yaw and pitch planes. Figures 2-2 and 2-4 depict the yaw and pitch planes for the model, respectively.

A listing of the equations is provided in the IODE specifications at Appendix F. Trajectory simulations were run with varying wind profiles and thrust error scenarios. Terminal guidance time (T_c) was determined by the baseline five degrees of freedom trajectory shown at Figure 2-1 as 101 seconds. This trajectory has no wind and thrust exactly equaled drag until discard of the air inlet spike and

canard deployment. All simulations assumed a 45 degree launch angle and Mach 2.2 muzzle velocity. Dispersion from the pseudo-vacuum trajectory was measured at terminal guidance time including the following variables:

- X=range at 101 seconds
- Y=crossrange at 101 seconds
- Z=height at 101 seconds
- Tb=burnout time
- Vcg=speed at time 101 seconds

Dispersion is defined as the difference between value for perturbed trajectories and the baseline trajectory.

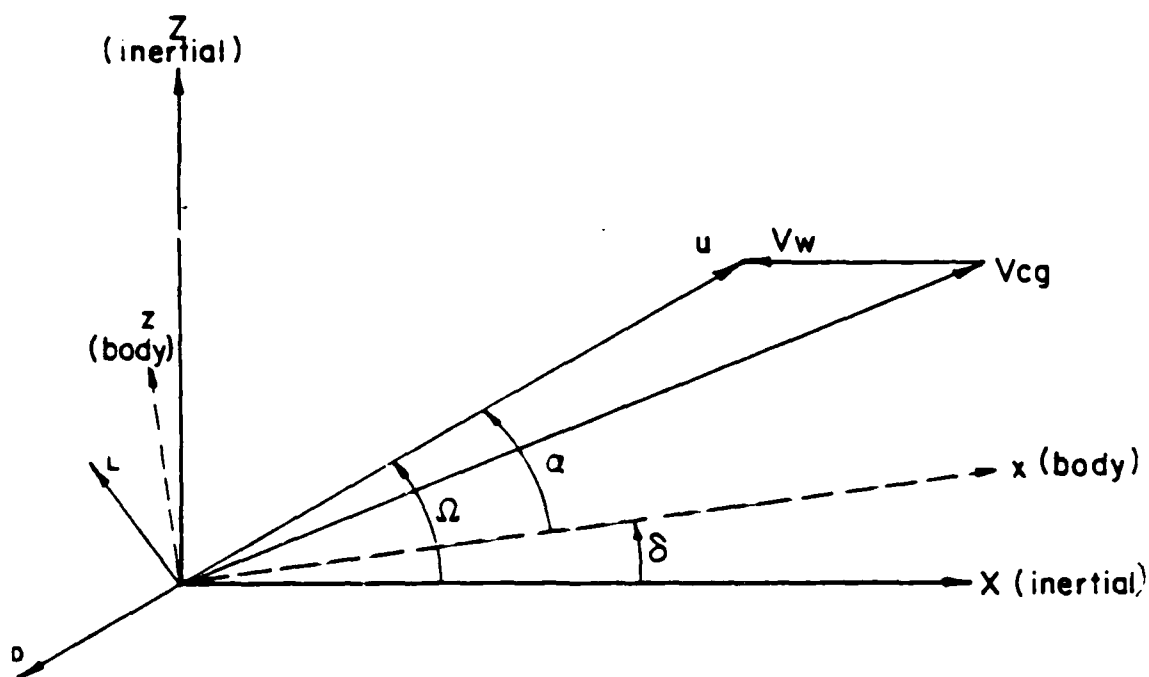


Figure 2-4 Five-Degrees-Of-Freedom Pitch Plane Model

D. SIX-DEGREES-OF-FREEDOM MODEL

The Ballistics Research Laboratories (Aberdeen) six degrees of freedom model HTRAJ was obtained and adapted for use on the NPGS IBM 370 system. The adapted listing is included as Appendix G. Program compilation was achieved but output data was not satisfactory due primarily to input data syntax problems. Further, the program requires extensive modification to be able to vary thrust as a function of drag with the ease of the previous models already described. Time was not available to correct these problems. Detailed documentation on the program HTRAJ is available through BRL.

III. TRAJECTORY RESULTS

A. THREE DEGREES OF FREEDOM

1. Crosswind And Thrust Error Sensitivity

Figures 3-1 and 3-2 show the effects of constant thrust errors as a percentage of drag with no wind. Recall that the three-degrees-of freedom trajectory is at constant altitude. The figures therefore represent a thrust error sensitivity in terms of burn time and range variations due to drag or thrust. The trajectories all pass nearly through the 218000 foot range mark at $t=100$ seconds, but the burnout ranges are significantly different due to the varying burn times resulting from projectile thrust. Figure 3-2 demonstrates the obvious conclusion that the burnout time decreases as thrust increases.

Figure 3-3 combines the effects of constant crosswinds and thrust errors to demonstrate resultant cross range dispersion. The constant wind velocity lines are very nearly linear, and the pattern is essentially a shift about the zero-zero point. If thrust is less than drag, the dispersion is in the direction of the wind vector. If thrust is greater than drag then the overcompensation produces a dispersion opposite to the wind vector.

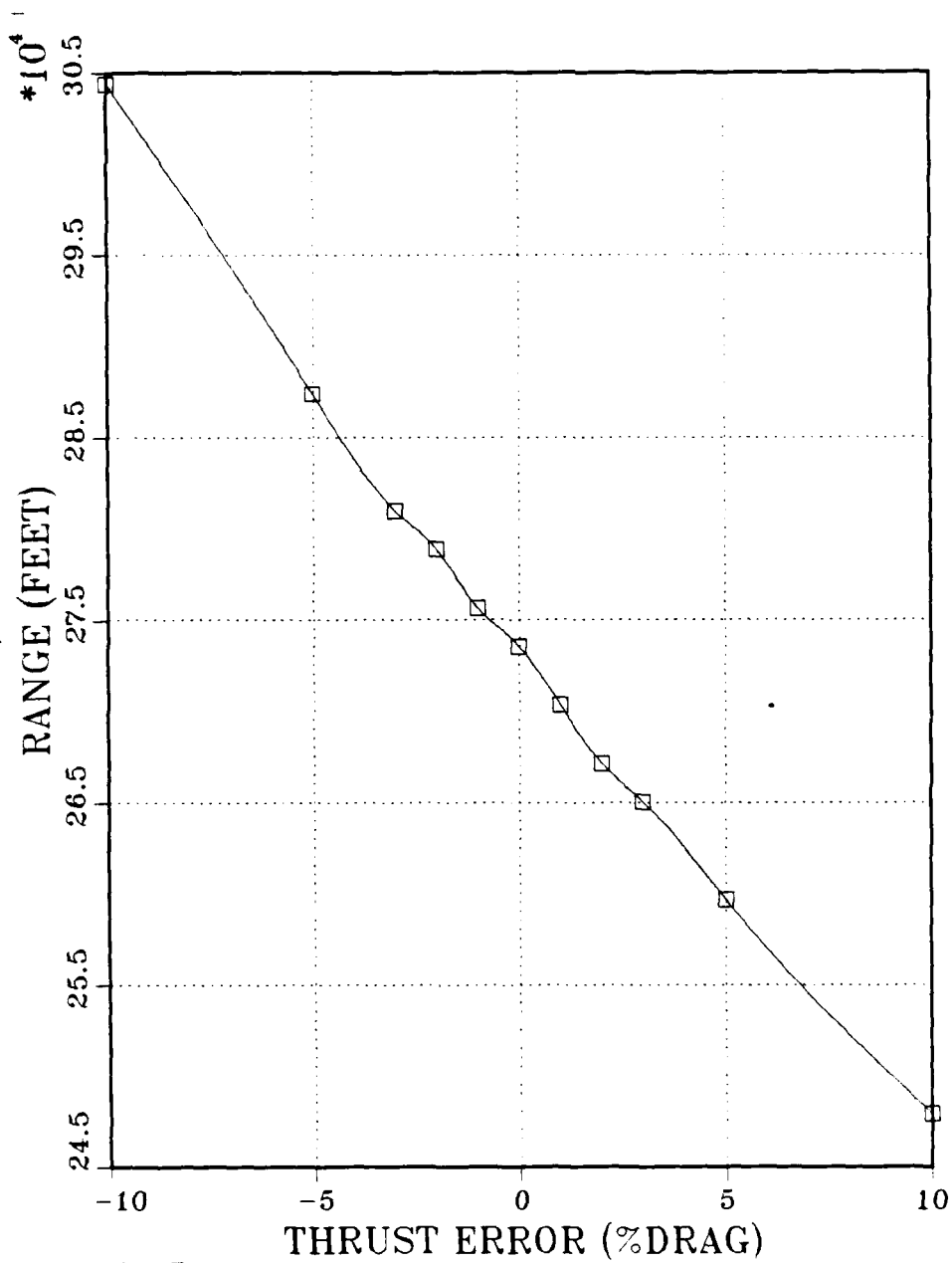


Figure 3-1 Thrust Error Sensitivity (Range)
Three Degrees Of Freedom

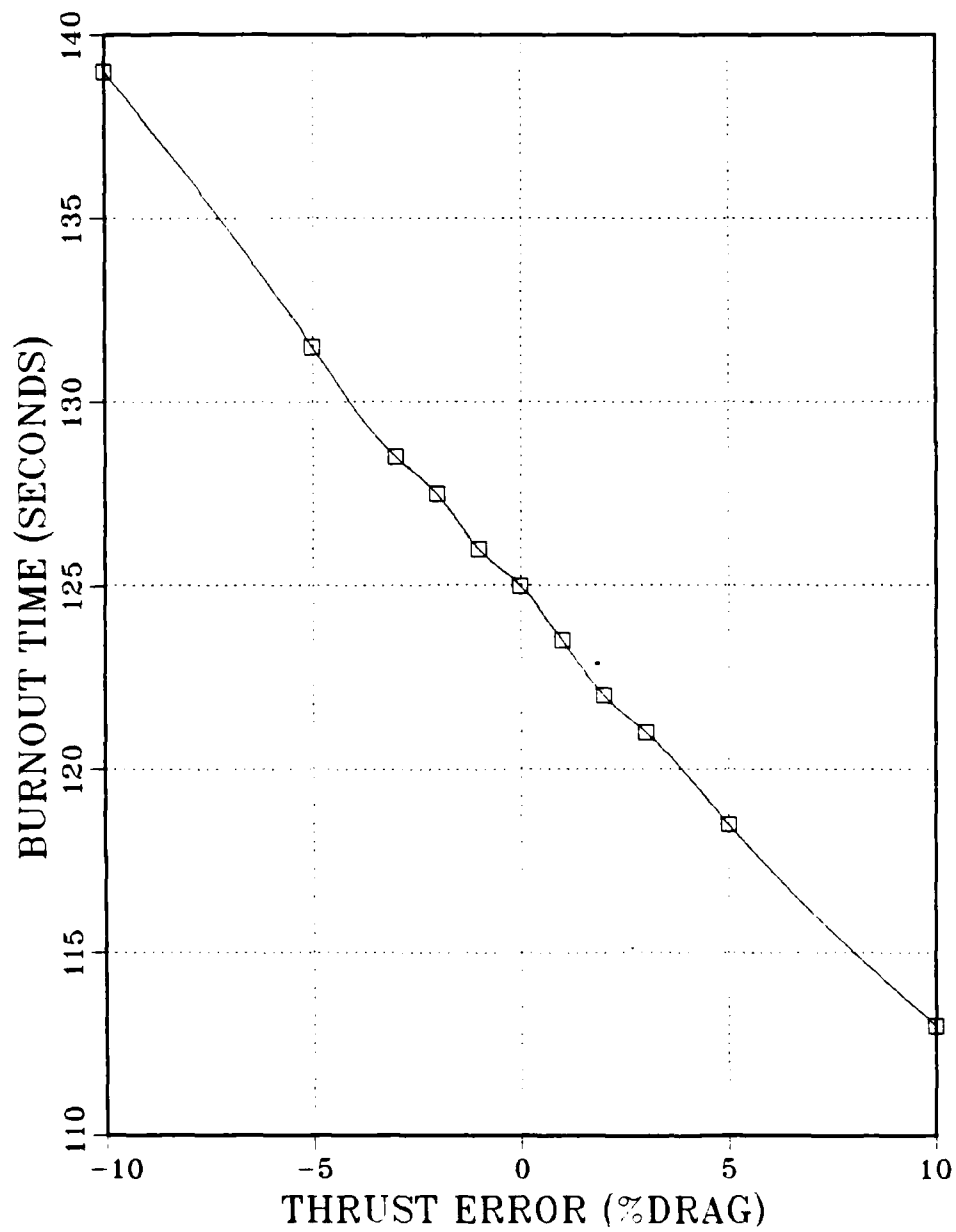


Figure 3-2 Thrust Error Sensitivity (Burntime)
Three Degrees Of Freedom

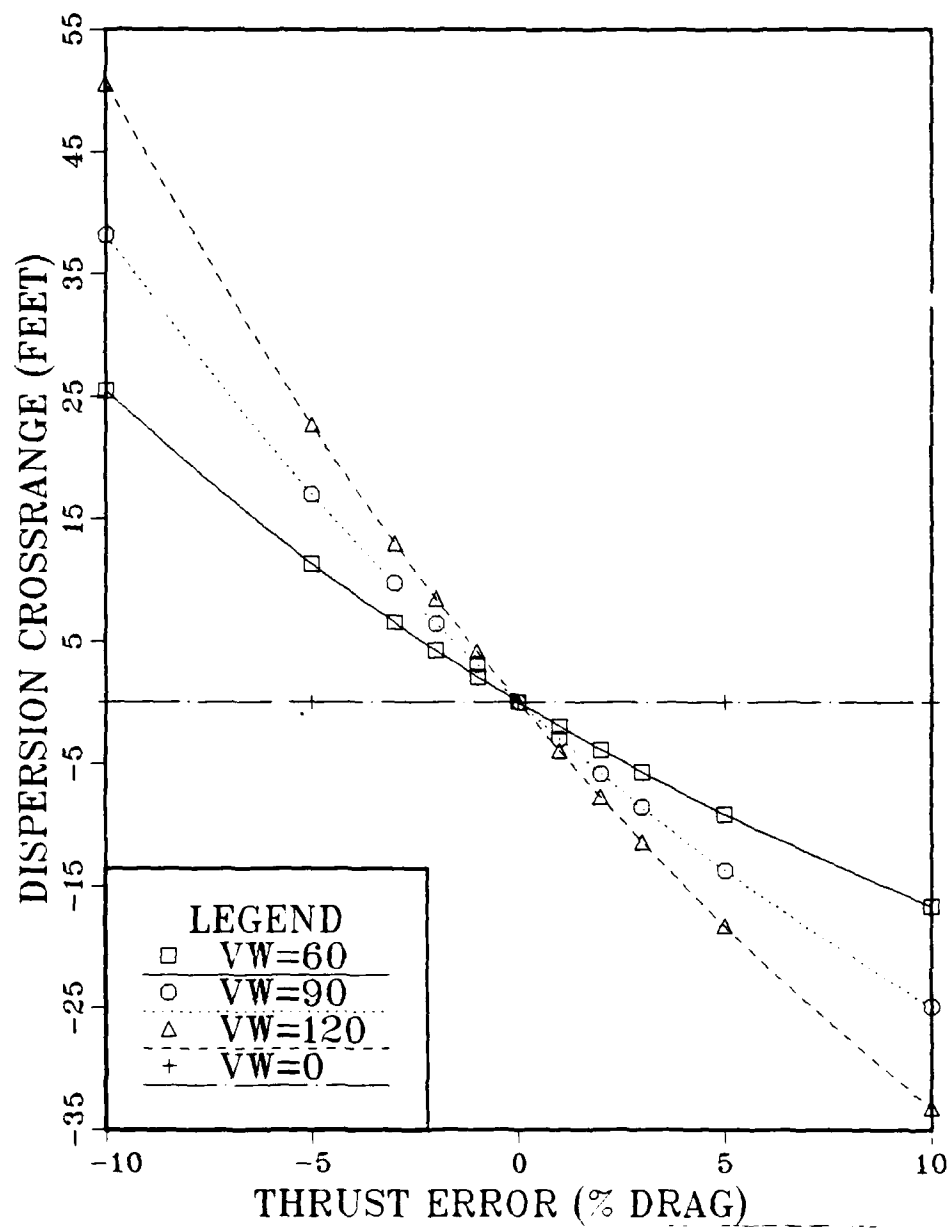


Figure 3-3 Crosswind Sensitivity Three Degrees Of Freedom

Of interest was the dispersion due to the same wind profiles without thrust or mass loss. This represents an absolute dispersion with a given wind profile. These results are in Table 3.1.

Table 3.1 No Thrust Crosswind Effects
Three Degrees of Freedom

Thrust=0 t=125 seconds	
vw (ft/sec)	dispersion (feet) crossrange
0	0
60	195.76
90	293.80
120	392.02

The data clearly shows that crosswinds have a minimal effect in the thrust scenarios. The dispersion in the thrust-equals-drag case is due to the transients (Lw) and is negligible as well. This is illustrated at Table 3.2.

Table 3.2 Dispersion Due to Net Lift
from Transients

Thrust=drag	
vw (feet/sec)	dispersion (feet) crossrange
0	0
60	.018
90	.027
120	.036

Angle of attack damped to virtually zero during the trajectories (see Figure E-3) but the absolute maximum values were also recorded. Figure 3-4 demonstrates the relation between angle of attack (α) and the wind velocity. Thrust errors had virtually no effect on the angle of attack magnitude.

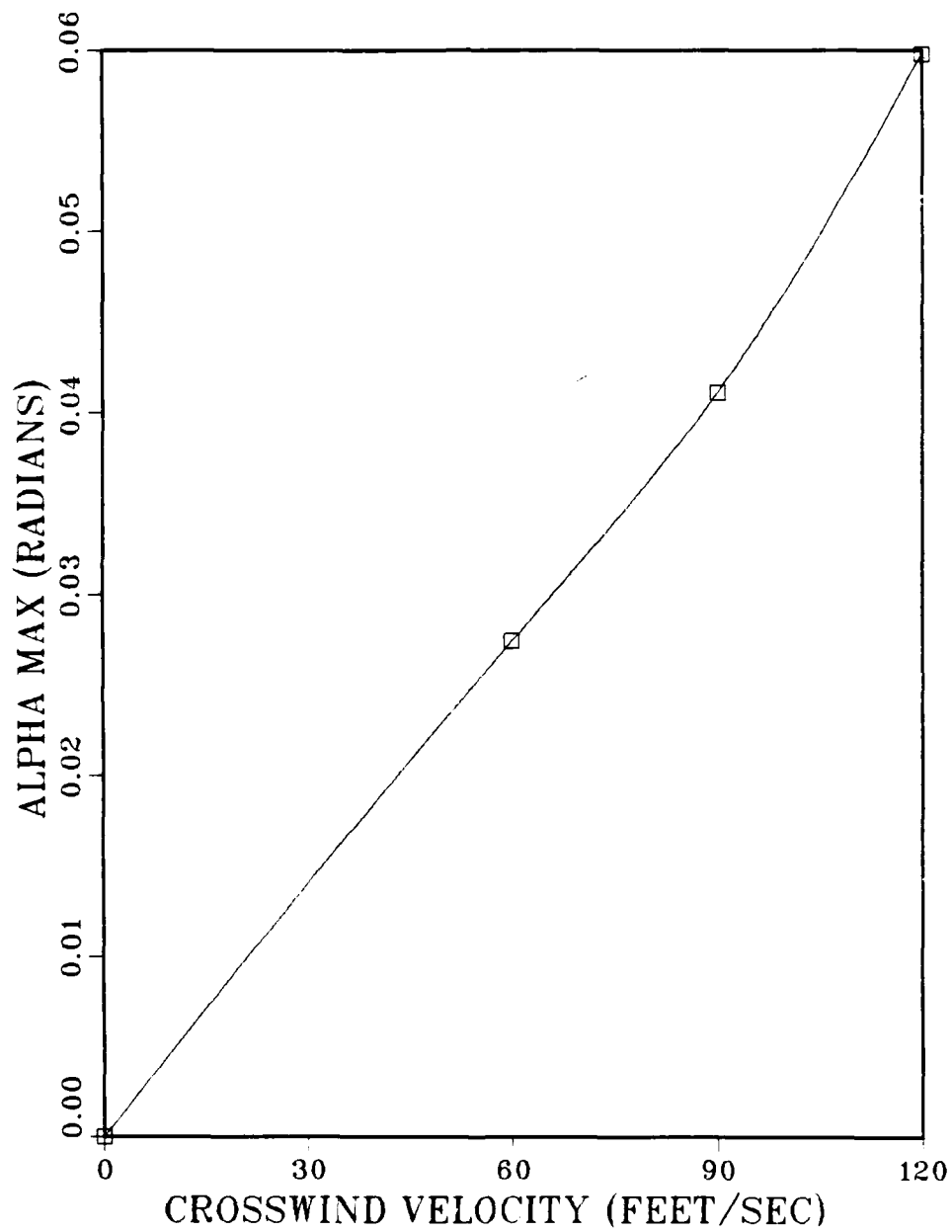


Figure 3-4 Wind Effects On Maximum Angle Of Attack

2. Damping Coefficient Effects

The magnitude of C_{mq} was determined to be approximately -200 in the flight speed ranges of the ARMT projectile [Reference 4]. To determine if this coefficient significantly affected dispersion C_{mq} was varied from 0 to 1.9×10^6 and the dispersion recorded. Figure 3-5 shows the relation between C_{mq} and dispersion (crossrange) with a constant wind of 60 feet/second and time of 125 seconds.

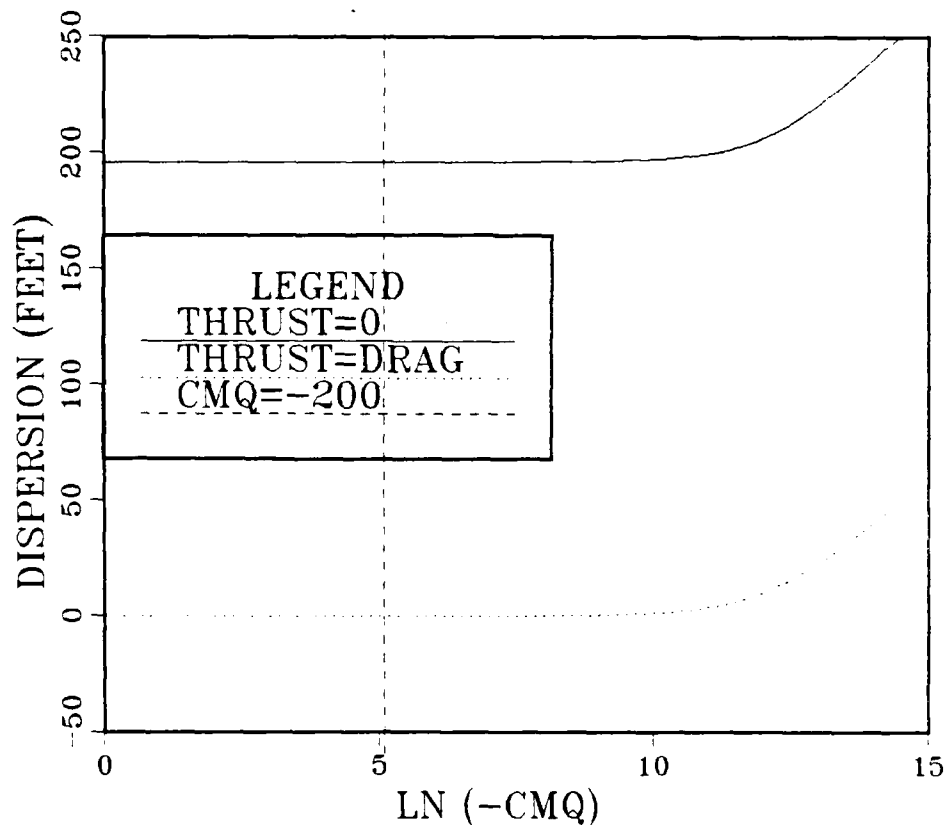


Figure 3-5 Damping Coefficient Effects

Careful examination of Figure 3-5 shows that dispersion increases slightly for realistic values of C_{mq} and is therefore proportional to C_{mq} . Due to the small sensitivity of dispersion to C_{mq} for all practical purposes one can conclude dispersion is independent to C_{mq} . (The increased dispersion proportional to C_{mq} can be explained as the difference in the areas under a highly damped sinusoid versus a non-damped sinusoid is considerable.)

3. Sinusoidal Wind Analysis

To test the effects of phase angles and wavelengths on the projectile dynamics a sinusoidal wind was input to test the model. The wind (V_w) was of the form $V_o \sin(2 \text{ PI } V_o t / \lambda + \text{phase})$ where V_o was set at 60 feet/second. Figures 3-6 and 3-7 show the trajectories for the sine and cosine winds to burnout at thrust equal to 90% drag. ($\lambda = \text{range}$ and $\lambda = .5 \text{ range}$) Of note is the fact that the sine wind produces a continuous dispersion while the cosine wind does not when thrust does not equal drag. This discovery led to an expanded study of different phase and wavelength sinusoidal wind inputs for various thrust scenarios. As well a simplified model was constructed as shown at Figure 3-8 and calculations confirmed the three degrees of freedom model results. Figures 3-9 and 3-10 depict the results of the calculations.

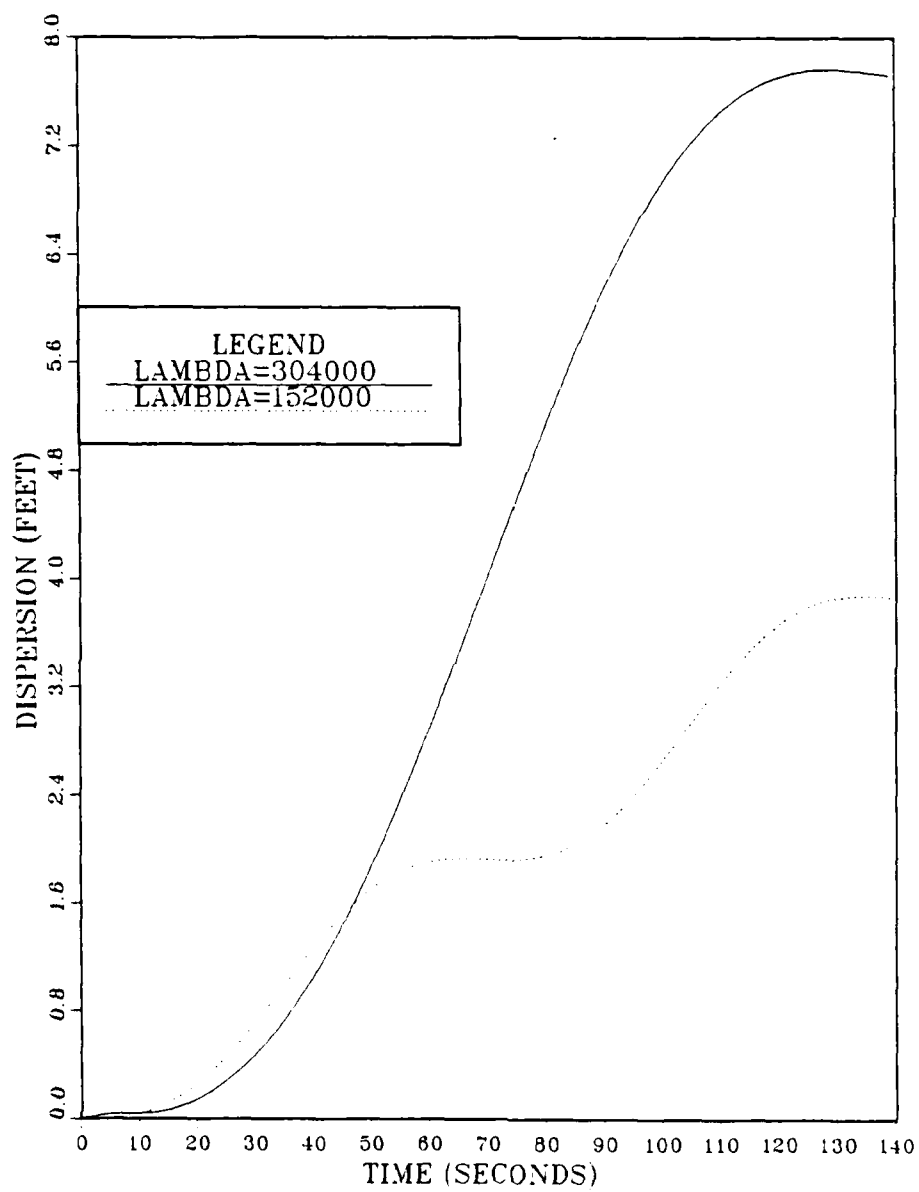


Figure 3-6 Sinusoidal Wind Effects (Sine)

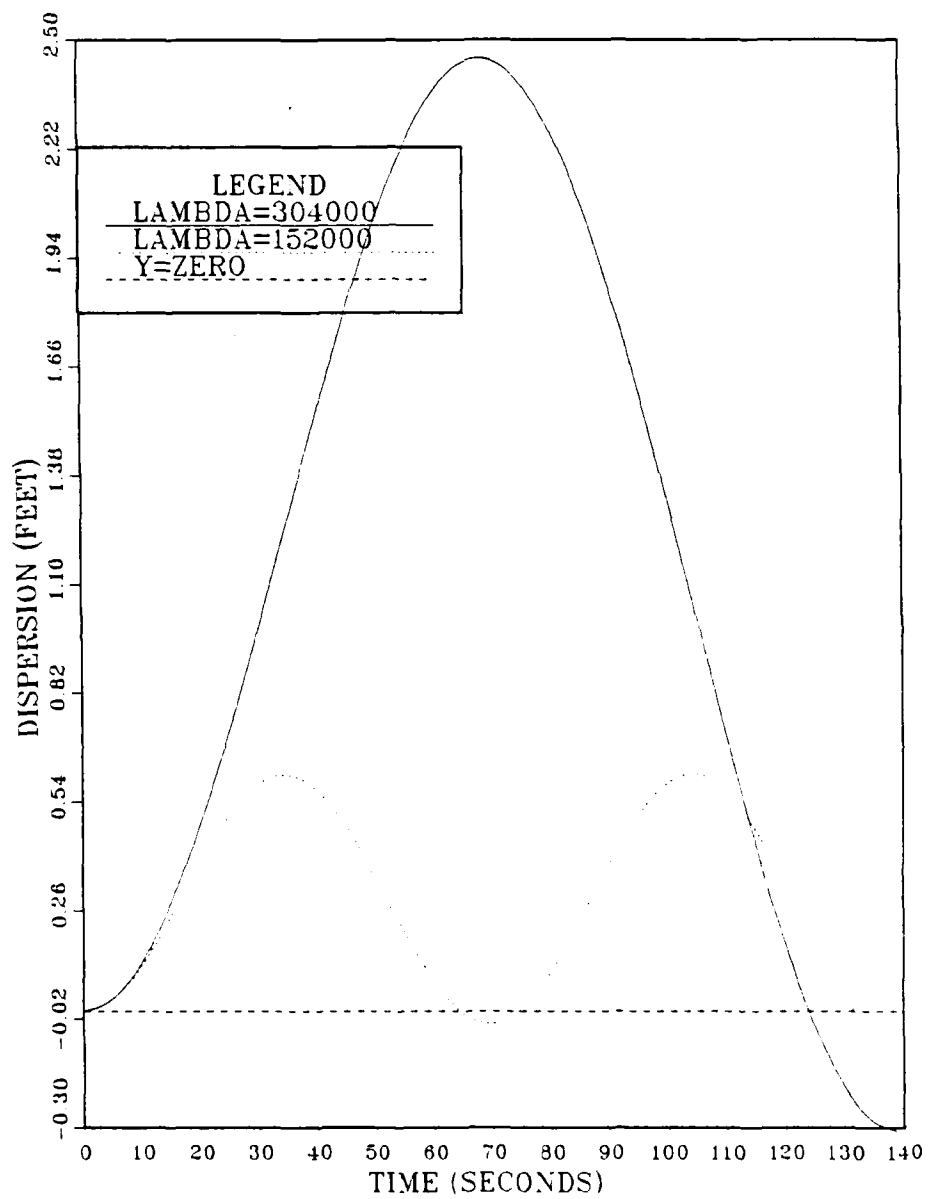


Figure 3-7 Sinusoidal Wind Effects (Cosine)

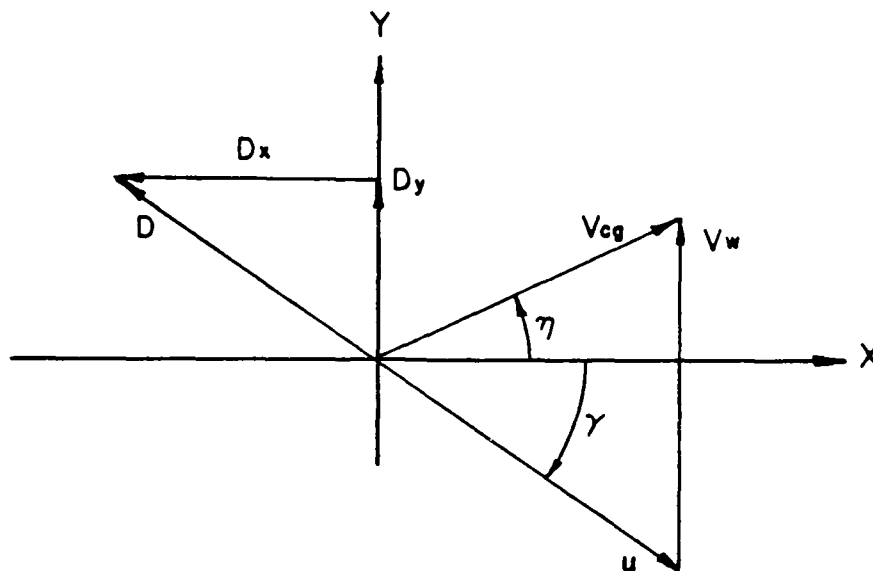


Figure 3-8 Simplified Three Degrees Of Freedom Model

The simplified model was used to analytically evaluate the crossrange dispersion (y) in the cases of sine and cosine winds to confirm the validity of the three-degrees-of-freedom model. Calculations follow:

General equations of motion in the y direction from Figure 3-8 are:

$$M \frac{dV_y}{dt} = D_y \text{ which approximately equals } D(V_w - V_y)/V_{x0}$$

if $V_{x0} = V_0 = \text{constant}$. Then transforming the equation we get:

$$dV_y/dt + D/(MV_0)V_y = D/(MV_0)V_w(t)$$

or in time differentiated notation:

$$\ddot{y} + B \dot{y} = B V_w(t) \quad \text{if } D/(M V_o) = B$$

If a cosine wind $V_w(t) = V_{wo} \cos(2 \pi V_o t / \lambda)$ is applied and the differential equation solved we have:

$$y(t)/\lambda = K \left[e^{-Bt} - \cos(2 \pi V_o t / \lambda) + \frac{D \lambda \sin(2 \pi V_o t / \lambda)}{2 \pi m V_o^2} \right]$$

$$\text{let } K = \frac{2 \frac{1}{2} m V_o^2 V_{wo}}{D \lambda V_o} \frac{1}{1 + \left[\frac{4 \pi D \lambda}{1/2 m V_o^2} \right]^2}$$

Figure 3-9 graphically depicts the results as t increases. A zero asymptote is observed and this conforms with model results.

Now if a sine wind $V_w(t) = V_{wo} \sin(2 \pi V_o t / \lambda)$ is applied and the differential equation solved:

$$y(t)/\lambda = K \left[\frac{D \lambda}{4 \pi 1/2 m V_o^2} (1 - \cos(2 \pi V_o t / \lambda)) - \sin(2 \pi V_o t / \lambda) + \frac{4 \pi (1/2 m V_o^2) (1 - e^{-Bt})}{D \lambda} \right]$$

Figure 3-10 graphically depicts these results as t increases. The asymptote is

$$K \left[\frac{(4 \pi 1/2 m V_o^2)}{D \lambda} (1 - e^{-Bt}) \right]$$

and this conforms to the model also.

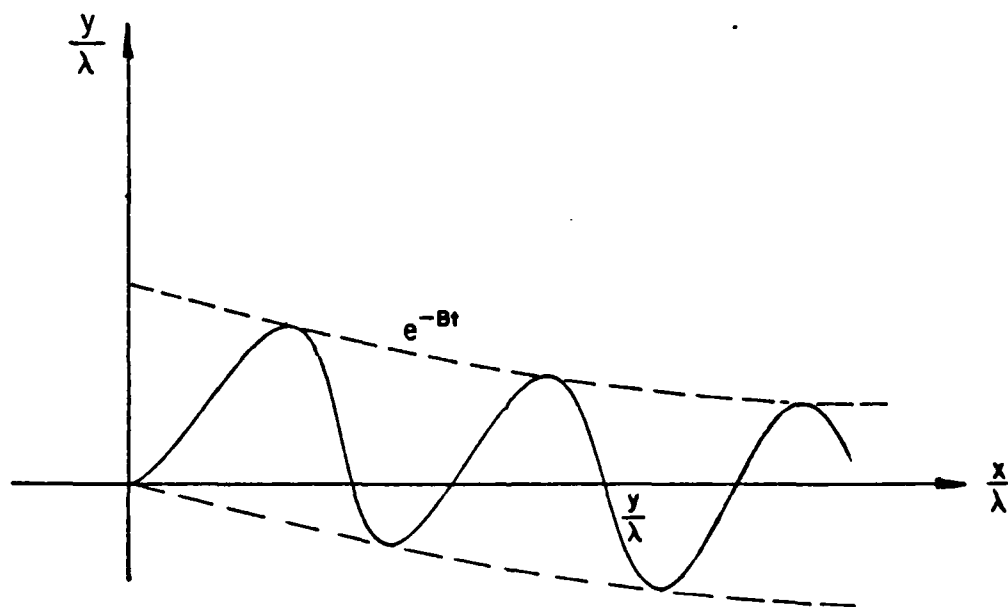


Figure 3-9 Cosine Wind Analysis Results

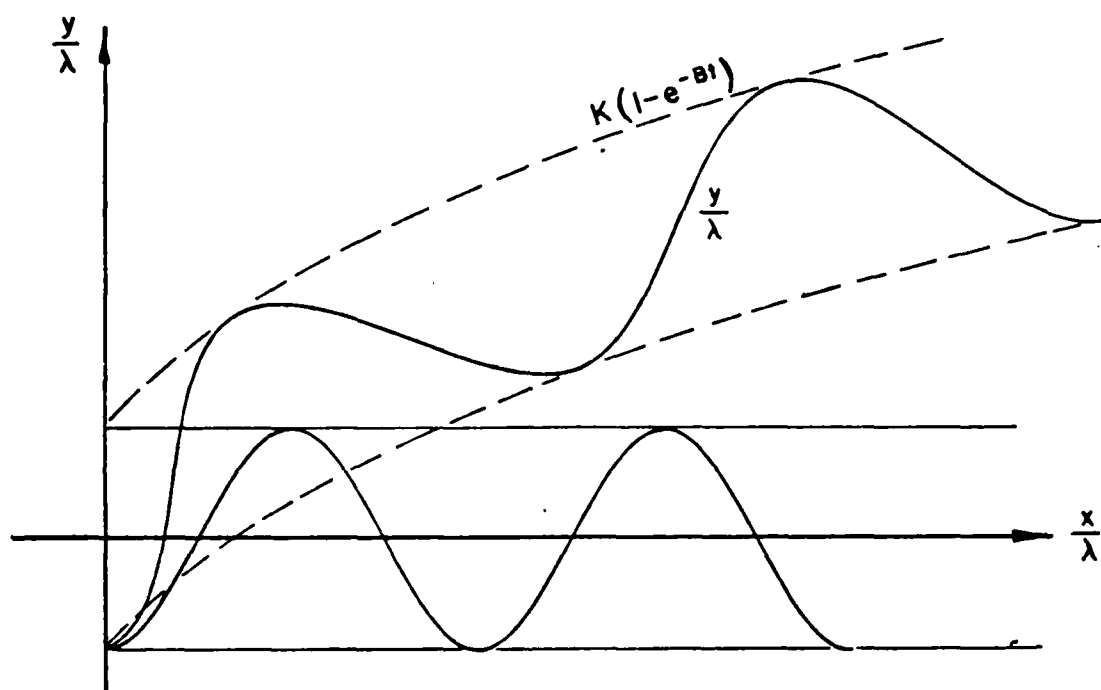


Figure 3-10 Sine Wind Analysis Results

The constant wind case was also derived:

$V_w(t) = V_w$ and the solved differential equation is:

$$y(t) = V_w t - V_w m V_o / D e^{-Bt}$$

and as t increases y approaches $V_w t$.

Specific calculations were done to confirm dispersion results at burnout. The calculations were based on:

$$y = dy/dx \cdot X = 1/V_o \cdot dy/dt \cdot X$$

$$V_{wo} = 60 \text{ ft/sec}$$

$$V_o = 2190 \text{ ft/sec}$$

$$\lambda = 304000 \text{ ft}$$

$$t = \lambda / V_o$$

$$D = 1/2 \rho V_o^2 A C_d (=226 \text{ lbf})$$

$$\text{Thrust} = .9D \text{ therefore } D = 22.6 \text{ lbf}$$

$$M = 225 \text{ lbm}$$

Taking the time derivative of the cosine wind $y(t)$ dispersion formula derived earlier we get

$$dy/dt = K \left[-B e^{-Bt} + \frac{2 \text{ PI } V_o}{\lambda} \sin(2 \text{ PI } V_o t / \lambda) + \right. \\ \left. \frac{D \lambda}{4 \text{ PI } 1/2 m V_o^2} \cdot \frac{2 \text{ PI } V_o}{\lambda} \cos(2 \text{ PI } V_o t / \lambda) \right]$$

at $t = \lambda/V_0$ the equation becomes:

$$dy/dt = K(-Be^{-B\lambda/V_0} + B)$$

and substituting the values into the approximationn
for y ; $y=0$ ft.

Now, performing the same operations on the sine
wind dispersion equation :

$$dy/dt = K \left[\begin{aligned} &\frac{D\lambda}{4 \text{ PI } 1/2 m V_0^2} \cdot \frac{2 \text{ PI } V_0 \sin(2 \text{ PI } V_0 t/\lambda)}{\lambda} \\ &- \frac{2 \text{ PI } V_0 \cos(2 \text{ PI } V_0 t/\lambda)}{\lambda} + \frac{(4 \text{ PI } 1/2 m V_0^2)}{D\lambda} \cdot \\ &(Be^{-Bt}) \end{aligned} \right]$$

and at $t = \lambda/V_0$

$$dy/dt = K \left[\frac{-2 \text{ PI } V_0}{\lambda} - \frac{4 \text{ PI } 1/2 m V_0^2 \cdot Be^{-Bt}}{D\lambda} \right]$$

and $y=20$ ft approximately.

Finally, taking the constant wind dispersion
formula and taking its derivative :

$$dy/dt = V_w - V_w e^{-Bt}$$

and $y=10$ ft approximately.

These results are consistent with the three-degrees-of-
freedom model considering the initial approximations.

To study the short period resonance phenomenom the
phase and wavelength wind variations were documented in

detail for a condition of thrust equal to 90% drag. Figures 3-11 to 3-13 show the crossrange dispersion effects from wavelengths of 5000 ($\lambda = .016$ range) to 303000 ($\lambda = \text{range}$) feet and the phase angle variations from 0 to 2 PI. At approximately 9850 feet the dispersion characteristics were no longer symmetric but remained under one foot. This is demonstrated at Figure 3-14. A crossrange dispersion contour was constructed at Figure 3-15 but this did not emphasize the resonance phenomenon sufficiently due to linearized aerodynamics and small dispersion magnitudes. The parameters that varied most significantly near resonance were angle of attack and burn time. Indeed, it is clear that the projectile is unstable in this region with a maximum angle of attack of 1.21 radians (70 degrees). Due to the increased angle of attack, drag increased and burn time decreased in the order of seven seconds (5%) compared to the baseline trajectory. This clearly affected the range at burnout. Due to large angle of attack the linearized aerodynamics are not valid. Projectile performance at wind resonance is worthy of additional analysis. It was decided to demonstrate resonance by plotting the maximum angle of attack (α) versus wavelength with different thrust/ drag scenarios. The resonance results are at Figure 3-16. The projectile natural frequency is estimated at 0.22 Hz. Resonance was confirmed in the 0.22 Hz regime for thrust

errors under 10% including varying V_{wo} . This was necessary as the system is non-linear and V_{wo} could have affected resonance. It was noted that the curve shifted and increased or decreased in magnitude slightly in each case. This is due to the non-linearity of the system equations and the variations in V_o during flight. The absolute case of no thrust showed resonance at 10000 feet with a maximum angle of attack of 1.25 radians (72 degrees).

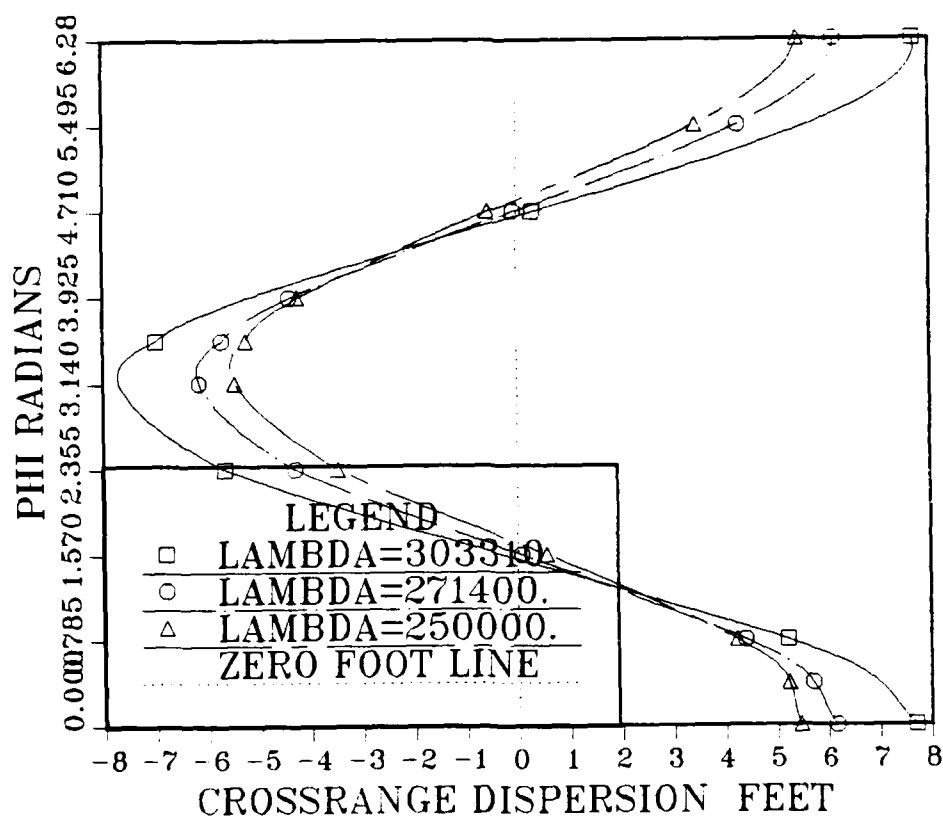


Figure 3-11 Dispersion Versus Wind Phase Angle (Large Lambda)

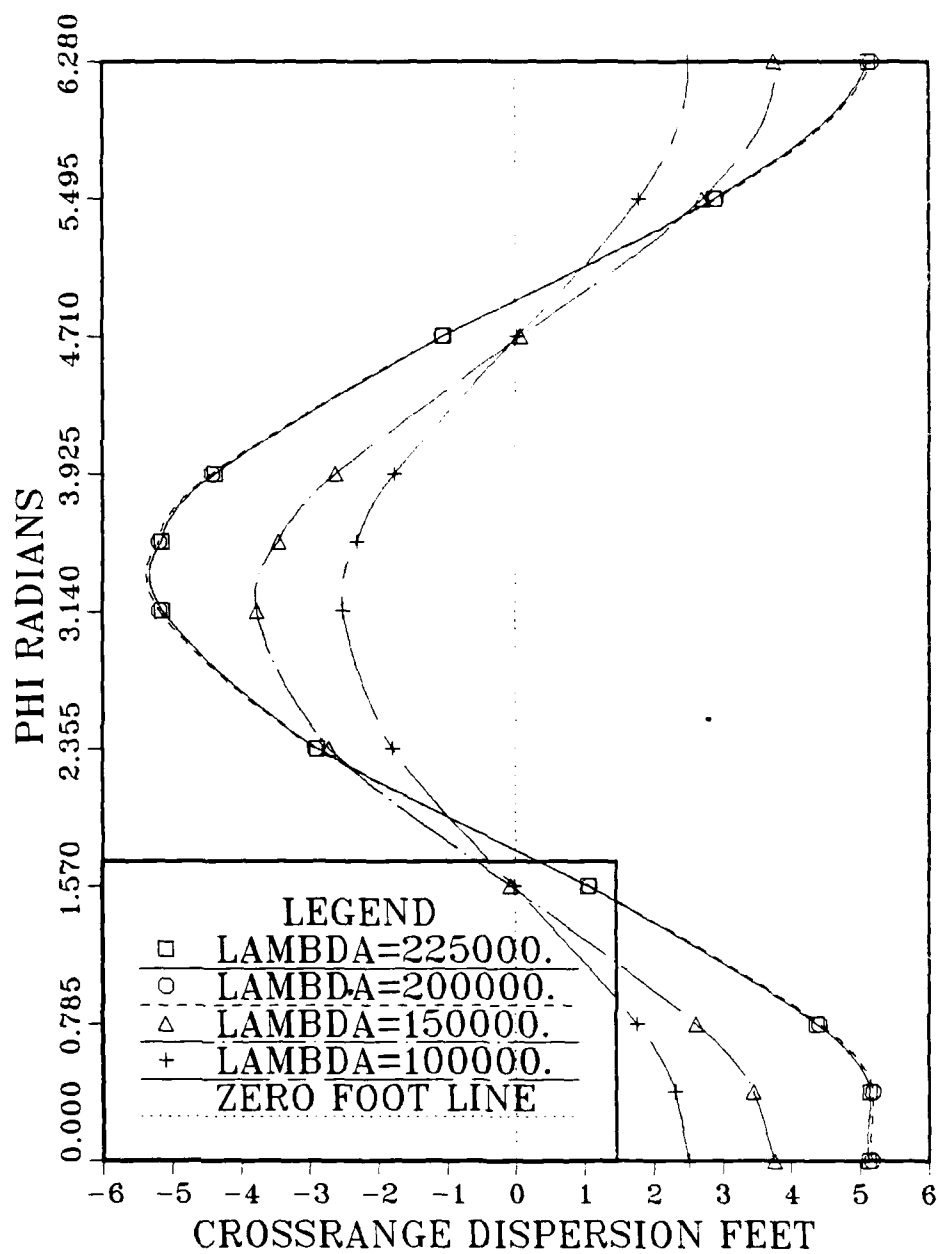


Figure 3-12 Dispersion Versus Phase Angle
(Medium Lambda)

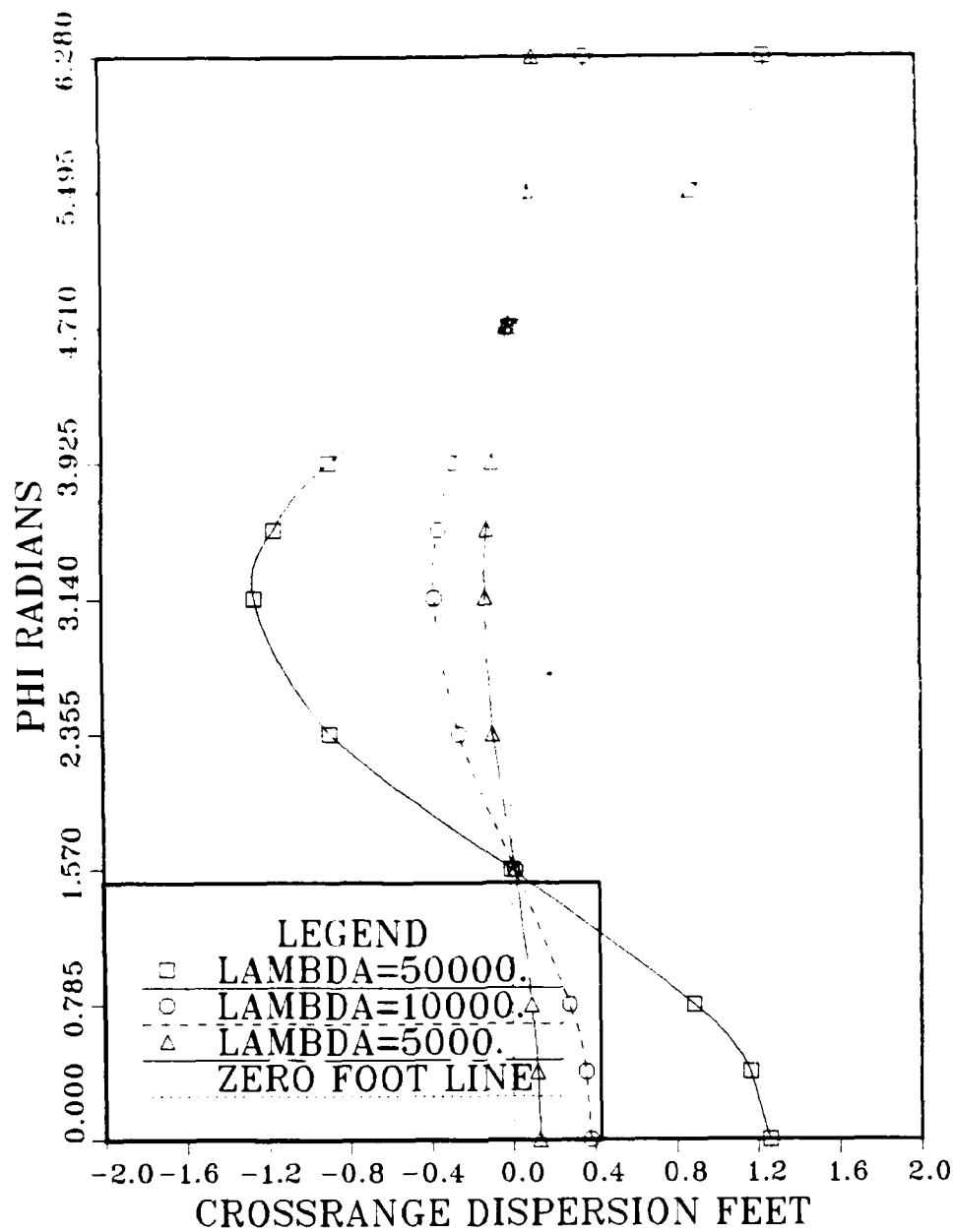


Figure 3-13 Dispersion Versus Phase Angle (Small Lambda)

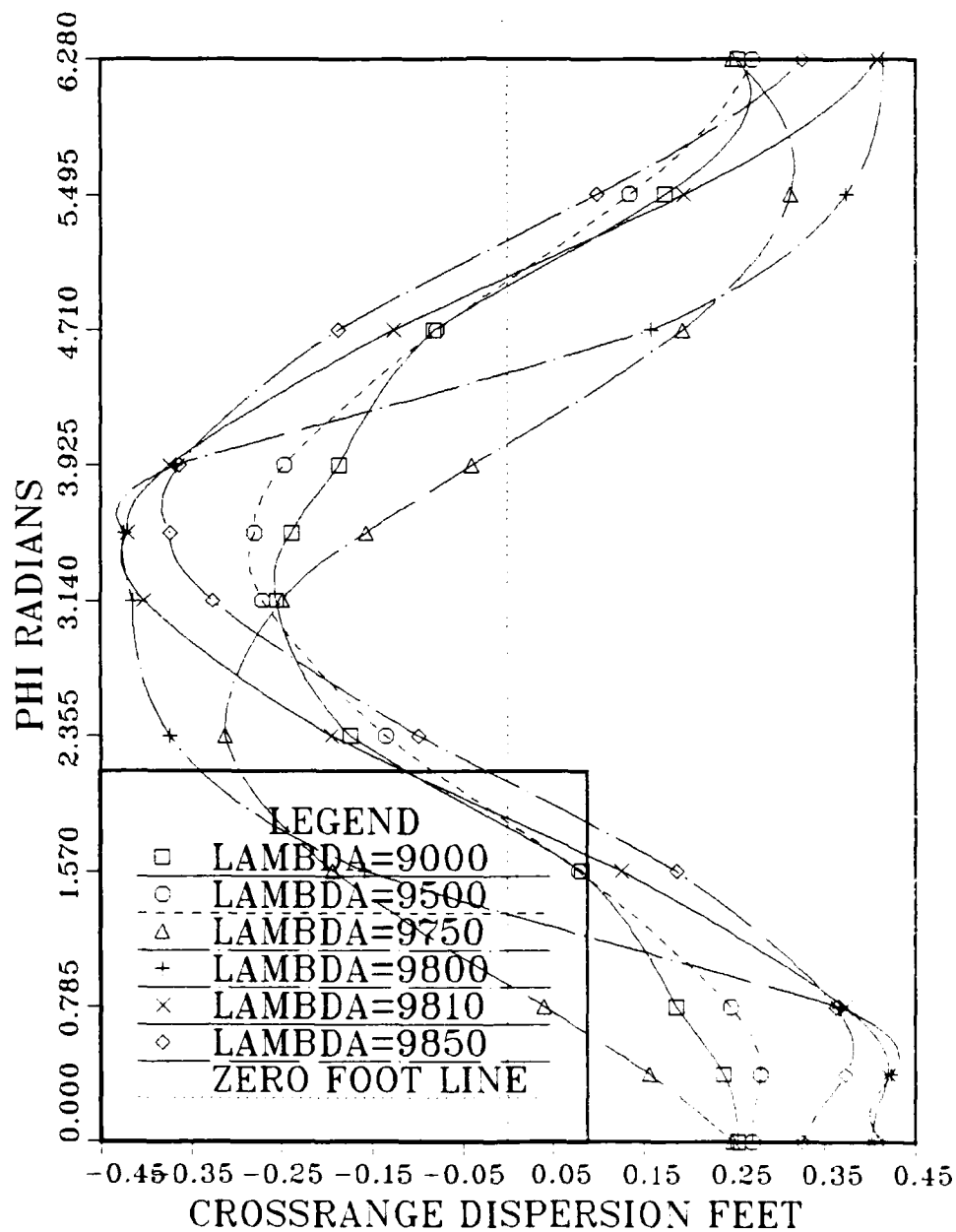


Figure 3-14 Dispersion Versus Phase Angle
Resonance Lambda

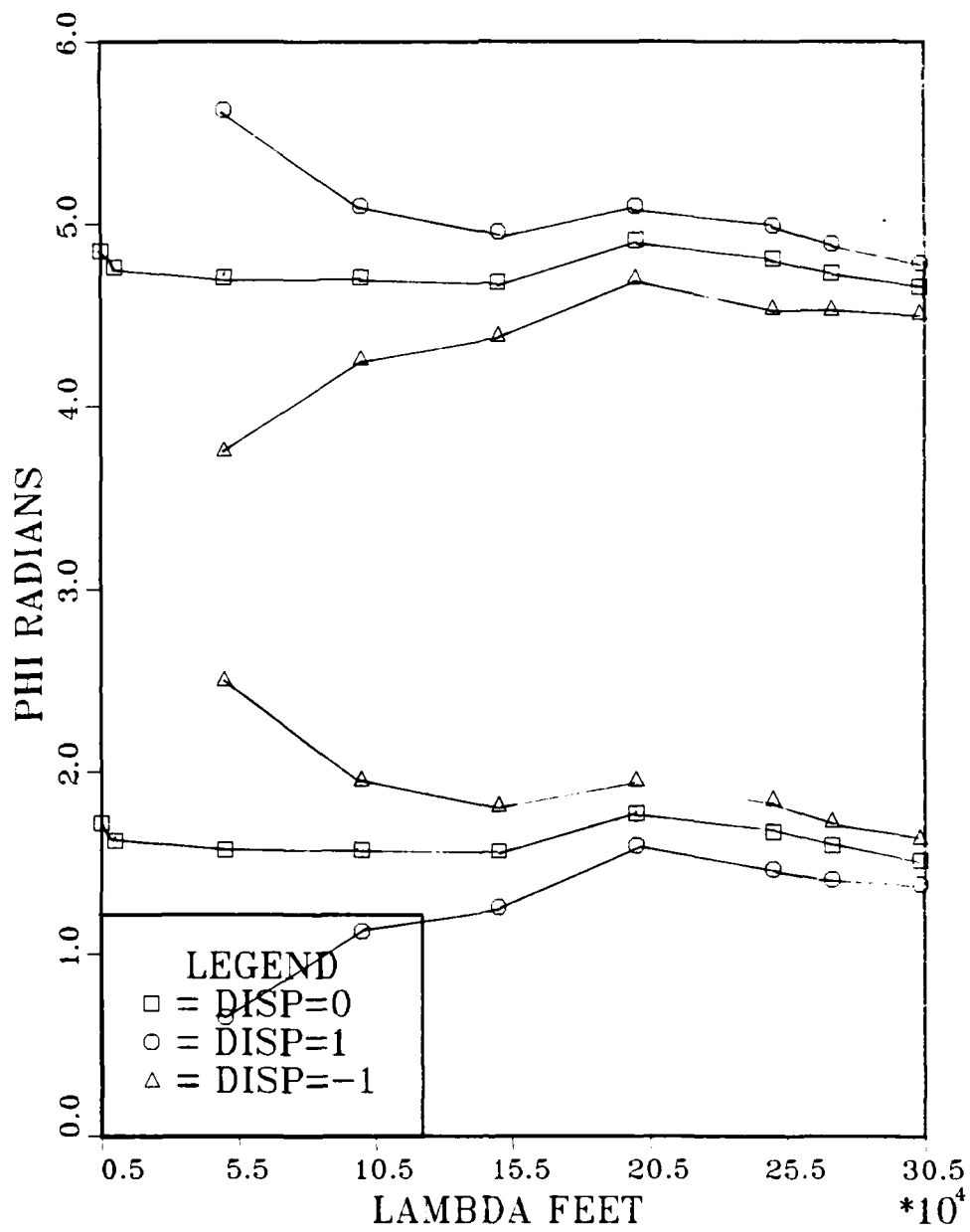


Figure 3-15 Phase Angle Versus Wavelength

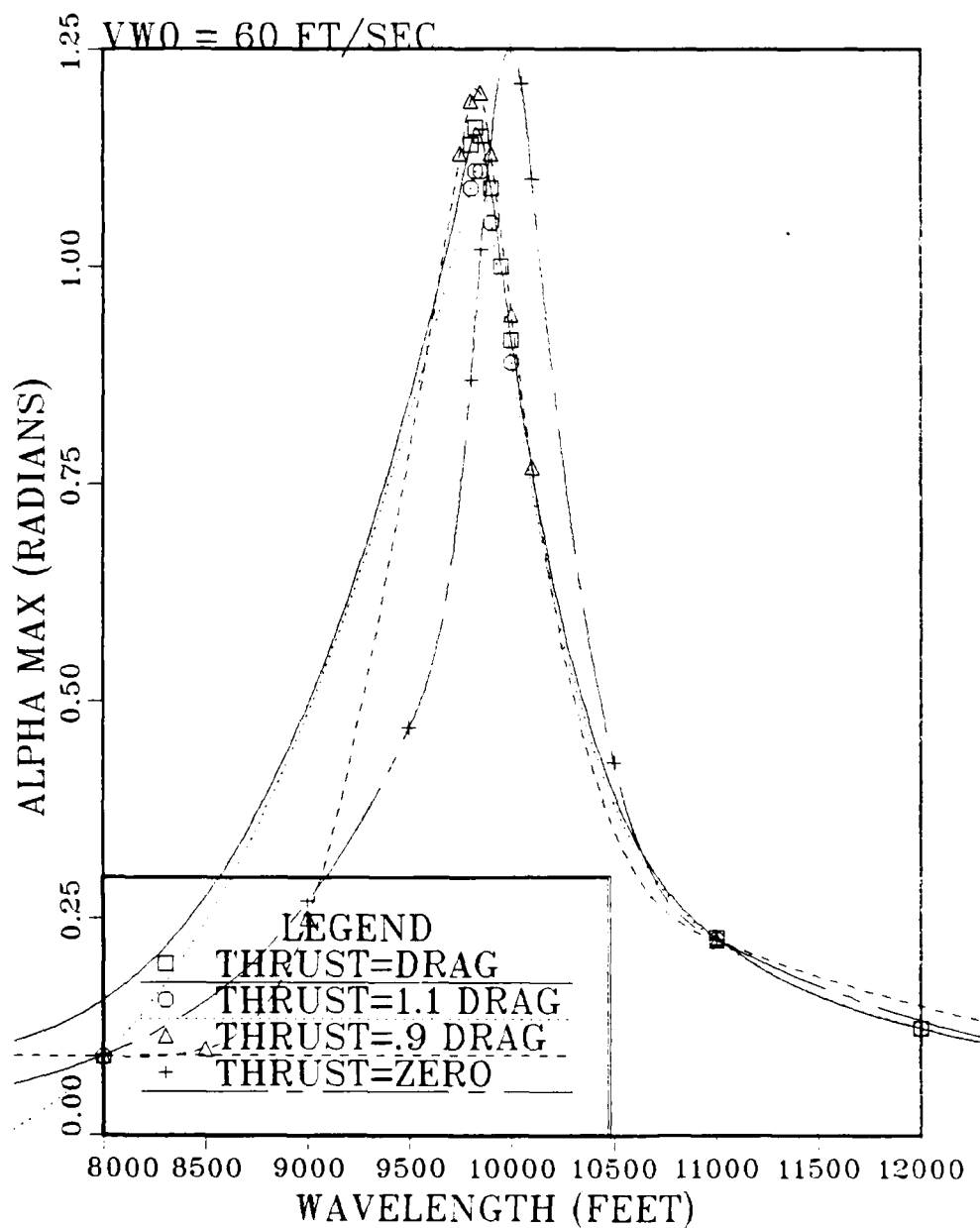


Figure 3-16 Detrimental Resonance Between Projectile
Short Period and Spatial Frequency of
Wind Profile

It is clear that if the wind profile experienced by the projectile has harmonic content near the natural frequency then the round will be unstable and/or have large dispersion at burnout. This is best illustrated by viewing the wind as $V_w(t)$ with reference to the projectile. By a Fourier transform of the wind profile resonance with projectile natural frequency (f_n) will be evident in the frequency domain. The wind oscillations need only be velocity variations with the appropriate harmonic content. Figure 3-17, which illustrates this concept, shows f_n coinciding with a maximum of $V_w(f)$. One would anticipate stability problems for this case.

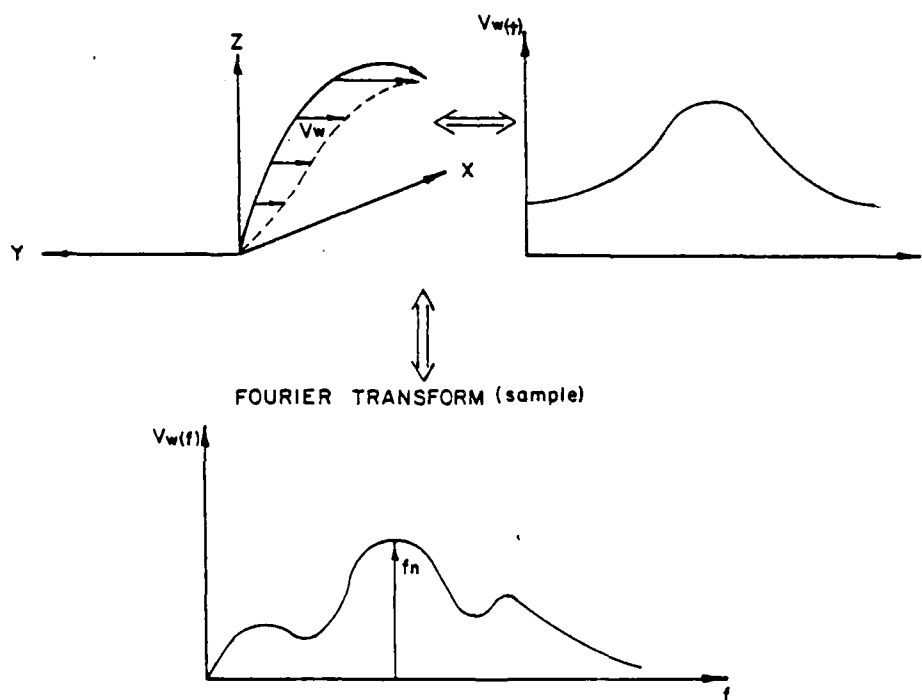


Figure 3-17 Fourier Transform Of Wind Profile Concept

Calculations for the long period resonance or phugoid show that the phugoid is irrelevant as flight time is too short:

$$T=4.44*V_0/g=301.8 \text{ seconds [Reference 3]}$$

The results of the sinusoidal winds were also compared with the aerodynamic jump phenomenon outlined in BRL report 1077 [Reference 4]. At first glance the sinusoidal wind results appear consistent with aerogump, but detailed calculations show otherwise. The rate of change of initial angle of attack is critical to aerogump and is easily incorporated into the aerogump equation. The results for the sine wind are a function of wavelength and of the same form as the simplified model results but the cosine wind and constant wind both yielded a small aerogump proportional to the initial wind. The magnitudes of the aerogump dispersions were more consistent with the net lift transient effects. Further, continuous perturbations in the form of wind after time zero are not in the aerogump equations and for all practical purposes the phenomenon is not observed in the model. These results should have been apparent before calculations were performed. Aerogump equations are not appropriate for non-zero wind conditions. Clearly, when wind is included the aerogump equations cannot predict dispersion.

B. FIVE DEGREES OF FREEDOM

As previously stated dispersion was measured from the ideal pseudo-vacuum trajectory at a fixed time for initiation of terminal guidance (T_c) 101 seconds. Thrust error sensitivity in the zero wind condition is presented in Figures 3-18 and 3-19. In these two figures it is clear that thrust errors can have a significant impact on the location of the projectile at the T_c . Figure 3-18 indicates that as thrust increases the dispersion moves downrange as expected. Figure 3-19 shows that as thrust increases the height of the projectile at T_c decreases. Due to added thrust the projectile is located at a point further along the parabolic trajectory; hence the height is less.

As well Figure 3-20 shows these effects on available burn time of the ramjet. For thrust equals drag burnout at 101 seconds exactly equals the T_c . With less thrust, terminal guidance is initiated before all the propellant is burned. Conversely, when thrust exceeds drag, burnout occurs prior to initiation of terminal guidance. Assuming this fixed time for initiation of terminal guidance, the projectile may experience up to seven seconds of unpowered flight (7% error) before the guidance is deployed. The period of unpowered flight with associated high drag will cause major dispersions as shown in subsequent figures.

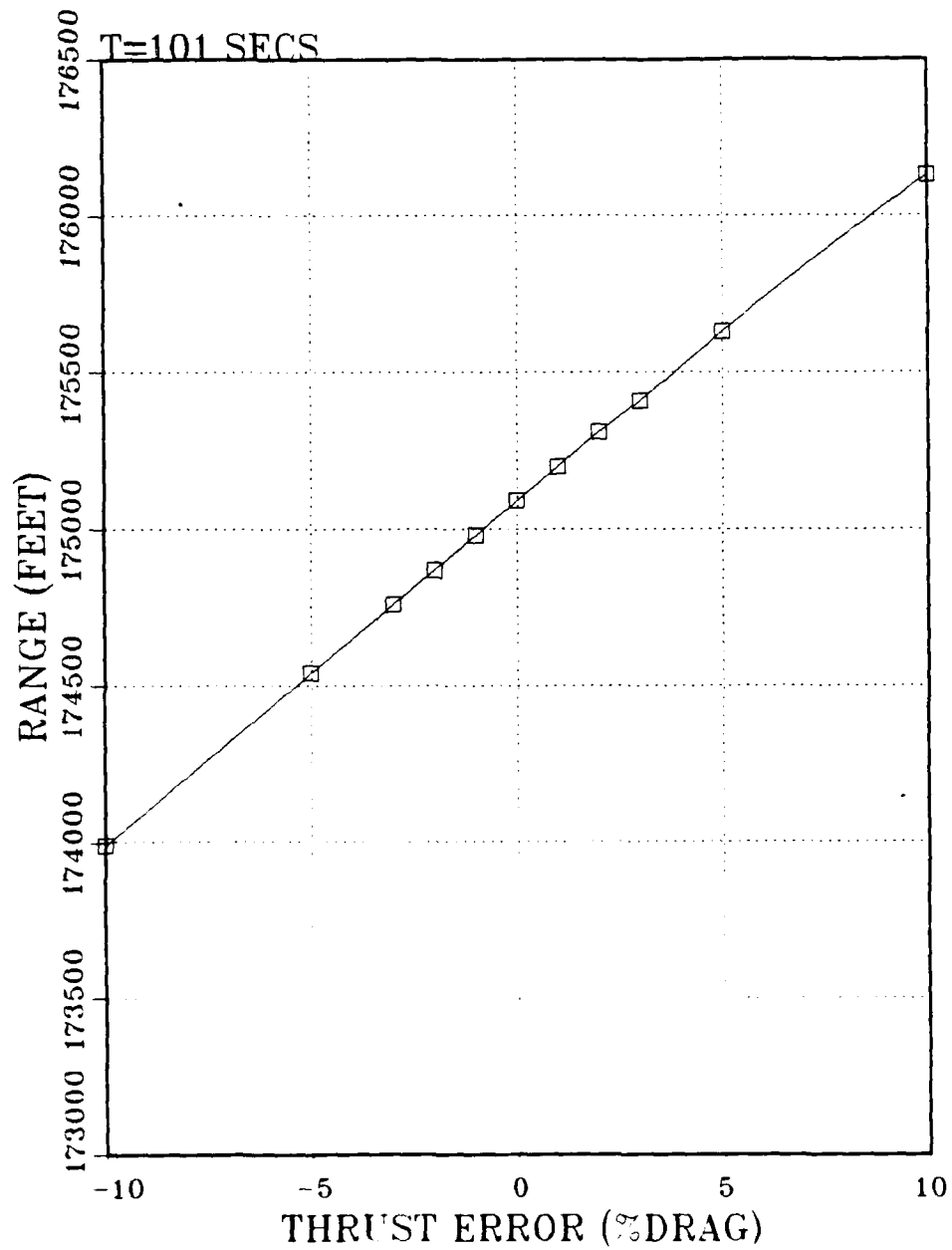


Figure 3-18 Thrust Error Effects (Range)

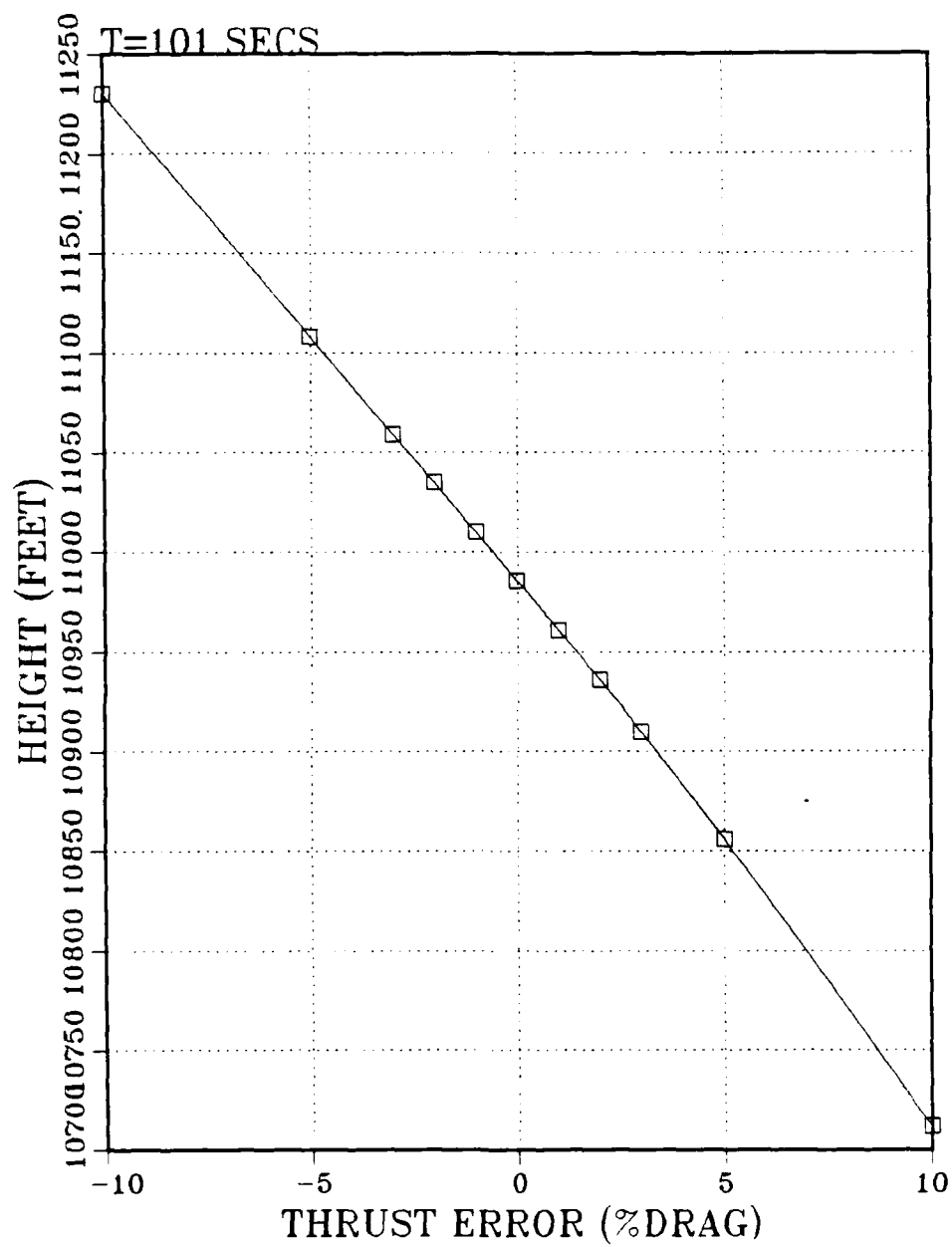


Figure 3-19 Thrust Error Effects (Height)

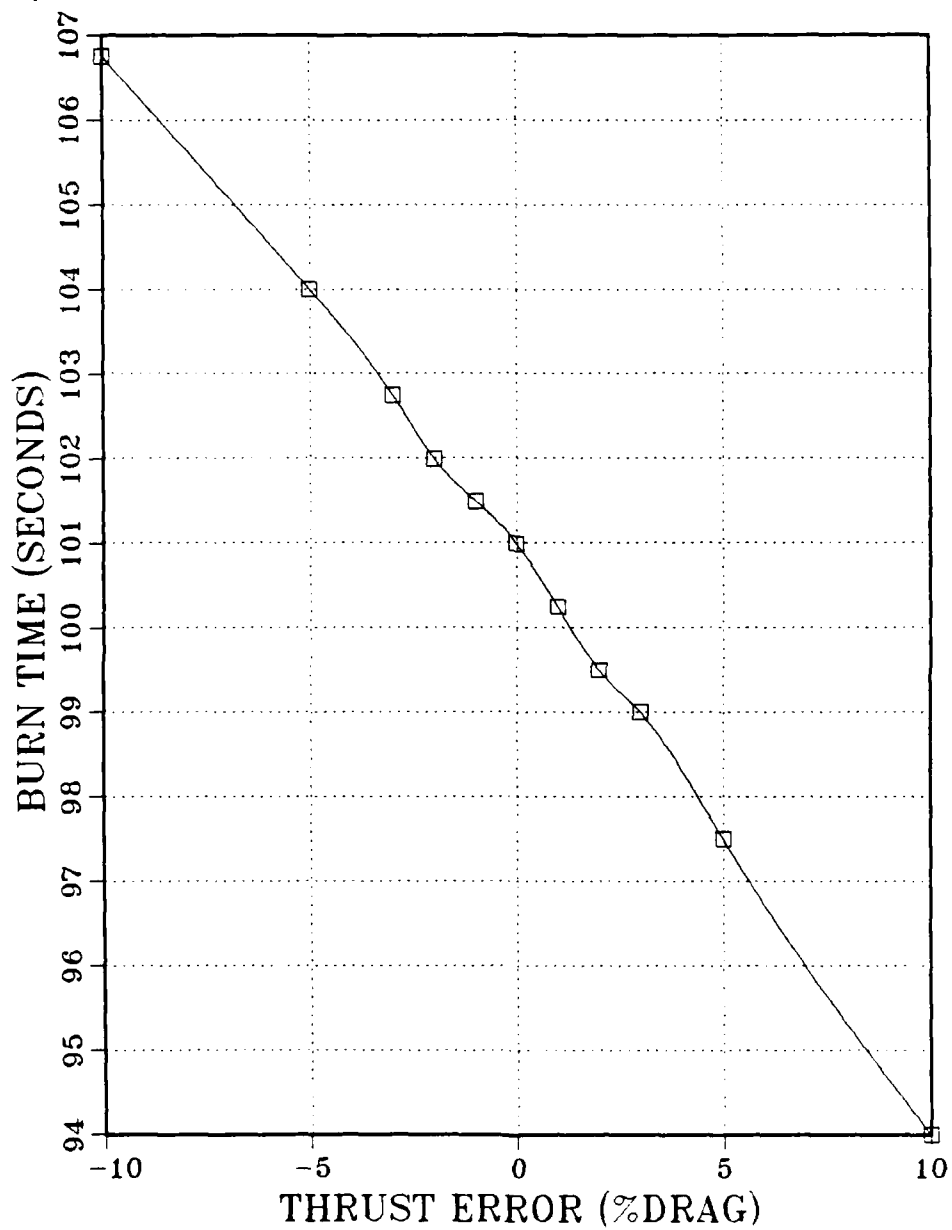


Figure 3-20 Thrust Error Effects (Burn Time)

Crosswind sensitivity results were very much the same as the three degree simulation. In fact the results appear even more linear with the same rotation about the zero zero point as in Figure 3-21. The gross features of Figure 3-3 and 3-21 are identical but Figure 3-3 shows dispersion at burnout whereas Figure 3-21 shows dispersion at T_c .

The crossrange dispersion results of a no thrust projectile with constant crosswind profiles and with thrust equal to drag (transients effects) are at Tables 3.3 and 3.4 respectively.

Table 3.3 No Thrust Wind Effects
Five Degrees

Thrust =0 time=101 seconds	
Vwxy(feet/sec)	diapersion (feet) crossrange
0	0
30	92.51
60	185.11
90	272.90
120	370.97

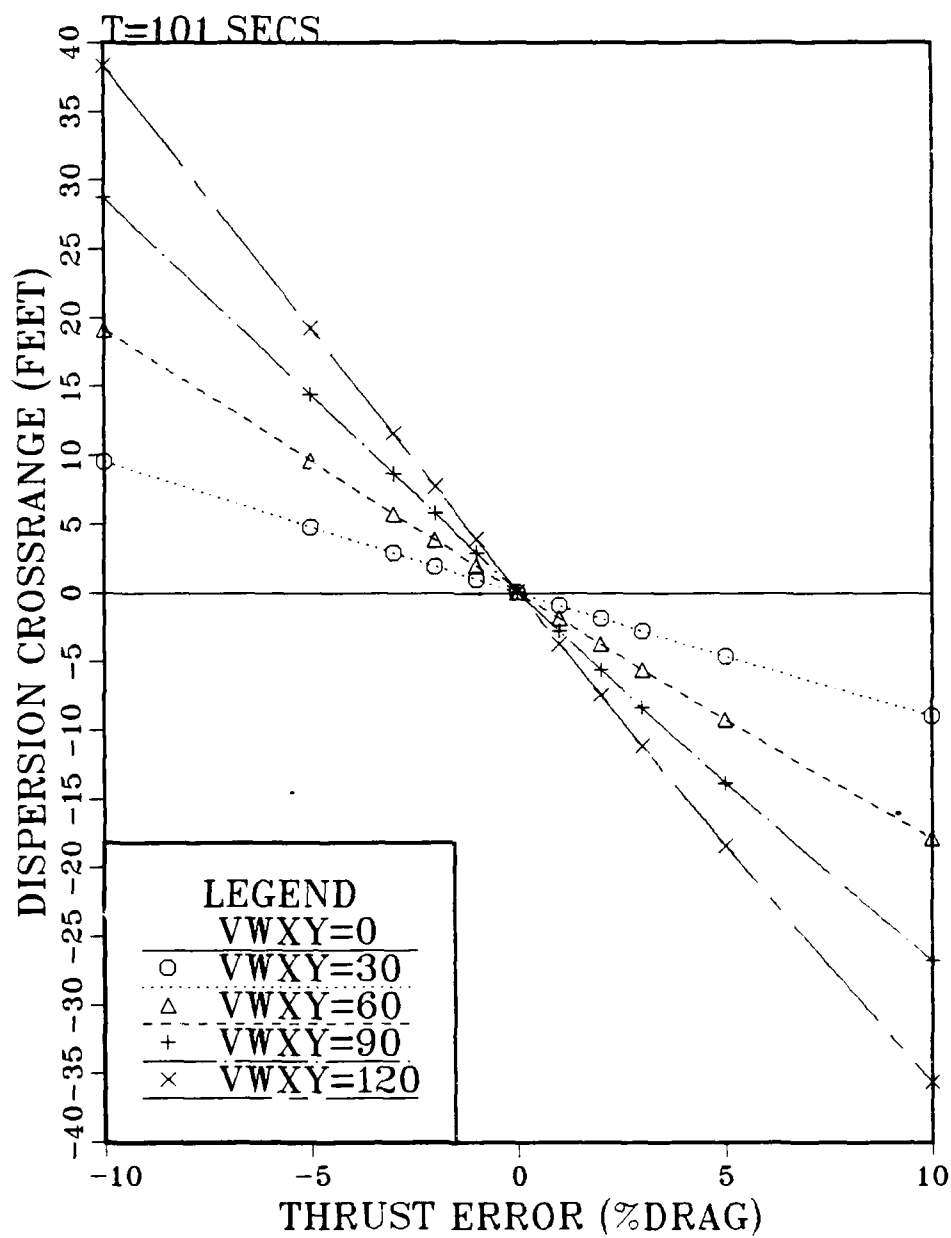


Figure 3-21 Crosswind Effects Five Degrees

Table 3.4 Dispersion Due to Net Lift
from Transients

Thrust=drag time=101 secs

Vwxy(feet/sec)	dispersion(feet)
0	0
30	.0202
60	.0413
90	.0643
120	.0919

Burn time was not significantly affected by crosswinds.

Headwind and tailwind effects on range,height and burntime in different thrust scenarios are shown in Figures 3-22 to 3-26. It is clear that dispersion from the pseudo-vacuum trajectory is minimized when thrust nearly equals drag.It is also apparent that the overthrust trajectories involve greater dispersion as burnout occurs prior to terminal guidance and unpowered flight occurs for some time dependent on the scenario.This same error is observed in the case of headwinds and is most clear in the Figures 3-22B to 3-25B about the thrust equal to drag axis. (Note that Figure 3-22 to 3-25 inclusive have A,B and C sub-figures which are simply enlargements of key portions of the respective main figure).

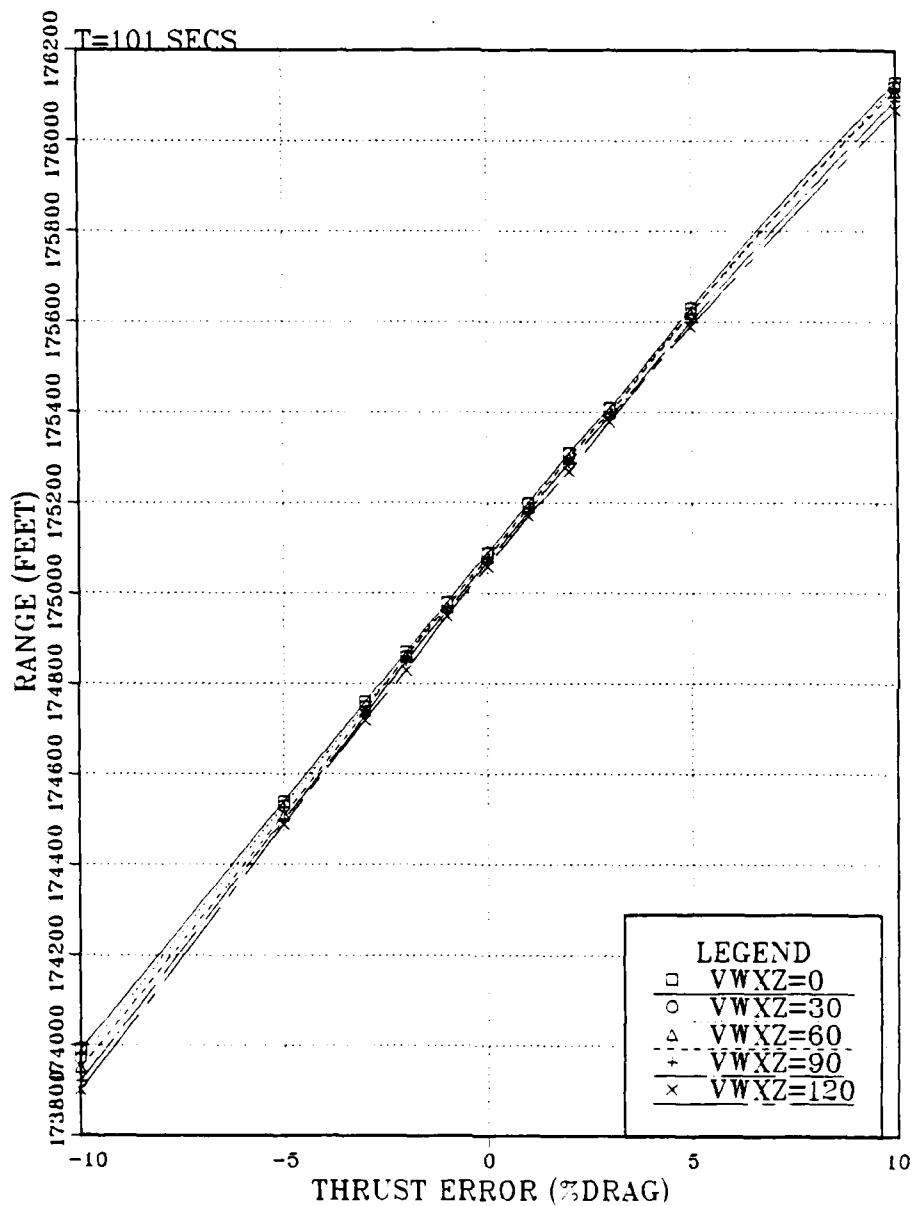


Figure 3-22 Headwind Sensitivity (Range)

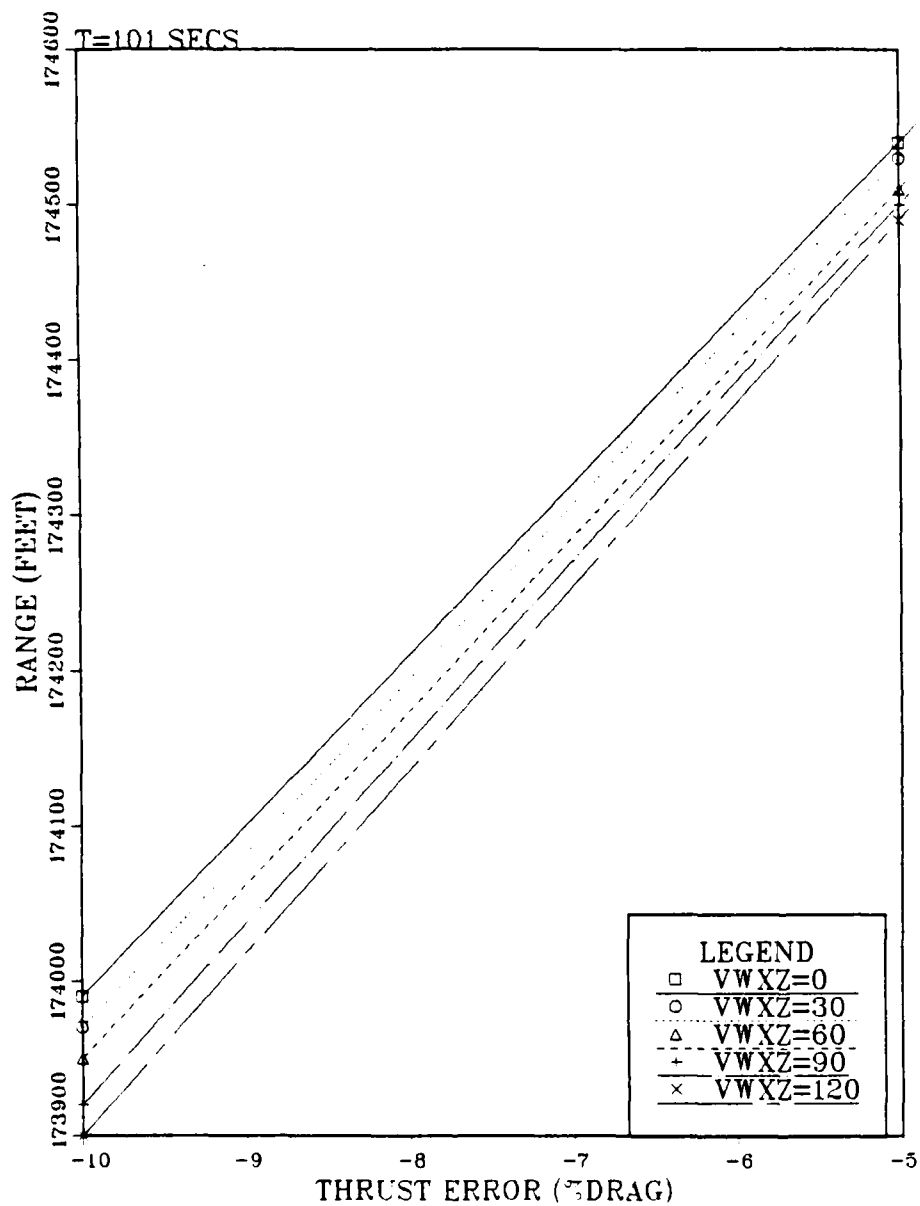


Figure 3-22A Headwind Sensitivity (Range)

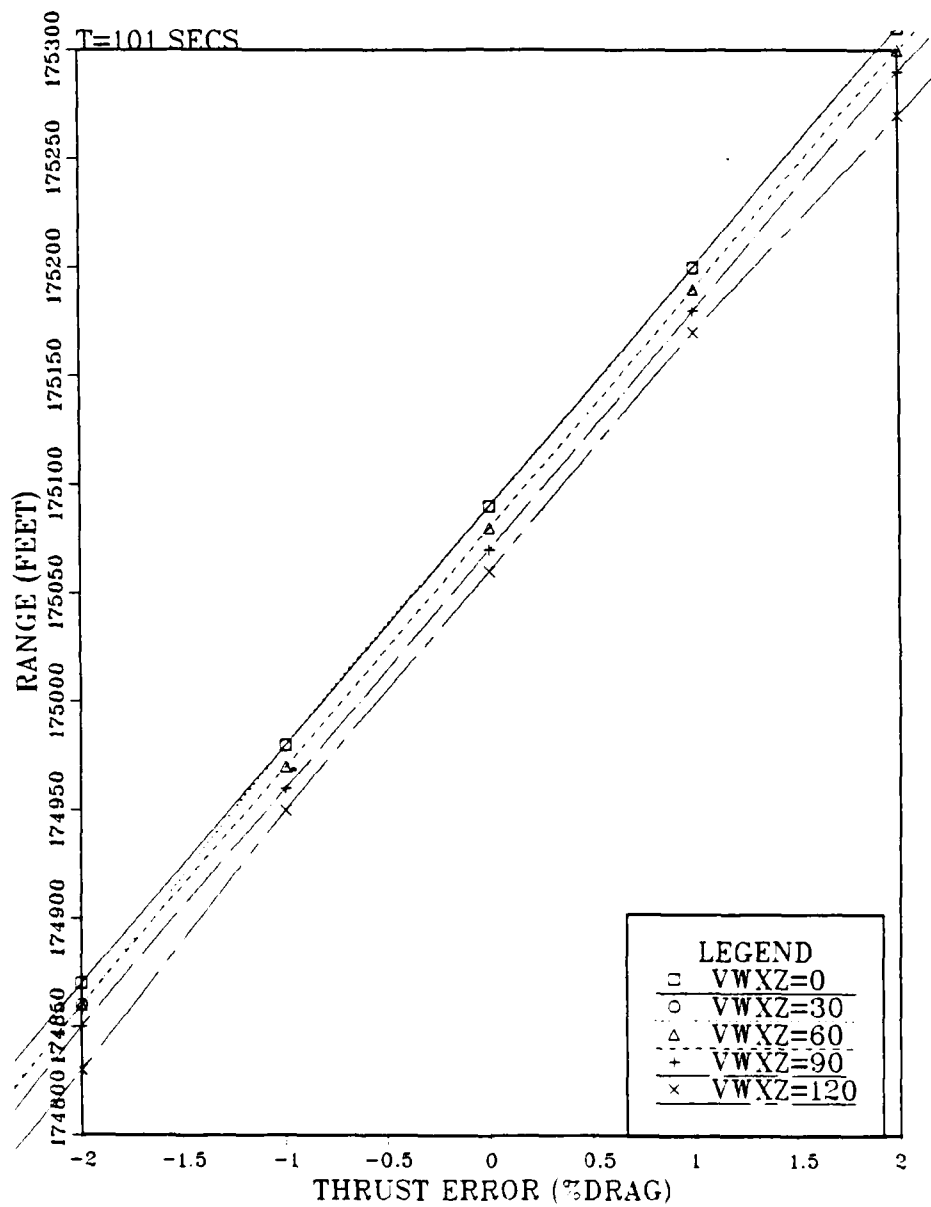


Figure 3-22B Headwind Sensitivity (Range)

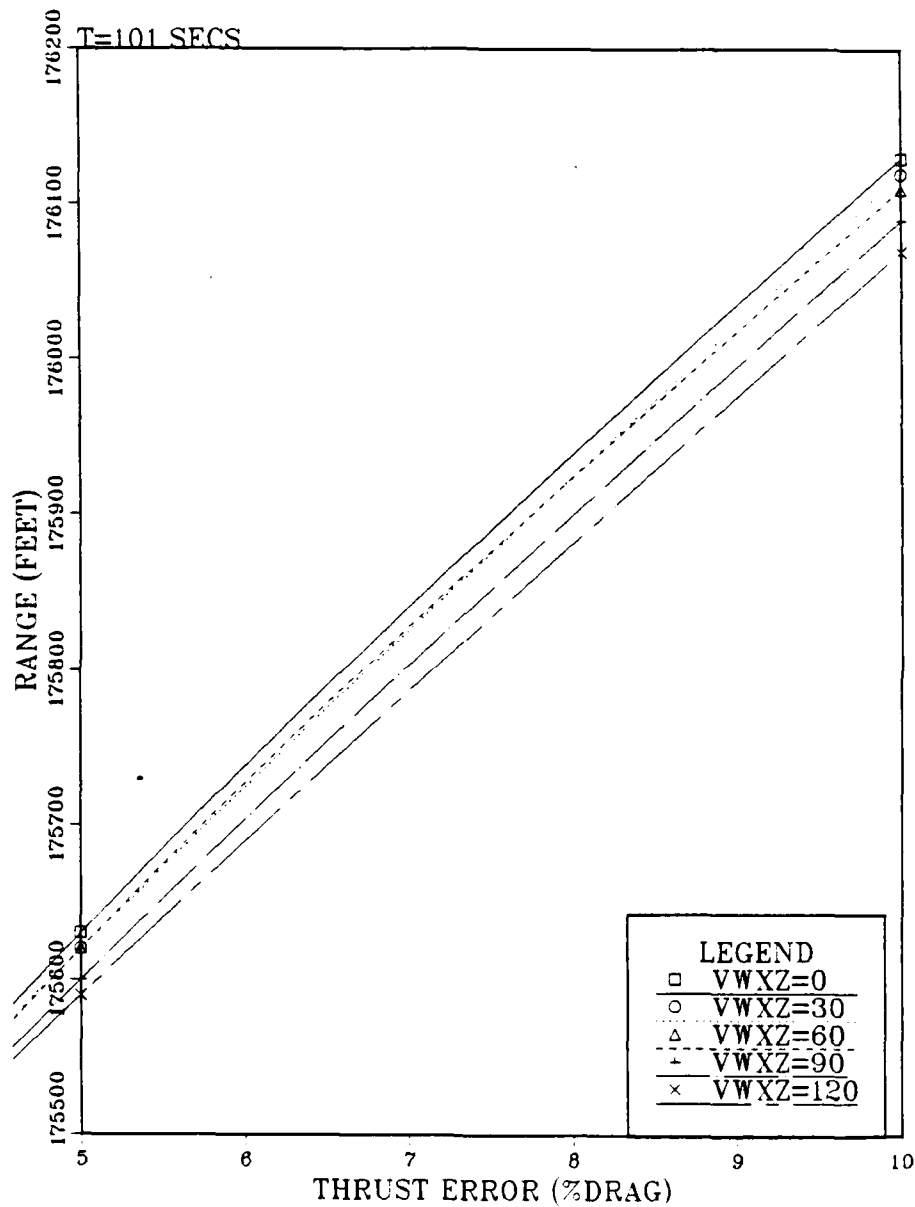


Figure 3-22C Headwind Sensitivity (Range)

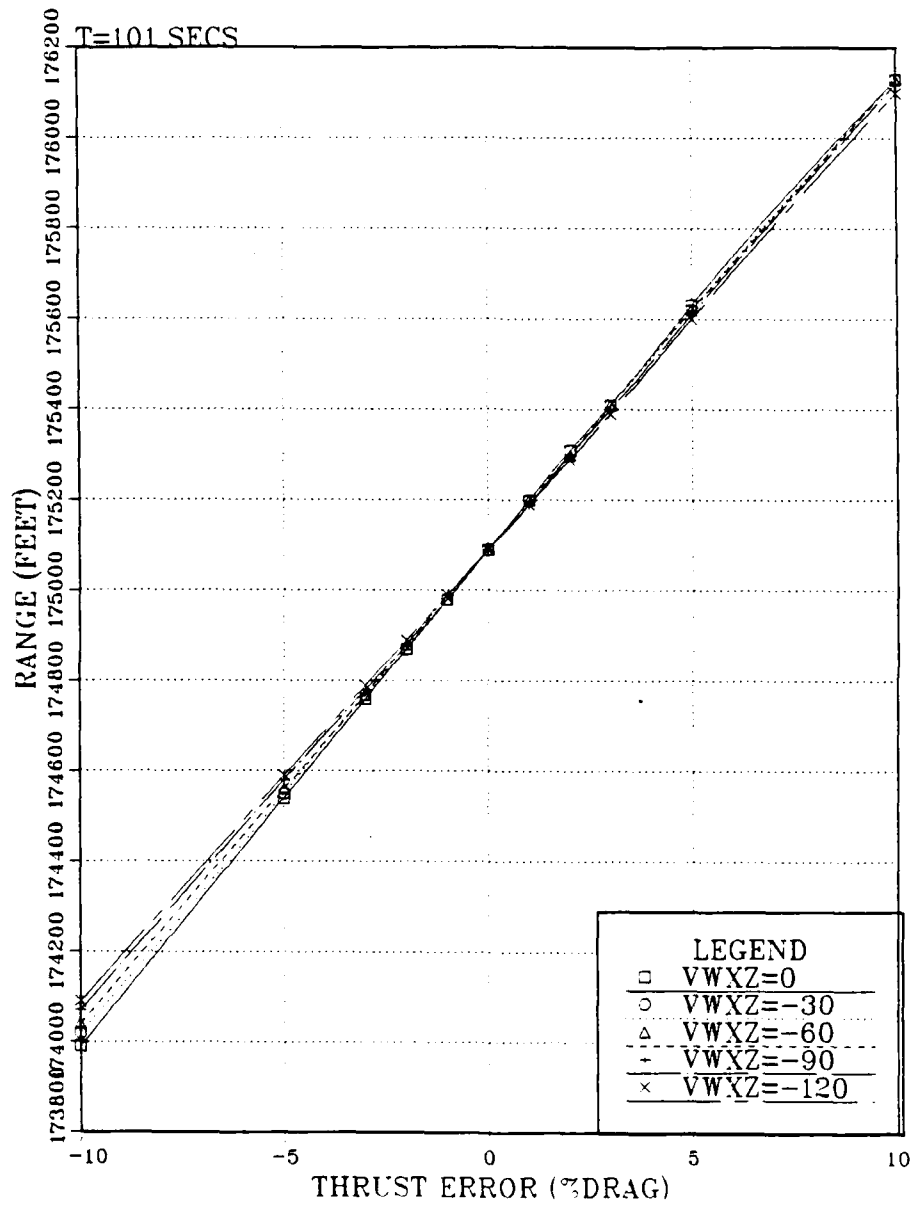


Figure 3-23 Tailwind Sensitivity (Range)

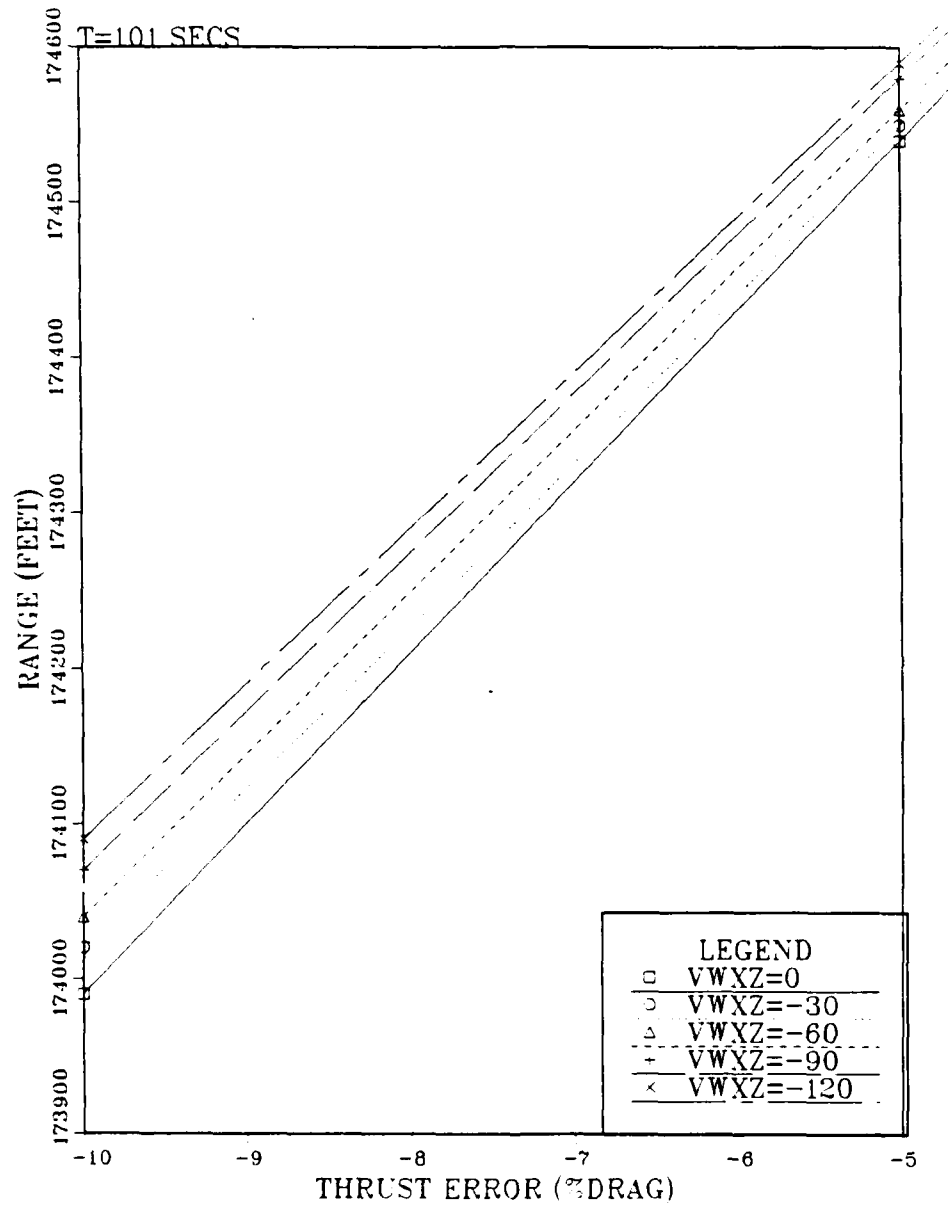


Figure 3-23A Tailwind Sensitivity (Range)

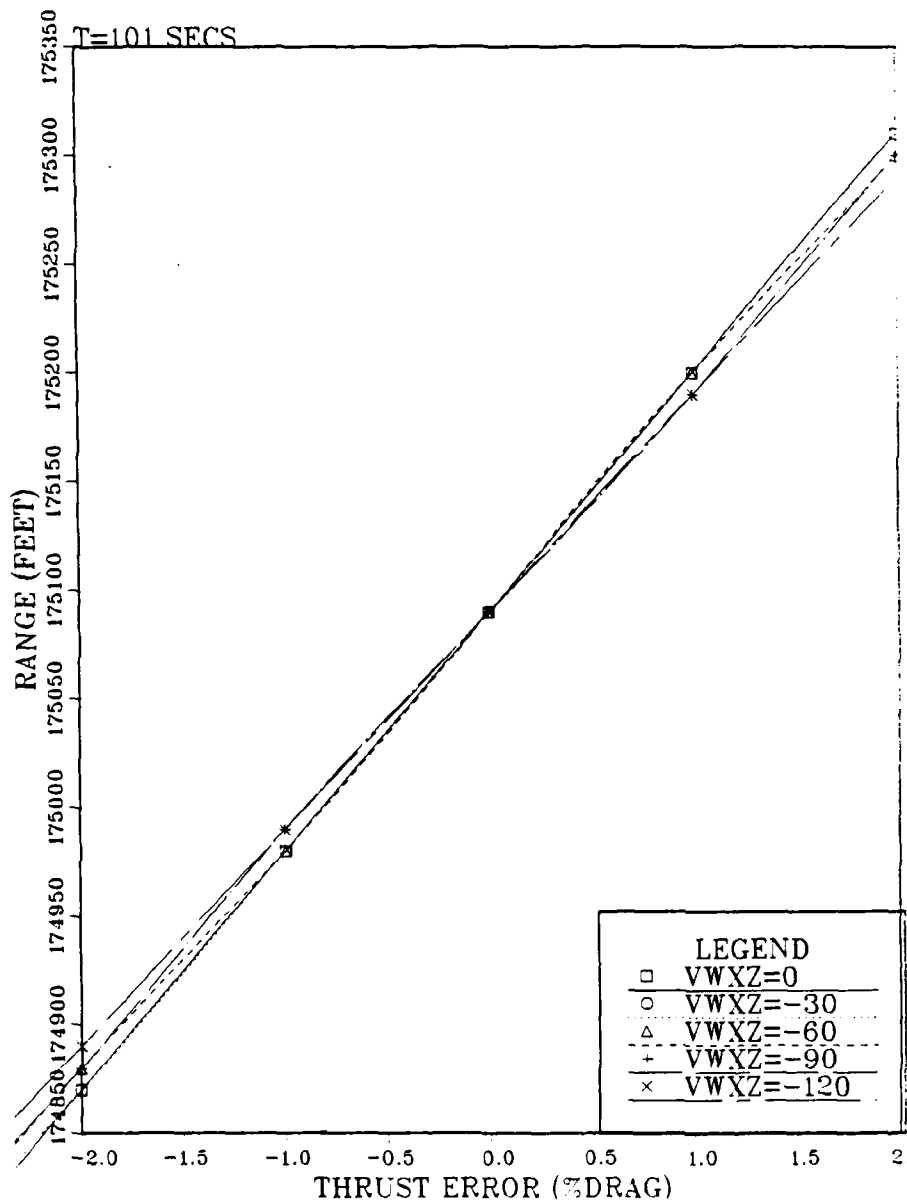


Figure 3-23B Tailwind Sensitivity (Range)

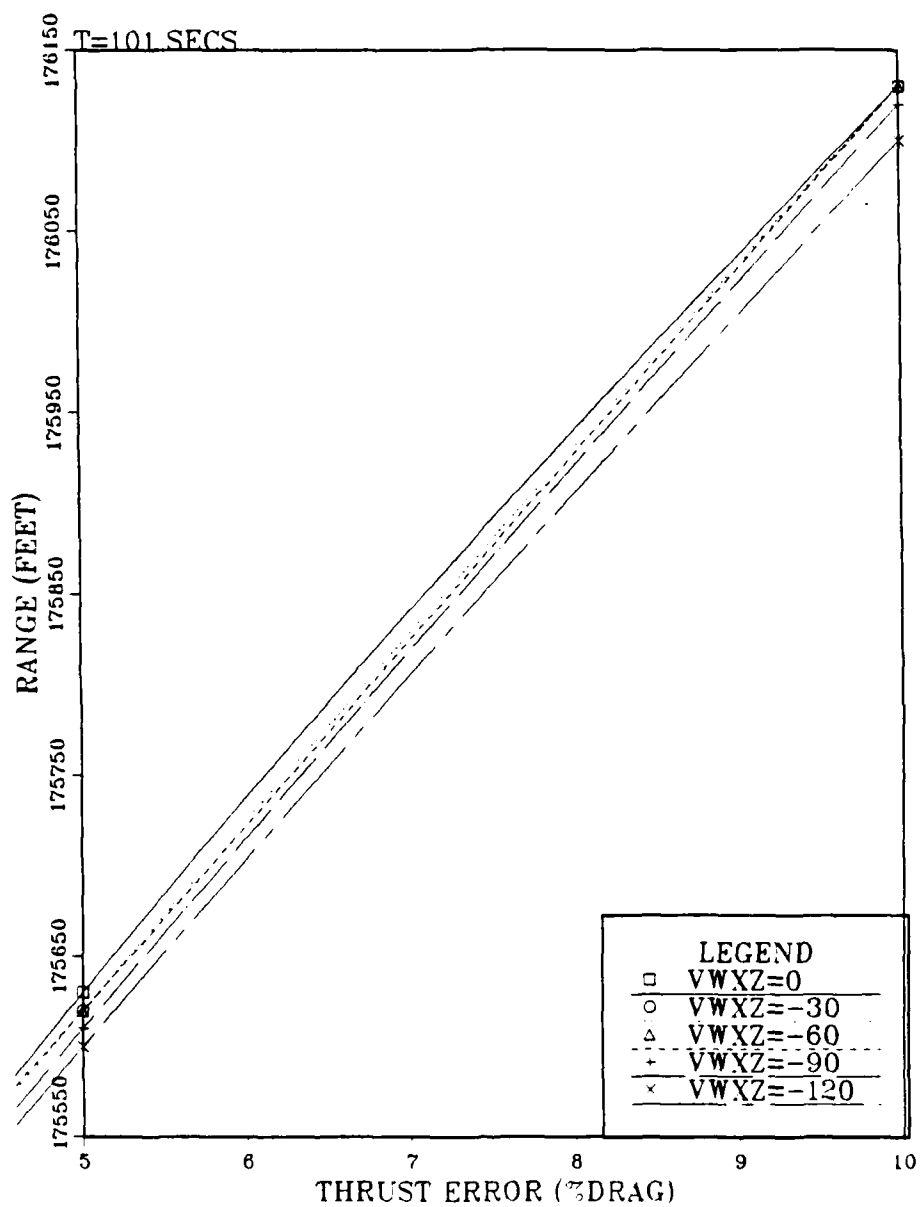


Figure 3-23C Tailwind Sensitivity (Range)

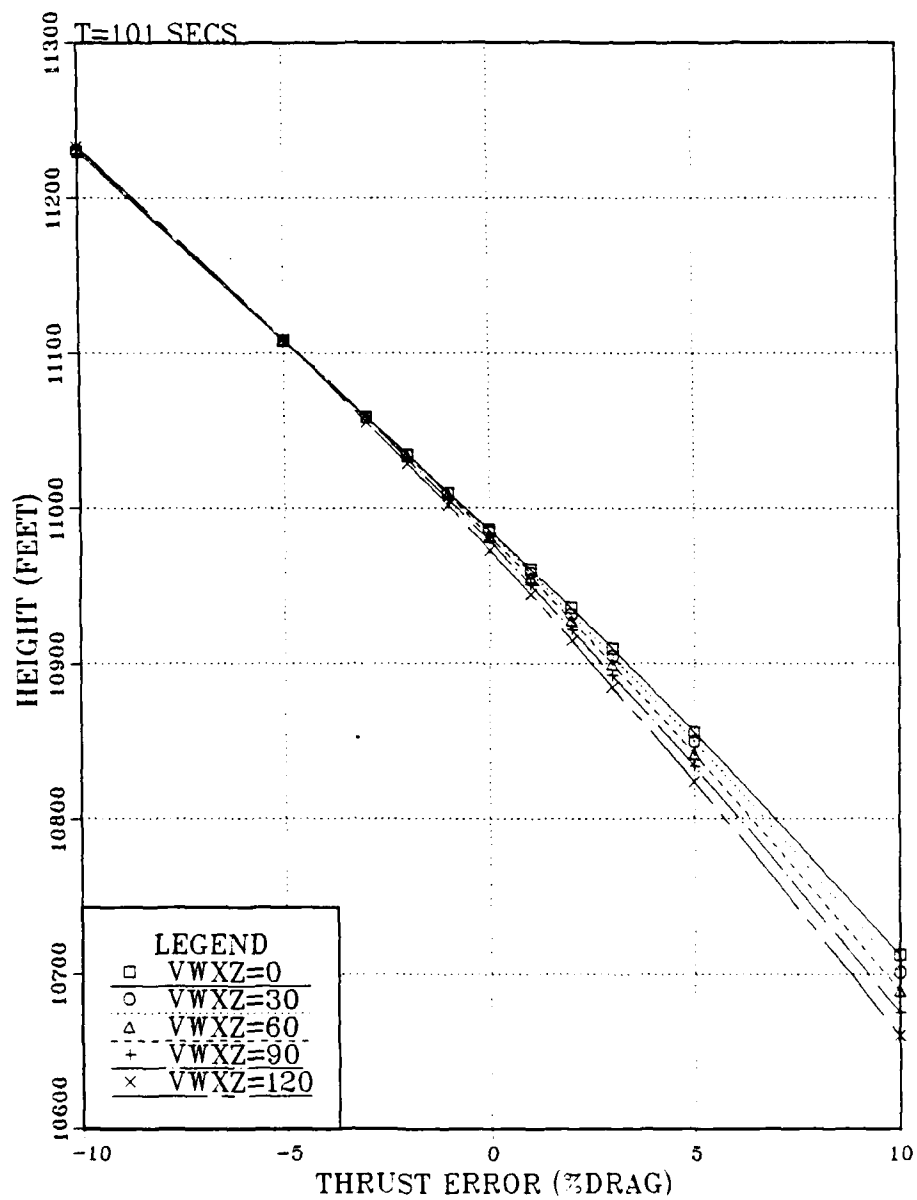


Figure 3-24 Headwind Sensitivity (Height)

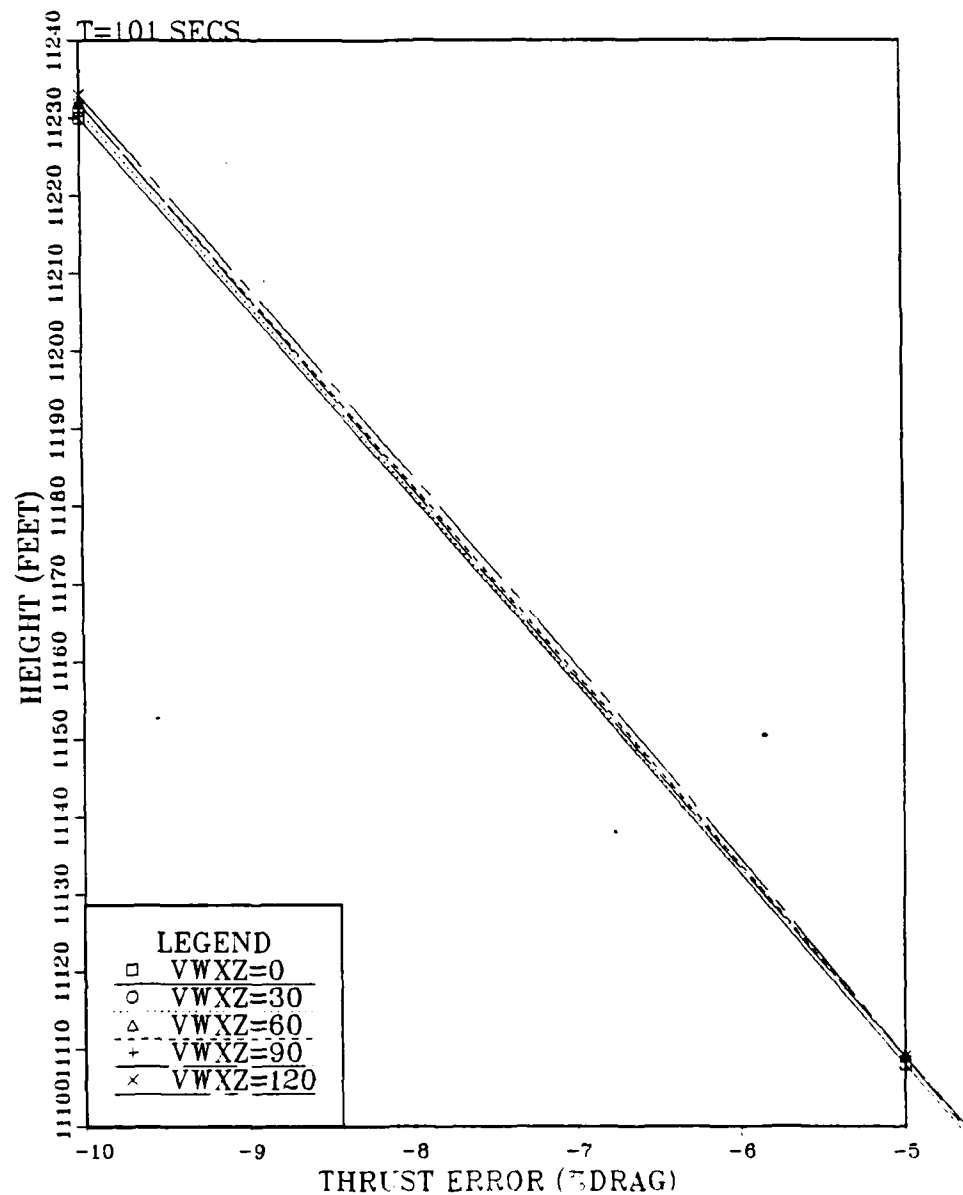


Figure 3-24A Headwind Sensitivity (Height)

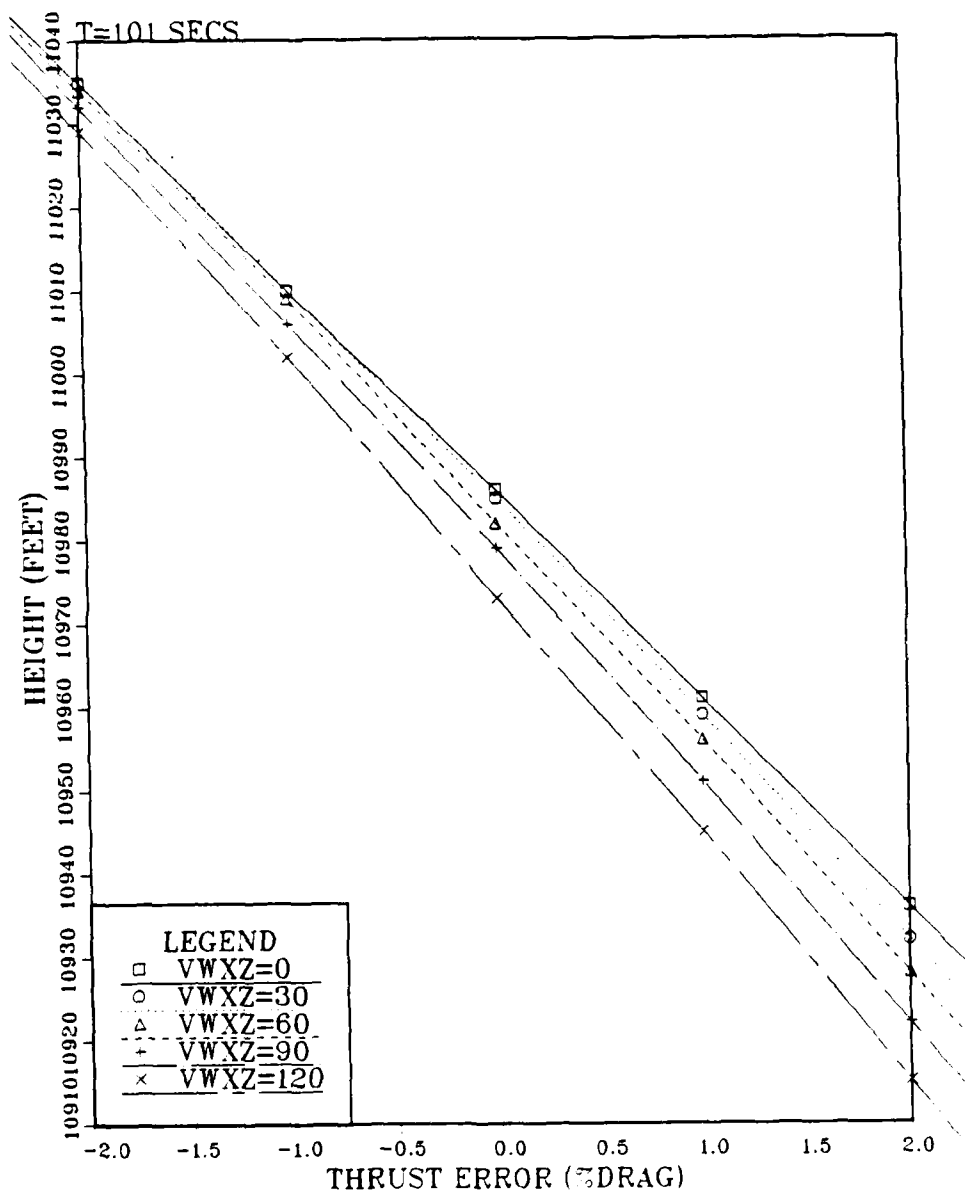


Figure 3-24B Headwind Sensitivity (Height)

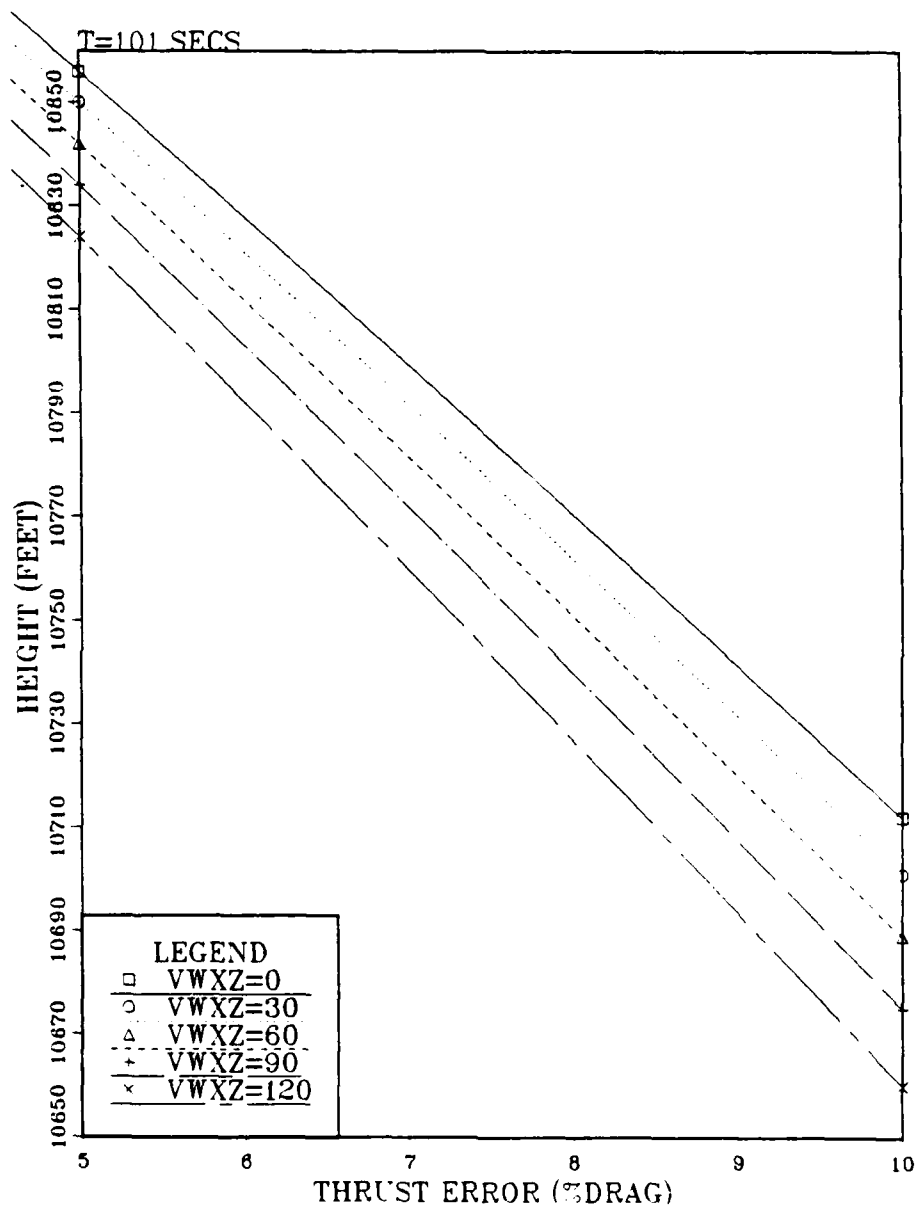


Figure 3-24C Headwind Sensitivity (Height)

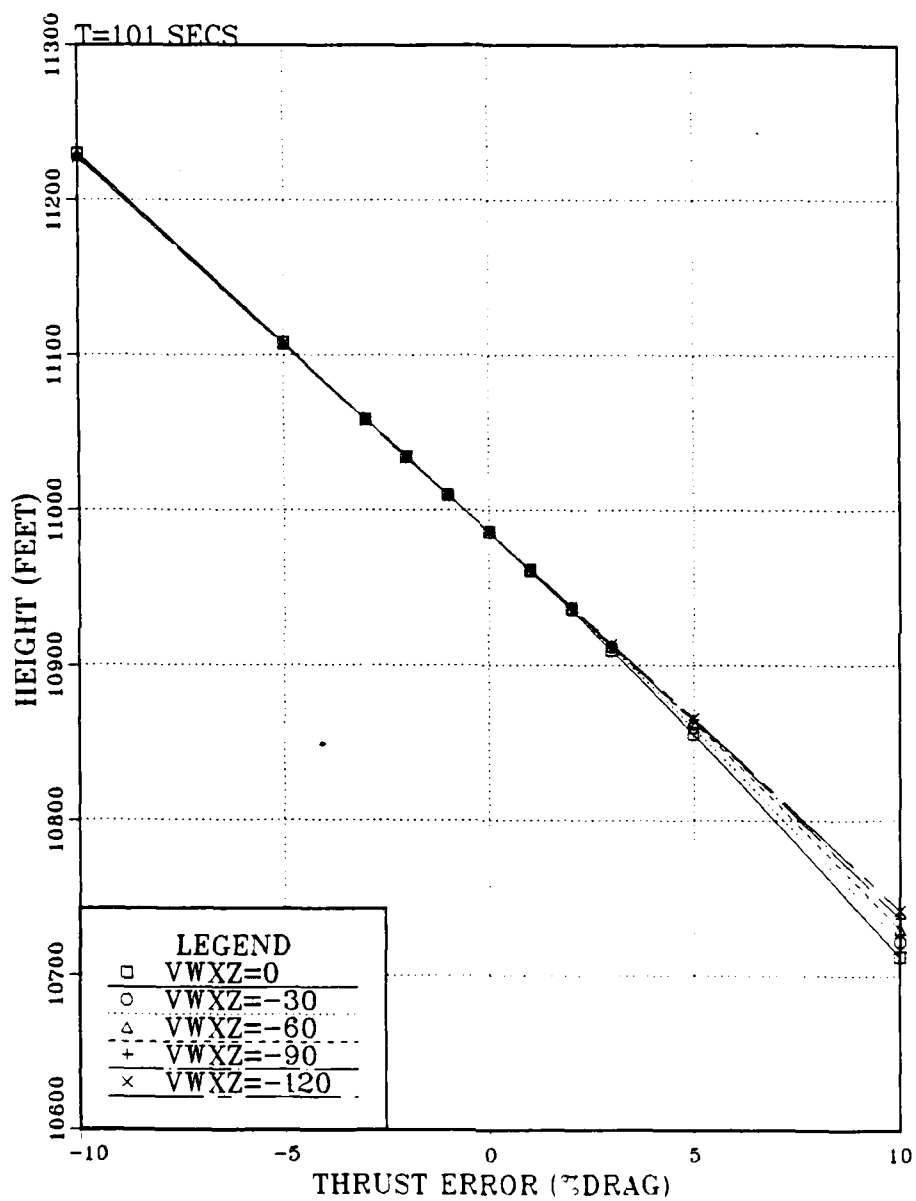


Figure 3-25 Tailwind Sensitivity (Height)

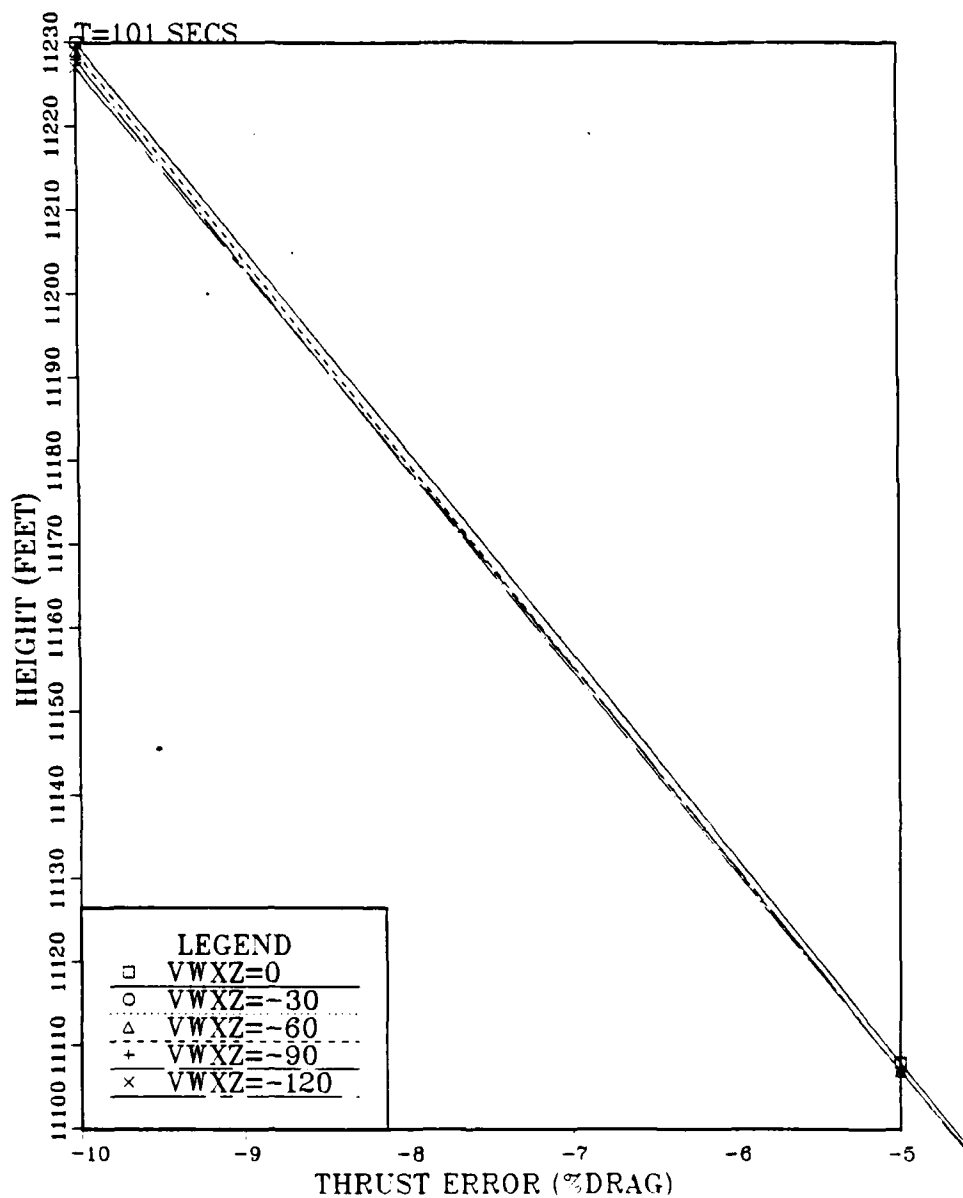


Figure 3-25A Tailwind Sensitivity (Height)

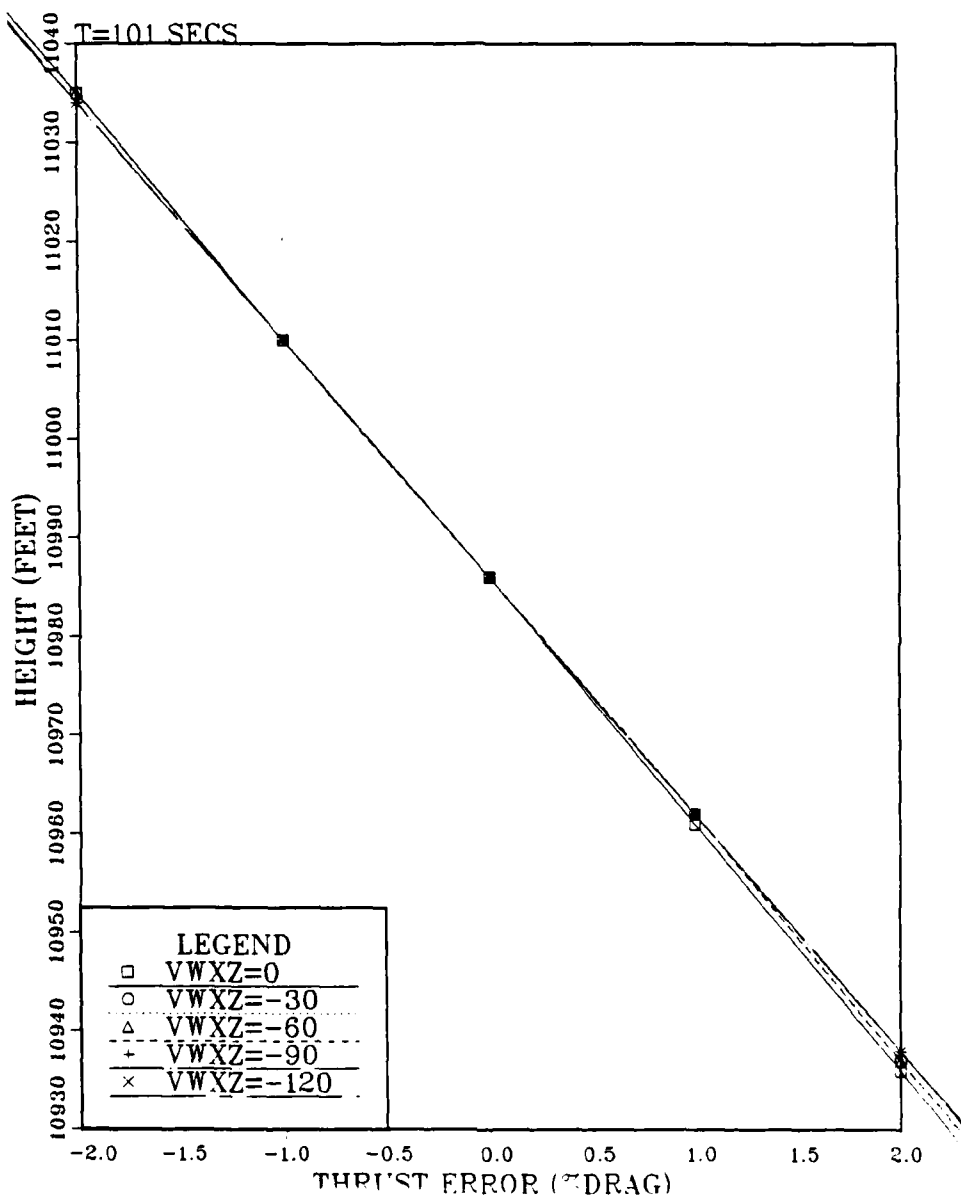


Figure 3-25B Tailwind Sensitivity (Height)

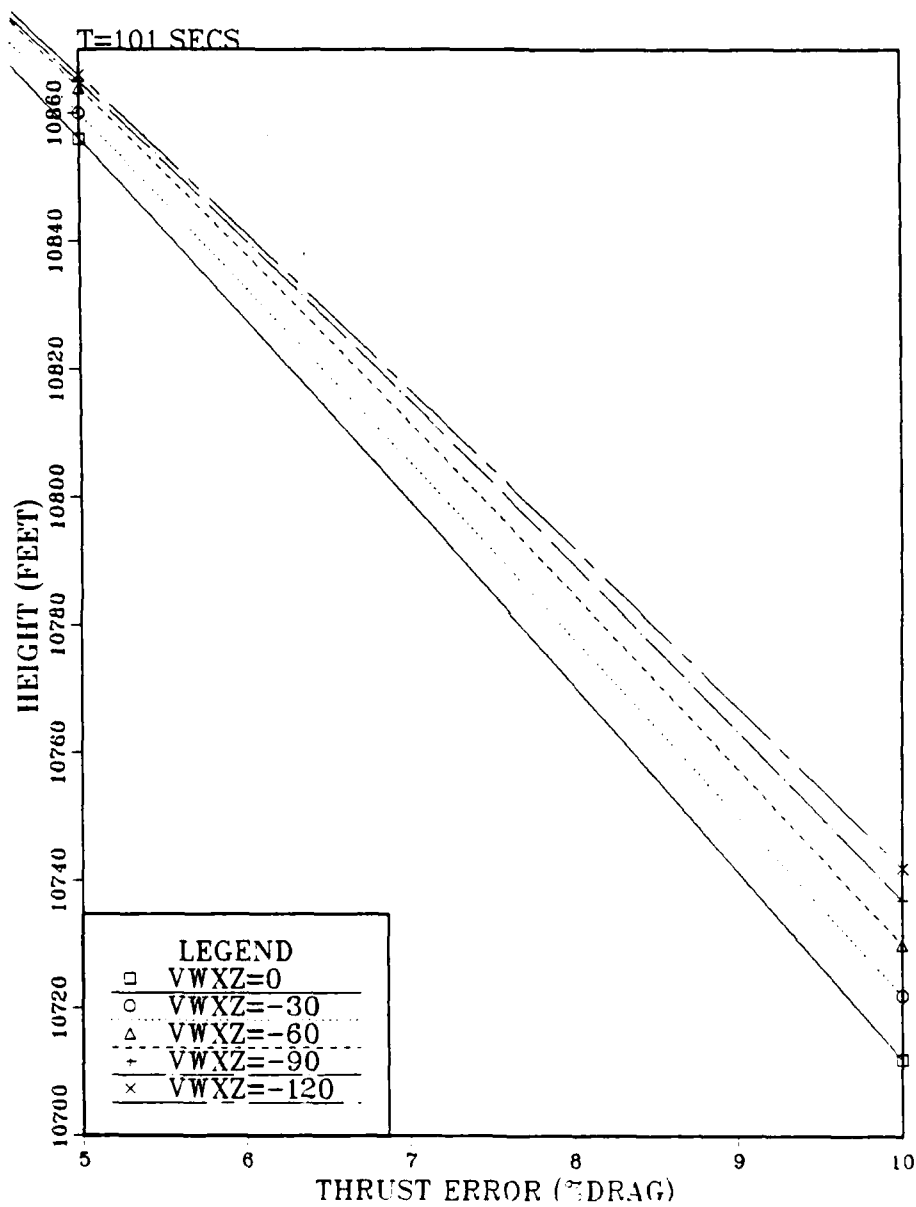


Figure 3-25C Tailwind Sensitivity (Height)

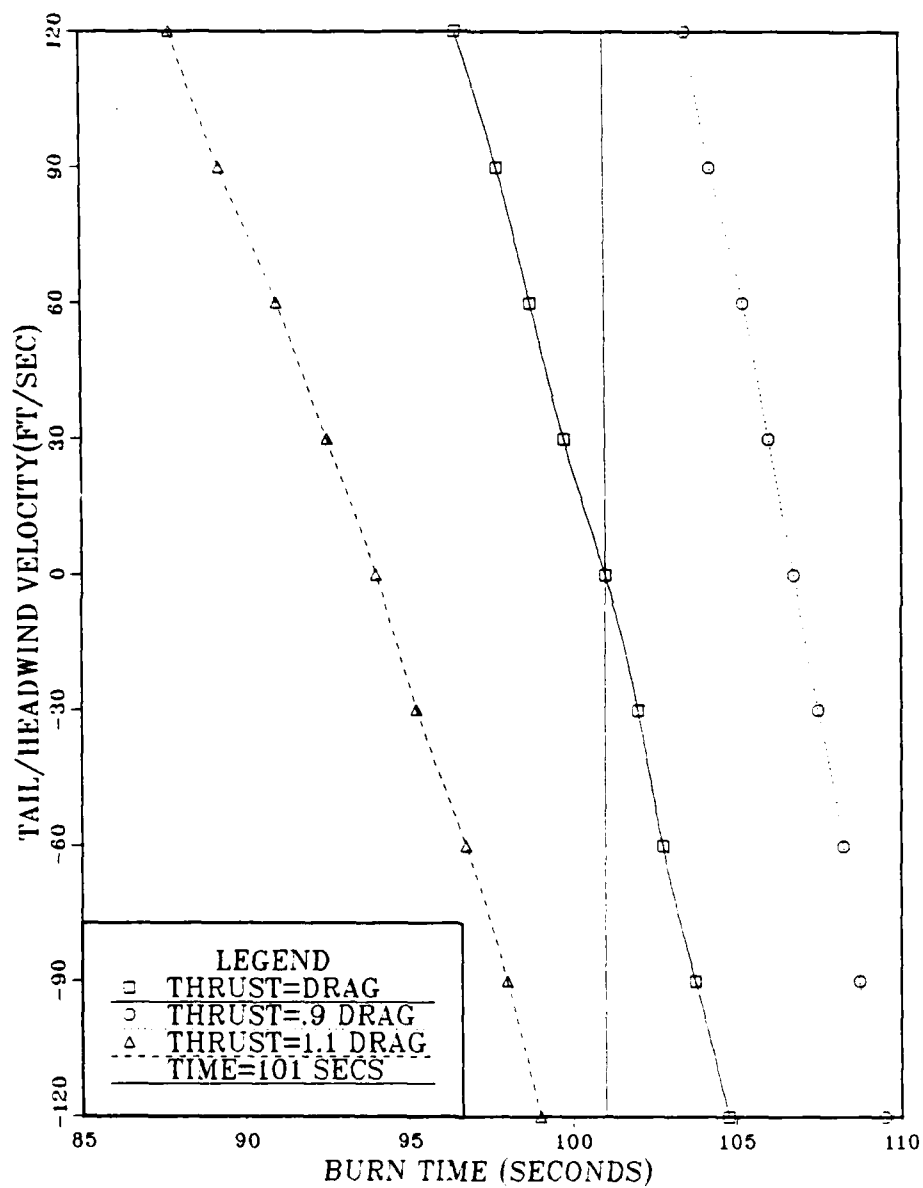


Figure 3-26 Tail/Headwind Effects (Burntime)

Deviations from the ideal trajectory were correlated and tabulated in Table 3.5. Results were conservatively linearized and are presented in that manner. Wind errors are read in addition to the thrust errors at the left of the table. For example:

If thrust error=-5%
crosswind=120 ft/sec

predicted dispersion is X=-540 ft
Y=19 ft
Z=130 ft ;from ideal basket.

Table 3.5 Dispersion Analysis Results

	Thrust Errors		Winds continuous 120 ft/sec				
Errors	X	Z	Cross Y	Head X	Z	Tail X	Z
0 %	0	0	.1	30	7	.1	.1
1 %	110	25	4	30	15	10	1
2 %	220	50	8	40	20	20	2
5 %	540	130	19	50	32	50	10
10 %	1100	345	38	90	50	100	30

Velocities at time 101 seconds were measured and are shown at Figure 3-27. The total variation of extreme cases is from 2285 feet/sec to 2315 feet/sec, or only 30 feet/sec.

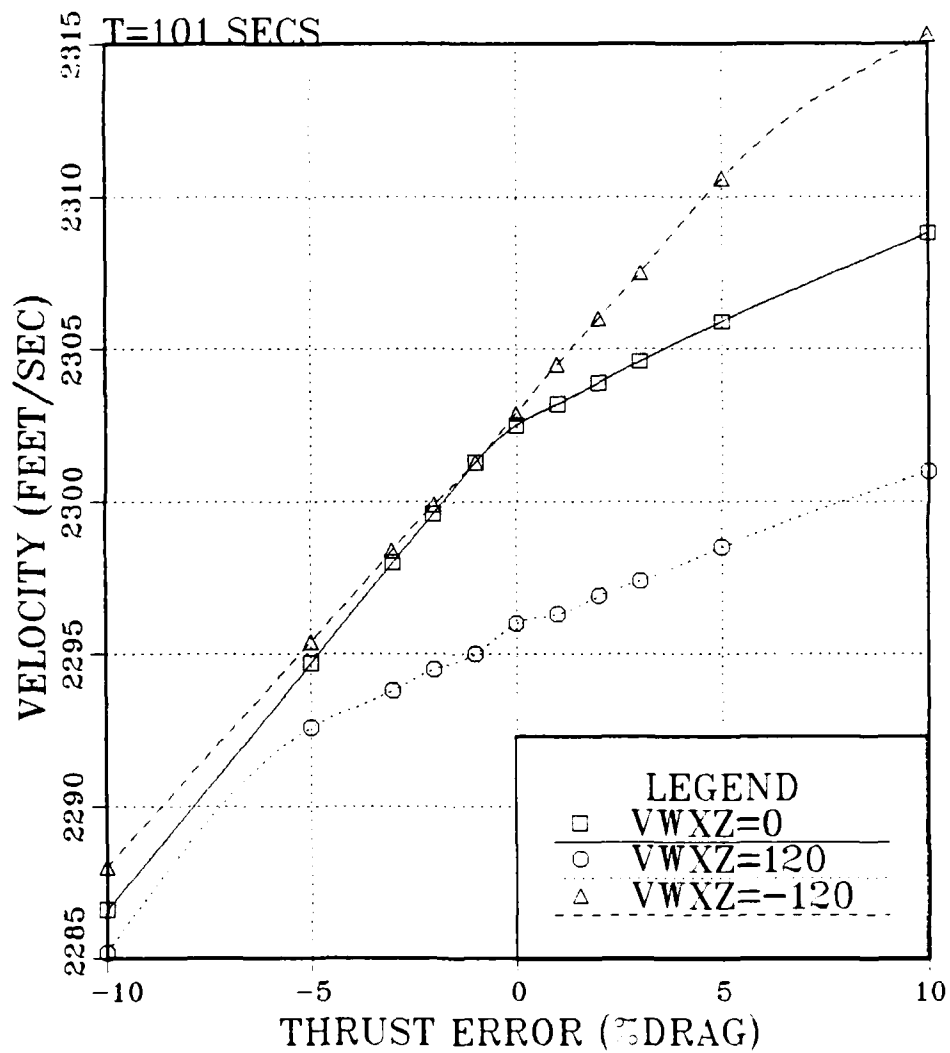


Figure 3-27 Velocity Sensitivity

Wind effects during near thrust equals drag portions of the trajectory were very small. The critical factor affecting the dispersion will be the setting of the terminal guidance clock in the projectile. This presents several options for setting initiation of terminal guidance:

- Fixed time irrespective of trajectory (ie. elevation of gun). Burn time would be shorter at less than 45 degree launch and the basket would be more sensitive to wind and thrust errors. As well the trajectory would change and so would the predicted basket.

- Fixed time for a given trajectory. This requires analysis of the sensitivity to elevation of the gun and a manual Tc setting method for gunners.

- Ramjet burnout. This would ensure that Tc occurred at an "optimum" point almost exactly on the pseudo-vacuum trajectory but the location along it at Tc would be difficult to predict.

- At given pressure for altitude [Reference 5]. This would establish accurate baskets for given gun elevations assuming the altitude chosen was before ramjet burnout.

Several trajectories were simulated with a varying wind profile as a function of altitude in the Standard Atmosphere. These are shown at Figure 3-28 as compared to the pseudo-vacuum trajectory.

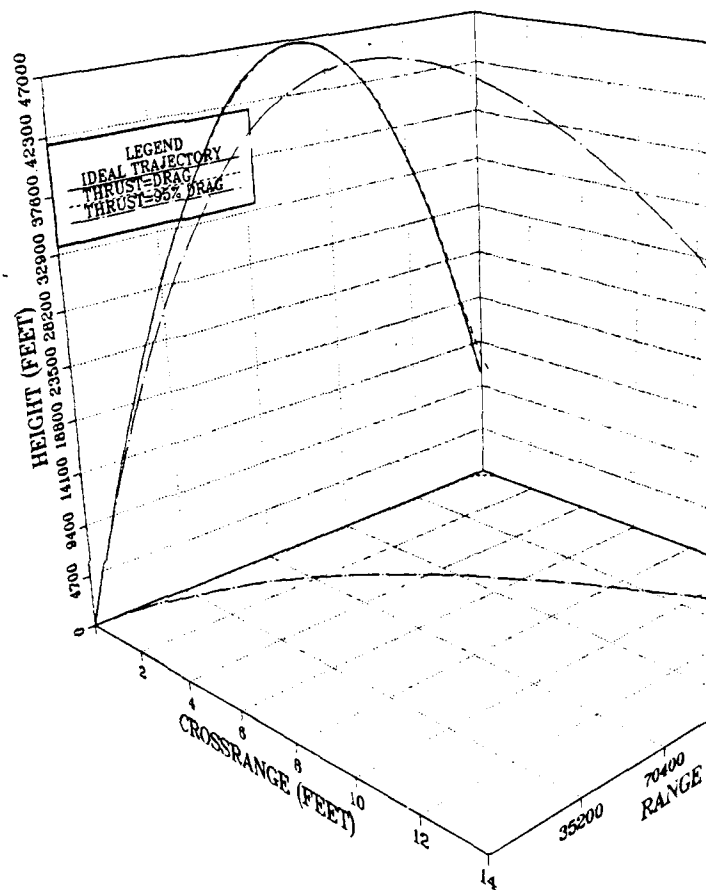


Figure 3-28 Three Dimensional Trajectory
 Dependent Wind Profile

IV. CONCLUSIONS

Generally this thesis confirms the viability of the pseudo-vacuum trajectory from a thrust equals drag projectile. Indeed winds up to 120 feet per second and thrust errors up to five percent created dispersions of less than 600 feet over a range of 175090 feet for the ARM projectile.

Specifically the following conclusions are made:

- the drag due to wind (D_w) is the aerodynamic force which creates the most dispersion.

- the net lift due to transients (L_w) is a minor aerodynamic force in creating dispersion.

- the dispersion is proportional to the damping coefficient ($C_m q$), although for practical values of C_m dispersion can be treated as insensitive to $C_m q$.

- the projectile resonance or short period is approximately 0.22 Hz and is unstable in the resonance regime due to variable wind profiles. The phugoid is irrelevant.

- thrust errors are the most significant error contributing to dispersion.

- winds have a minor effect on dispersion during powered flight when thrust approximates drag

except where harmonic content near resonance is contained in the wind profile.

-headwinds create greater dispersion as ramjet burnout occurs before terminal guidance is initiated. Crosswinds and tailwinds generally will have minimal effects.

Recommendations for further study related to this thesis are:

-Dynamics at launch including the initial spin damping, Magnus effects and aerodynamic jump.

-Dynamics at terminal guidance including air inlet spike ejection and canard deployment.

-Complete adaptation of BRL HTRAJ on the NPGS IBM system to use non-linear aerodynamics.

APPENDIX A-PROJECTILE CHARACTERISTICS

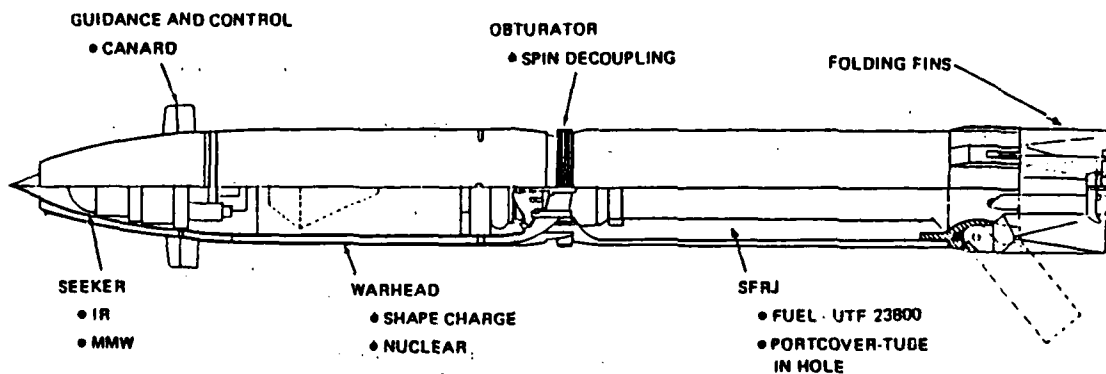


Figure A-1 ARMT Projectile Baseline Design

The following characteristics are obtained from References 2 and 6.

length=72 inches

diameter=8 inches

launch weight=225 lbm

launch CG=39.4 inches from spike apex

fuel weight=27 lbm (CG at 52.0 inches from apex)

impulse=950 "seconds"

Mass Property Equations:

$$CG = (225 \times 39.4) - (52.0 \times \text{fuel burned}) / (225 - \text{fuel burned}) \quad \text{in}$$

$$I_{zz} = .35 - (.0019 \times \text{fuel burned}) \quad \text{in slug-ft}$$

$$I_{xx} = I_{yy} = 18.8 - (.0423 \times \text{fuel burned}) \quad \text{in slug-ft}$$

Aerodynamic Coefficient Equations:

$$C_d = C_{d0} + .5 \times C_l \times \sin(\alpha)$$

$$C_{d0} = -.1025 \times \text{MACH} + .5015 \quad (1.8 < \text{MACH} < 2.2)$$

$$C_m = C_l (X_{cg} - X_{cp}) / d$$

$$C_l = C_{l_\alpha} \times \alpha$$

Key Wind Tunnel Results (per degree):

MACH=1.8

$$C_{d0} = .317 \quad C_{mq} = -203$$

α	0	2	4	6	8	10
C_l	0	.18	.38	.62	.92	1.3
X_{cp}	45.4	45.6	48.2	49.7	50.2	50.0

MACH=2.2

$$C_{d0} = .276 \quad C_{mq} = -190$$

α	0	2	4	6	8	10
C_l	0	.19	.40	.65	.95	1.3
X_{cp}	42.9	42.9	44.6	45.1	46.0	44.6

$$C_{mq} = d(C_m) / d(qd/2V)$$

Initial Muzzle Spin Rate 30 PI radians /sec

APPENDIX B TRANSIENT ANGLE OF ATTACK CALCULATIONS

The following equation of motion applies to the dynamics of angle of attack (α) oscillations due to the torque equation described in the three-degrees-of-freedom model.

$$m\ddot{y} = Lw \text{ which is proportional to } \alpha(t)$$

where angle of attack is of the form :

$$\alpha(t) = e^{-\delta t} \sin(\omega t) \text{ where } \delta \text{ is the damping constant}$$

and ω is the angular velocity. Therefore:

$$\begin{aligned} m\dot{y} &= \int_0^t \int_0^T \alpha(t) dt dT \\ &= \int_0^t \int_0^T e^{-\delta t} \sin(\omega t) dt dT \\ &= \int_0^t \left[\frac{e^{-\delta T} (-\delta \sin(\omega T) - \omega \cos(\omega T)) + \omega}{\delta^2 + \omega^2} \right] dT \\ &= \frac{\left[\begin{array}{l} \omega t (\delta^2 + \omega^2) - 2\delta\omega + \\ e^{-\delta t} (\delta^2 \sin(\omega t) + 2\delta\omega \cos(\omega t) - \omega^2 \sin(\omega t)) \end{array} \right]}{(\delta^2 + \omega^2)^2} \end{aligned}$$

When $t=0$, the equation reduces to:

$-2\delta w + 1(2\delta w) = 0$ which is expected if the initial condition is zero. (ie. dispersion at zero equals zero at time zero).

As t approaches infinity the equation value approaches infinite dispersion, but the oscillations of α have damped out. Note that the first derivative, proportional to velocity, tends to a constant value:

$(w/(\delta^2 + w^2))/m$ as t approaches infinity which is also to be expected.

APPENDIX C-PSEUDO-VACUUM TRAJECTORY CONCEPT

The basic concepts behind the pseudo-vacuum are not always readily apparent. This appendix analyzes the basic equations of motion in the following sequence of cases to illustrate the concept:

vacuum trajectory

atmosphere trajectory

thrust trajectory

wind influenced trajectory

thrust equal drag trajectory

In Figure C-1 (curve 1) the applicable equations of motion are:

$$m\ddot{x}_1 = 0$$

$$m\ddot{z}_1 = -mg$$

An accelerometer on the projectile in the z direction would measure no acceleration as it is in free fall already. This is similar to a satellite orbit or someone on an elevator in free fall.

When atmosphere is added the key equations are:

$$m\ddot{x}_2 = -D_x = -1/2 \rho U_x^2 A C_d$$

$$m\ddot{z}_2 = -D_z - mg$$

where U is relative wind and D is atmospheric drag. In this

case $U_x=V_x$ and $U_z=V_z$. This trajectory is represented by curve 2. An accelerometer in the x direction measures D_x/m and D_z/m in the z direction.

If thrust is added, the trajectory is as shown at curve 3 (thrust greater than drag). The key equations are then:

$$m\ddot{x}_3 = -D_x + T_x$$

$$m\ddot{z}_3 = -D_z + T_z - mg$$

Accelerometers would measure $(T_x - D_x)/m$ and $(T_z - D_z)/m$ respectively. If thrust equals drag the trajectory would be curve 1.

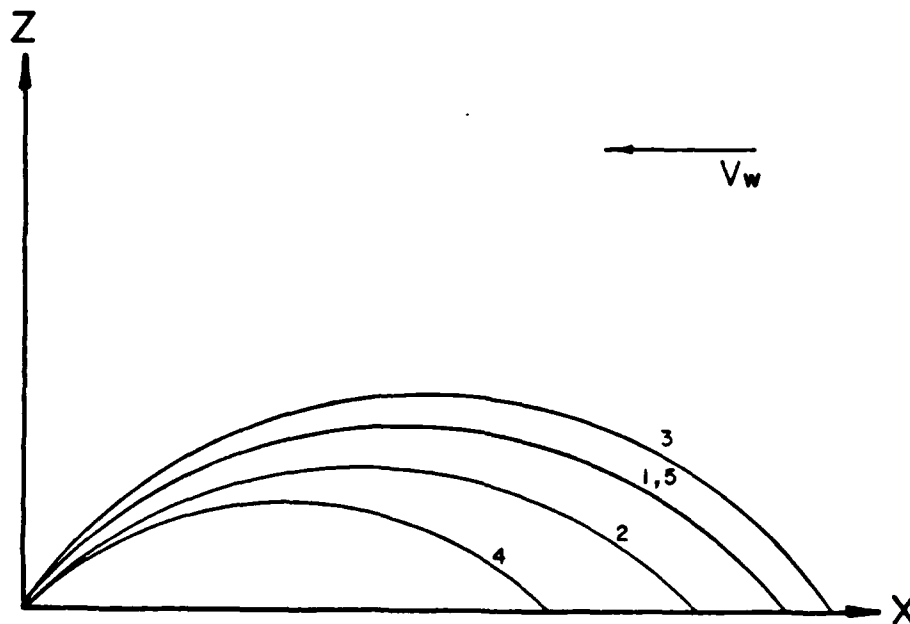


Figure C-1 Pseudo-Vacuum Trajectory Concept Curves

In Figure C-1 wind (V_w) has been added for the curve #4 in the x direction. The new equations are :

$$m\ddot{x}_4 = (-D_x + D_w) + T_x$$

$$m\ddot{z}_4 = -D_z + T_z - mg$$

where $D_x + D_w = 1/2 \rho U_x^2 C_d A$

and U_x (wind relative to the projectile) $= V_x + V_w$. With no thrust curve 4 results.

Finally, if thrust is added to equal drag the following equations are valid:

$$m\ddot{x}_5 = 0 \text{ or } T_x = D_x + D_w$$

$$m\ddot{z}_5 = -mg \text{ or } T_z = D_z$$

The accelerometer(s) read the acceleration caused by any differences in the thrust and drag forces (zero in this case).

It is clear that curves 1 and 5 are equal (and 3 if thrust=drag) but the burntime of a ramjet will not be equal in each case due to different drag profiles.

$$t = (\text{mass fuel})(I_{sp})/\text{thrust}$$

Therefore headwinds will require more thrust and burntime will be shorter. Conversely tailwinds allow longer

burning. Burnout will occur on the vacuum trajectory but not at the same point, as shown in Figure C-2.

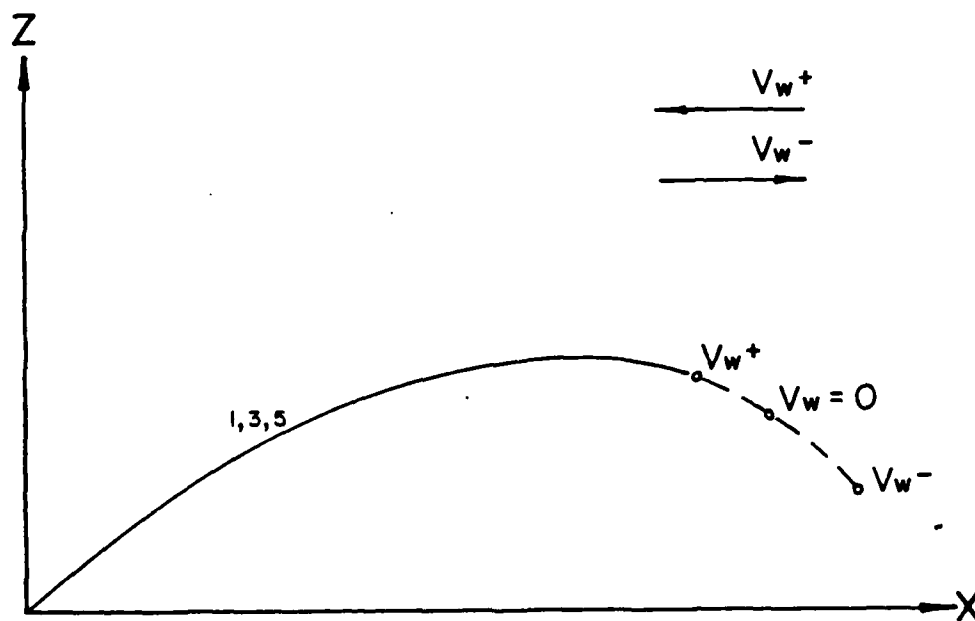


Figure C-2 Burnout Variations

APPENDIX D PSEUDO-VACUUM TRAJECTORY PROGRAM

```

10 DIM X(300),Y(300),RO(300),D(300),MDOT(300),M(300),V(300)
12 DIM CDO(300),MA(300)
15 DIM T(300)
20 MMIN=198
30 ISP=950
40 DELT=.5
50 M(1)=225
60 THETA=.7853981634000006#
70 VO=2452
75 LPRINT "TIME","X","Y","MASS","SPEED"
80 FOR I=1 TO 300
90   X(I)=VO*COS(THETA)*T(I)
100  Y(I)=(VO*SIN(THETA)*T(I))-(16.087*T(I)^2)
110  V(I)=((VO*COS(THETA))^2+(VO*SIN(THETA)-
      32.174*T(I))^2)^.5
120  TEMP =518.688-.0035662*Y(I)
150  RO(I)=(2116.22*(1-(.0035662*Y(I)/518.688))^5.256)/
      (1716.5*TEMP)
155  IF Y(I)>=36089! THEN RO(I)=.001271
157  IF Y(I)>=36089! THEN TEMP=389.99
158  MA(I)=V(I)/SQR(1.4*1716.3*TEMP)
159  CDO(I)=.5015-.1025*MA(I)
160  D(I)=.276*.5*RO(I)*.3491*V(I)^2
161  D(I)=D(I)/.276*CDO(I)
170  MDOT(I+1)=D(I)/ISP
180  M(I+1)=M(I)-MDOT(I)*DELT
190  T(I+1)=T(I)+DELT
195  LPRINT T(I),X(I),Y(I),M(I),V(I)
200  IF M(I+1)<=MMIN GOTO 220
210 NEXT I
220  LPRINT "RAMJET BURNOUT BETWEEN T=";T(I);"AND";T(I+1)

```

TIME	X	Y	MASS	SPEED
0	0	0	225	2452
.5	866.913	862.891	225	2440.65
1	1733.83	1717.74	224.637	2429.36
1.5	2600.74	2564.54	224.286	2418.11
2	3467.65	3403.3	223.947	2406.93
2.5	4334.57	4234.02	223.618	2395.8
3	5201.48	5056.7	223.3	2384.73
3.5	6068.39	5871.32	222.993	2373.71
4	6935.3	6677.91	222.695	2362.75
4.5	7802.22	7476.46	222.407	2351.85
5	8669.13	8266.96	222.128	2341.01
5.5	9536.04	9049.41	221.858	2330.24
6	10403	9823.82	221.597	2319.52
6.5	11269.9	10590.2	221.344	2308.86
7	12136.8	11348.5	221.099	2298.27
7.5	13003.7	12098.8	220.861	2287.74
8	13870.6	12841	220.631	2277.28
8.5	14737.5	13575.2	220.409	2266.89
9	15604.4	14301.4	220.193	2256.55
9.5	16471.3	15019.5	219.983	2246.29
10	17338.3	15729.6	219.781	2236.1
10.5	18205.2	16431.6	219.584	2225.98
11	19072.1	17125.6	219.394	2215.92
11.5	19939	17811.5	219.209	2205.94
12	20805.9	18489.4	219.03	2196.03
12.5	21672.8	19159.2	218.856	2186.2
13	22539.7	19821	218.687	2176.43
13.5	23406.7	20474.8	218.523	2166.75
14	24273.6	21120.5	218.364	2157.14
14.5	25140.5	21758.2	218.21	2147.61
15	26007.4	22387.8	218.061	2138.15
15.5	26874.3	23009.4	217.915	2128.78
16	27741.2	23622.9	217.774	2119.49
16.5	28608.1	24228.4	217.637	2110.27
17	29475	24825.9	217.504	2101.14
17.5	30342	25415.3	217.374	2092.1
18	31208.9	25996.7	217.248	2083.14
18.5	32075.8	26570	217.126	2074.27
19	32942.7	27135.3	217.007	2065.48
19.5	33809.6	27692.5	216.891	2056.78
20	34676.5	28241.7	216.778	2048.17
20.5	35543.4	28782.9	216.669	2039.65
21	36410.3	29316	216.562	2031.23
21.5	37277.3	29841	216.458	2022.89
22	38144.2	30358.1	216.357	2014.65
22.5	39011.1	30867	216.258	2006.51
23	39878	31368	216.162	1998.46
23.5	40744.9	31860.9	216.068	1990.51
24	41611.8	32345.7	215.977	1982.66
24.5	42478.7	32822.5	215.888	1974.9
25	43345.7	33291.3	215.801	1967.25
25.5	44212.6	33752	215.717	1959.7
26	45079.5	34204.7	215.634	1952.26
26.5	45946.4	34649.3	215.553	1944.91
27	46813.3	35085.9	215.474	1937.68
27.5	47680.2	35514.4	215.397	1930.55
28	48547.1	35934.9	215.322	1923.53
28.5	49414	36347.4	215.249	1916.62
29	50281	36751.8	215.177	1909.82
29.5	51147.9	37148.2	215.048	1903.13

30	52814.8	37338.3	214.381	1898.35
30.5	52881.7	37916.8	214.794	1890.59
31	53748.6	38289	214.668	1883.74
31.5	54615.5	38653.2	214.542	1877.51
32	55482.4	39009.3	214.417	1871.4
32.5	56349.3	39357.4	214.292	1865.4
33	57216.3	39697.5	214.168	1859.53
33.5	58083.2	40029.5	214.045	1853.78
34	58950.1	40353.5	213.922	1848.14
34.5	59817	40669.5	213.799	1842.64
35	60683.9	40977.3	213.677	1837.25
35.5	61550.8	41277.2	213.556	1831.99
36	62417.7	41569	213.435	1826.86
36.5	63284.6	41852.7	213.314	1821.86
37	64151.6	42128.5	213.194	1816.98
37.5	65018.5	42396.1	213.075	1812.24
38	65885.4	42655.8	212.956	1807.62
38.5	66752.3	42907.3	212.837	1803.14
39	67619.2	43150.9	212.719	1798.79
39.5	68486.1	43386.4	212.601	1794.57
40	69353	43613.8	212.483	1790.49
40.5	70220	43833.3	212.366	1786.54
41	71086.9	44044.6	212.249	1782.73
41.5	71953.8	44247.9	212.133	1779.06
42	72820.7	44443.2	212.017	1775.52
42.5	73687.6	44630.5	211.901	1772.12
43	74554.5	44809.7	211.786	1768.87
43.5	75421.4	44980.8	211.671	1765.75
44	76288.3	45143.9	211.556	1762.78
44.5	77155.3	45299	211.441	1759.95
45	78022.2	45446	211.327	1757.26
45.5	78889.1	45585	211.213	1754.71
46	79756	45715.9	211.099	1752.31
46.5	80622.9	45838.8	210.986	1750.05
47	81489.8	45953.6	210.873	1747.94
47.5	82356.7	46060.4	210.76	1745.97
48	83223.7	46159.2	210.647	1744.15
48.5	84090.6	46249.9	210.534	1742.47
49	84957.5	46332.6	210.421	1740.95
49.5	85824.4	46407.2	210.309	1739.57
50	86691.3	46473.8	210.197	1738.34
50.5	87558.2	46532.3	210.085	1737.25
51	88425.1	46582.8	209.973	1736.32
51.5	89292	46625.3	209.861	1735.53
52	90158.9	46659.7	209.749	1734.89
52.5	91025.9	46686.1	209.637	1734.4
53	91892.8	46704.4	209.526	1734.06
53.5	92759.7	46714.7	209.414	1733.87
54	93626.6	46716.9	209.302	1733.83
54.5	94493.5	46711.1	209.191	1733.94
55	95360.4	46697.3	209.079	1734.19
55.5	96227.3	46675.3	208.967	1734.6
56	97094.3	46645.5	208.856	1735.16
56.5	97961.2	46607.4	208.744	1735.86
57	98828.1	46561.4	208.632	1736.71
57.5	99695	46507.4	208.521	1737.72
58	100562	46445.2	208.409	1738.86
58.5	101429	46375.1	208.297	1740.16
59	102296	46296.9	208.185	1741.61
59.5	103163	46210.6	208.073	1743.2
60	104030	46116.4	207.96	1744.94
60.5	104896	46014	207.848	1746.82
61	105763	45903.6	207.735	1748.86
61.5	106630	45785.2	207.623	1751.03
62	107497	45658.8	207.51	1753.36
62.5	108364	45534.3	207.396	1755.87

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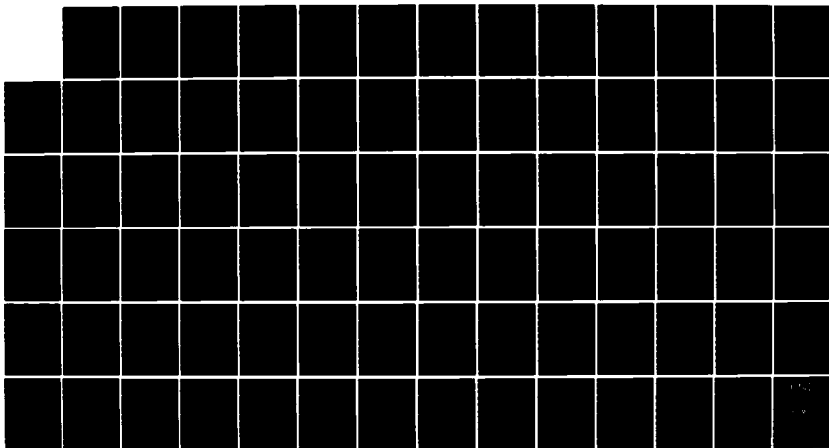
DISPERSION SENSITIVITY OF THE EIGHT INCH ADVANCED
RAMJET MUNITIONS TECHNO. (U) NAVAL POSTGRADUATE SCHOOL
MONTEREY CA S R POOLE SEP 84 NPS-67-84-015

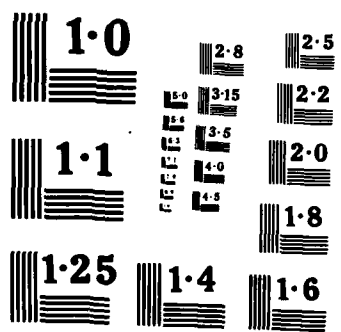
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63	109231	45381.7	207.283	1758.43
63.5	110098	45231.1	207.169	1751.18
64	110965	45072.5	207.056	1764.08
64.5	111832	44905.8	206.942	1767.12
65	112699	44731.1	206.827	1770.3
65.5	113566	44548.4	206.713	1773.61
66	114433	44357.5	206.598	1777.07
66.5	115299	44158.7	206.482	1780.67
67	116166	43951.8	206.367	1784.4
67.5	117033	43736.9	206.251	1788.28
68	117900	43513.9	206.135	1792.28
68.5	118767	43282.9	206.018	1796.43
69	119634	43043.8	205.901	1800.7
69.5	120501	42796.6	205.784	1805.11
70	121368	42541.5	205.666	1809.65
70.5	122235	42278.4	205.548	1814.33
71	123102	42007.2	205.43	1819.13
71.5	123969	41727.8	205.311	1824.06
72	124835	41440.4	205.191	1829.13
72.5	125702	41145.1	205.072	1834.31
73	126569	40841.7	204.951	1839.63
73.5	127436	40530.2	204.831	1845.07
74	128303	40210.7	204.709	1850.63
74.5	129170	39883.1	204.588	1856.32
75	130037	39547.5	204.466	1862.12
75.5	130904	39204	204.343	1868.05
76	131771	38852.3	204.22	1874.1
76.5	132638	38492.6	204.096	1880.26
77	133505	38124.8	203.972	1886.55
77.5	134372	37749	203.847	1892.94
78	135238	37365.1	203.721	1899.46
78.5	136105	36973.2	203.595	1906.08
79	136972	36573.3	203.469	1912.82
79.5	137839	36165.2	203.342	1919.67
80	138706	35749.3	203.214	1926.63
80.5	139573	35325.3	203.086	1933.7
81	140440	34893.1	203.013	1940.88
81.5	141307	34453	202.939	1948.16
82	142174	34004.7	202.863	1955.55
82.5	143041	33548.5	202.785	1963.04
83	143908	33084.2	202.705	1970.63
83.5	144774	32611.9	202.624	1978.33
84	145641	32131.5	202.54	1986.13
84.5	146508	31643.2	202.454	1994.03
85	147375	31146.6	202.367	2002.02
85.5	148242	30642.1	202.277	2010.11
86	149109	30129.7	202.184	2018.3
86.5	149976	29608.9	202.09	2026.58
87	150843	29080.4	201.992	2034.96
87.5	151710	28543.7	201.893	2043.42
88	152577	27999	201.79	2051.98
88.5	153444	27446.2	201.685	2060.63
89	154311	26885.3	201.577	2069.37
89.5	155177	26316.6	201.466	2078.19
90	156044	25739.6	201.352	2087.11
90.5	156911	25154.7	201.235	2096.1
91	157778	24561.8	201.114	2105.19
91.5	158645	23960.8	200.99	2114.35
92	159512	23351.6	200.863	2123.6
92.5	160379	22734.5	200.732	2132.93
93	161246	22109.3	200.597	2142.34
93.5	162113	21476.1	200.458	2151.83
94	162980	20834.9	200.315	2161.39
94.5	163847	20185.7	200.168	2171.04
95	164713	19528.3	200.016	2180.76
95.5	165580	18863.7	199.86	2190.55

REPRODUCED AT GOVERNMENT EXPENSE

96	166447	18189.5	199.699	2200.42
96.5	167314	17508	199.533	2210.36
97	168181	16818.6	199.362	2220.38
97.5	169048	16121	199.186	2230.46
98	169915	15415.4	199.004	2240.62
98.5	170782	14701.8	198.817	2250.84
99	171649	13980	198.623	2261.13
99.5	172516	13250.3	198.424	2271.49
100	173383	12512.6	198.218	2281.92
100.5	174250	11766.9	198.006	2292.41

RAMJET BURNOUT BETWEEN T= 100.5 AND 101

APPENDIX E- THREE DEGREES OF FREEDOM RESULTS

VARIABLES & INITIAL CONDITIONS:

XDOT = 2188.670000

X = .0

YDOT = .0

Y = .0

THEDOT = .0

THETA = .0

M = 225.0000000

T = .0

CONSTANTS:

PHASE = .0

CMA = -2.308000000

A = .3491000000

DI = .6666670000

CMT = 190.0000000

CDO = .2760000000

PI = 3.141592654

ISP = 550.0000000

LAMBDA = 15000.00000

PI8 = .3926990817

SPECIAL FUNCTIONS:

ETA = ATAN(YDOT/XDOT)

VCG = (XDOT**2+YDOT**2)**.5

VW = 0

GAMMA = ATAN((YDOT+VW)/XDOT)

V = (XDOT**2+(YDOT+VW)**2)**.5

Q = .5*.0008568*V**2

K = C*DI*A

THEDEL = (CMA*K*(THETA-GAMMA)-((CMT*K*DI*THEDOT)/(V*2)))/I

ALPHA = GAMMA-THETA

CD = CDO+.5*CL*SIN(ALPHA)

CL = .091*ALPHA

L = CL*Q*A

D = C*CD*C*A

XDBL = (L*SIN(GAMMA)-D*CCS(GAMMA))/M

YDBL = (L*CCS(GAMMA)+D*SIN(GAMMA))/M

C = C

MDUT = (1-C)*(CDO+.5*CL*SIN(ALPHA))*C*A/(-ISP)

DELM = 225-M

I = (18.6-.0423*DELM)*32.2

DERIVATIVES:

D(XDOT/C(T)) =

```

D(X /D(T) ) = =
D(YDCI /C(T) ) = =
D(Y /D(T) ) = =
D(THCOT/C(T) ) = =
D(THETA /D(T) ) = =
D(M /D(T) ) = =

```

```

OUTPUTS:
TITLE: THREE DEGREE CROSSWIND TRIAL
TABULATE: T
AT INTERVAL .5000000000
PLOT: X
AGAINST: T
PLCT: Y
AGAINST: T
PLCT: ALPHA
AGAINST: T
AT INTERVAL .2500000000

```

END CALCULATION WHEN M .LE. 198.000

THREE DEGREE CROSSWIND TRIAL

T	X	Y	VCG	V	MDUT
0	1094.3	.00	2188.7	2188.7	2188.7
1	2188.0	.00	2188.7	2188.7	2188.7
2	3283.0	.00	2188.7	2188.7	2188.7
3	4377.3	.00	2188.7	2188.7	2188.7
4	5471.0	.00	2188.7	2188.7	2188.7
5	6566.3	.00	2188.7	2188.7	2188.7
6	7660.3	.00	2188.7	2188.7	2188.7
7	8754.0	.00	2188.7	2188.7	2188.7
8	9849.3	.00	2188.7	2188.7	2188.7
9	10943.8	.00	2188.7	2188.7	2188.7
10	12038.2	.00	2188.7	2188.7	2188.7
11	13132.6	.00	2188.7	2188.7	2188.7
12	14227.1	.00	2188.7	2188.7	2188.7
13	15321.5	.00	2188.7	2188.7	2188.7
14	16415.9	.00	2188.7	2188.7	2188.7
15	17509.4	.00	2188.7	2188.7	2188.7


```

END CF RUN
VARIABLES & INITIAL CONDITIONS:
XDOT = 218.610000
X = .0
YDOT = .0
Y = .0
THEDCT = .0
THETA = .0
M = 225.0000000
T = .0

CONSTANTS:
PHASE = .0
CMA = -2.308000000
A = .3491000000
DI = .6666670000
CMT = 190.0000000
CDO = .2760000000
PI = 3.141592654
ISP = 950.0000000
LAMBDA = 15000.00000
PI8 = .352659017

SPECIAL FUNCTIONS:
ETA = ATAN(YDCT/XDCT)
VCG = (XDCT**2+YDCT**2)**.5
VM = 60
GAMMA = ATAN((YDCT+VM)/XDCT)
V = (XDCT**2+(YDCT+VM)**2)**.5
Q = .5*.000500000*V**2
K = C*DI*A
THEDEL = (CMA*K*(THETA-GAMMA)-((CMT*K*DI*THEDCT)/(V*2)))/I
ALPHA = GAMMA-THETA
CD = CDO+.5*(CL*SIN(ALPHA))
CL = .091*ALPHA
L = CL*Q*A
D = C*CD*C*A
XDBL = (L*SIN(GAMMA)-D*CCS(GAMMA))/M
YDBL = (L*CCS(GAMMA)+D*SIN(GAMMA))/M
C = C
MDOT = (1-C)*(CDO+.5*CL*SIN(ALPHA))*Q*A/(-ISP)
DELM = 225-M
I = (18.8-.0423*DELM)*32.2

DERIVATIVES:
D(XDCT/D(T)) =
D(YDCT/D(T)) =
D(X/D(T)) =

```

XDOT
 D(YDOT/C(T)) = =
 YDBL
 D(Y/D(T)) = =
 YDOT
 D(THEDCT/C(T)) = =
 THEDBL
 D(THETA/C(T)) = =
 THEDCT
 D(M/D(T)) = =
 MDCT

OUTPUTS: THREE DEGREE CRCSWIND TRIAL
 TITLE: TABULATE: T
 AT INTERVAL X .5000000000
 PLCT: X
 AGAINST: T
 PLCT: Y
 AGAINST: T
 PLOT: ALPHA
 AGAINST: T
 AT INTERVAL .250C000C00
 V
 MDOT

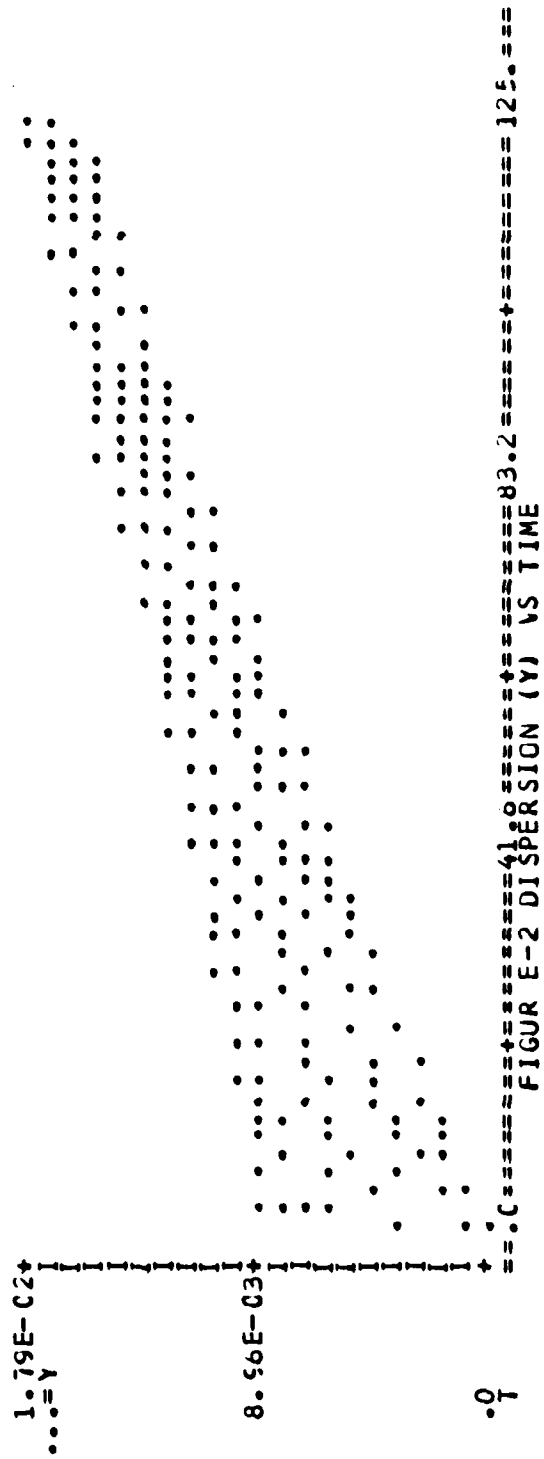
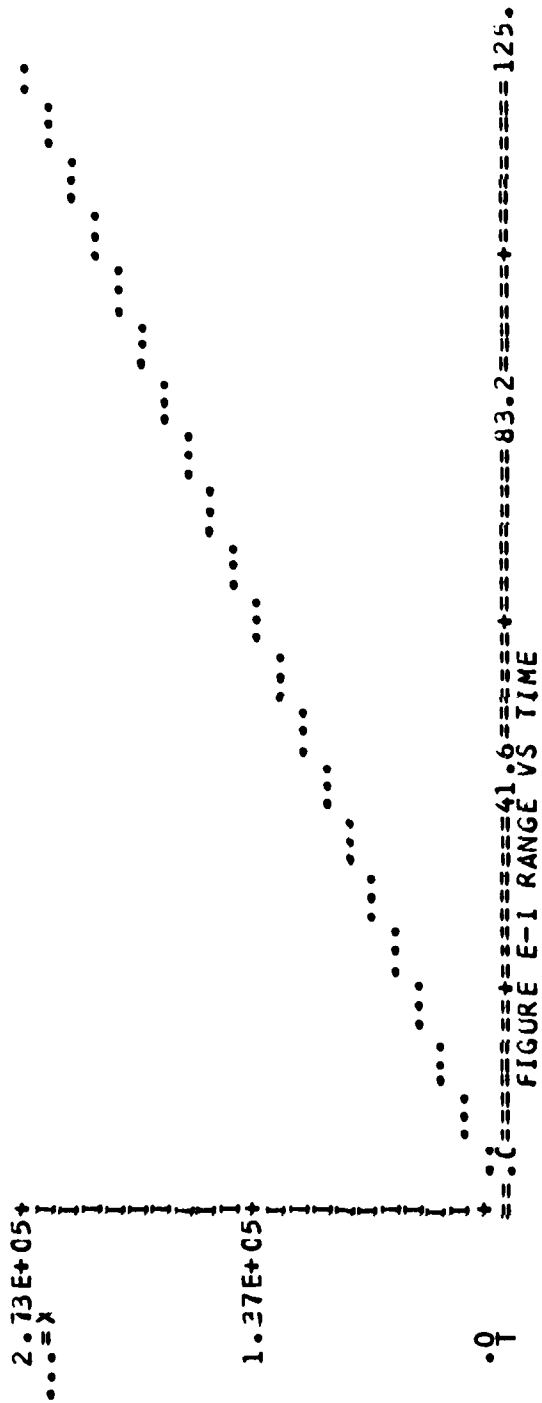
END CALCULATION WHEN M .LE. 198.000

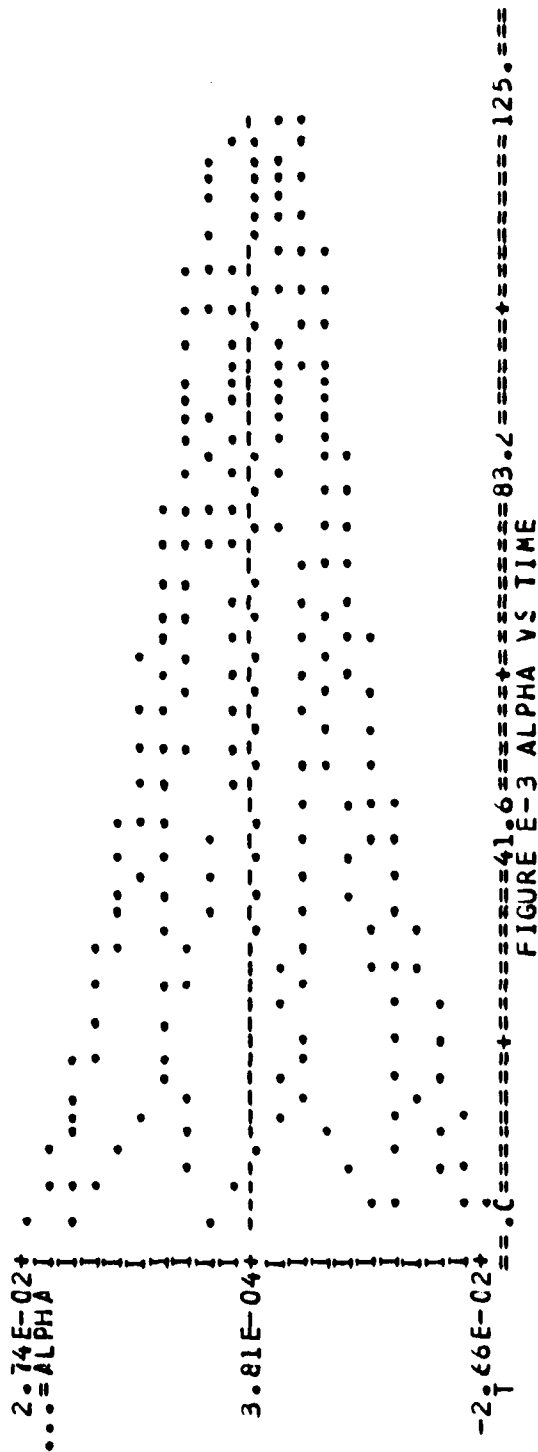
THREE DEGREE CRCSWIND TRIAL

T	C	X	Y	VCG	V	MDOT
0	50000	1094.3	0	2188.7	2189.5	21654
1	50000	2188.7	.352100-03	2188.7	2189.5	21654
2	50000	3283.0	.644660-02	2188.7	2189.5	21654
3	50000	4377.3	.846280-02	2188.7	2189.5	21654
4	50000	5471.7	.868930-02	2188.7	2189.5	21654
5	50000	6566.0	.706620-02	2188.7	2189.5	21654
6	50000	7660.3	.437260-02	2188.7	2189.5	21654
7	50000	8754.7	.186640-02	2188.7	2189.5	21654
8	50000	9849.0	.699920-03	2188.7	2189.5	21654
9	50000	10943.3	.141540-02	2188.7	2189.5	21654
10	50000	12038.2	.368850-02	2188.7	2189.5	21654
11	50000	13132.6	.857440-02	2188.7	2189.5	21654
12	50000	14226.1	.901760-02	2188.7	2189.5	21654
13	50000	15321.5	.766300-02	2188.7	2189.5	21654
14	50000	16415.9	.516890-02	2188.7	2189.5	21654
15	50000	17509.4	.270390-02	2188.7	2189.5	21654
16	50000	18604.8	.141090-02	2188.7	2189.5	21654
17	50000	19699.8	.188760-02	2188.7	2189.5	21654
18	50000	20792.2		2188.7	2189.5	21654

57.000	124750+C6	121800-01	2188.77	22189.5	21653
57.500	125850+C6	111380-01	2188.77	22189.5	21653
58.000	126940+C6	966710-02	2188.77	22189.5	21653
58.500	128040+C6	848040-02	2188.77	22189.5	21653
59.000	129130+C6	815010-02	2188.77	22189.5	21653
59.500	130230+C6	884380-02	2188.77	22189.5	21653
60.000	131320+C6	102510-01	2188.77	22189.5	21653
60.500	132410+C6	127310-01	2188.77	22189.5	21653
61.000	133510+C6	126180-01	2188.77	22189.5	21653
61.500	134600+C6	125530-01	2188.77	22189.5	21653
62.000	135700+C6	115410-01	2188.77	22189.5	21653
62.500	136790+C6	101470-01	2188.77	22189.5	21653
63.000	137890+C6	902550-02	2188.77	22189.5	21653
63.500	138980+C6	872020-02	2188.77	22189.5	21653
64.000	140070+C6	938780-02	2188.77	22189.5	21653
64.500	141170+C6	107290-01	2188.77	22189.5	21653
65.000	142260+C6	121350-01	2188.77	22189.5	21653
65.500	143360+C6	125720-01	2188.77	22189.5	21653
66.000	144450+C6	128790-01	2188.77	22189.5	21653
66.500	145550+C6	119340-01	2188.77	22189.5	21653
67.000	146640+C6	106120-01	2188.77	22189.5	21653
67.500	147740+C6	955840-02	2188.77	22189.5	21653
68.000	148830+C6	928610-02	2188.77	22189.5	21653

1	6E	500	X	149520+06	Y	993710-02	VCG	7	MD01	3
6E	500	500	151020+06	12200-01	12200-01	218E	7	216533	216533	3
6E	500	500	152110+06	125520-01	125520-01	218E	7	216533	216533	3
70	500	500	153210+06	133330-01	133330-01	218E	7	216533	216533	3
71	500	500	154300+06	132270-01	132270-01	218E	7	216533	216533	3
71	500	500	155400+06	123210-01	123210-01	218E	7	216533	216533	3
71	500	500	156490+06	110650-01	110650-01	218E	7	216533	216533	3
72	500	500	157580+06	100810-01	100810-01	218E	7	216533	216533	3
73	500	500	158680+06	984810-02	984810-02	218E	7	216533	216533	3
73	500	500	159770+06	104910-01	104910-01	218E	7	216533	216533	3
74	500	500	160870+06	117210-01	117210-01	218E	7	216533	216533	3
74	500	500	161960+06	125800-01	125800-01	218E	7	216533	216533	3
74	500	500	163060+06	137010-01	137010-01	218E	7	216533	216533	3
75	500	500	164150+06	135750-01	135750-01	218E	7	216533	216533	3
75	500	500	165240+06	126960-01	126960-01	218E	7	216533	216533	3
76	500	500	166340+06	115070-01	115070-01	218E	7	216533	216533	3
76	500	500	167430+06	105950-01	105950-01	218E	7	216533	216533	3
77	500	500	168530+06	104070-01	104070-01	218E	7	216533	216533	3
77	500	500	169620+06	110480-01	110480-01	218E	7	216533	216533	3
78	500	500	170720+06	122310-01	122310-01	218E	7	216533	216533	3
78	500	500	171810+06	134180-01	134180-01	218E	7	216533	216533	3
78	500	500	172900+06	140750-01	140750-01	218E	7	216533	216533	3
79	500	500	174000+06	139230-01	139230-01	218E	7	216533	216533	3





APPENDIX F-FIVE DEGREES OF FREEDOM RESULTS

VARIABLES & INITIAL CONDITIONS:

```
XDOT = 1723.564000
YDOT = .0
ZDOT = 1733.564000
THEDCT = .0
TH = .0
DELDCT = .0
DE = 7853980000
M = 225.0000000
I = .0
```

CONSTANTS:

```
CMA = -2.308000000
A = .3491000000
DI = .6666670000
ADI = .2327300000
DI2 = .4444440000
CMT = 190.0000000
ISP = 950.0000000
G = 32.17400000
CDO = .2760000000
K = 1.000000000
R = .0
```

SPECIAL FUNCTIONS:

```
ROUT = (2116.22*(1-((.0035662*Z/518.688))**5.256)/
        (1716.5*(518.688-((.0035662*Z)))
        CDEIF(2,36085,ROUT,.001271)
VMXY = 0
VMXZ = 0
GA = ATAN((YDOT+VMXY)/(XDOT+VMXZ))
O = ATAN(ZDOT/(XDOT+VMXZ))
VCG = (XDOT**2+YDOT**2+ZDOT**2)**.5
V = ((XDOT+VMXZ)**2+(YDOT+VMXY)**2+ZDOT**2)**.5
AL = C-DE
BE = GA-TH
Q = (RO*V**2)/2
LY = .091*BE*CA
L = .091*AL*CA
DY = D*CCS(Q)/COS(GA)
D = ((-1025*V/(2402.88*(518.688-((.0035662*Z)))**5+.5015)
        +.5*((.091*AL)*SIN(AL))*CA
```

```

DRAG = D/COS(GA)
C = CDEIF(M,158,1,R)
DELM = 2.25-M
I = (18.8-.0423*DELM)*32.2
MDOOT = (1-C)*[RAG/(-ISP)]

DERIVATIVES:
D(XDCT/D(T)) = (L*CS(O)-C*CS(O)+LY*SIN(GA)-C*DY*CS(GA))/M
D(X/D(T)) = XDCT
D(YDCT/D(T)) = (LY*CS(GA)+C*DY*SIN(GA))/M
D(Y/D(T)) = YDCT
D(ZDCT/D(T)) = (L*CS(O)+C*D*SIN(O)-M*G)/M
D(Z/D(T)) = ZDCT
D(THCOT/D(T)) = ((CMT*Q*ADI*DI*THCOT)/(V*2))/I
D(TH/D(T)) = THEDCOT
D(DELDCT/D(T)) = ((CMT*Q*ADI*DI*DELDCT)/(V*2))/I
D(DE/D(T)) = CELDCT
D(M/D(T)) = MDOCT

```

```

OUTPUTS:
TITLE: FIVE DEGREE
TABULATE: T X Y Z PDOT VCG M
AT INTERVAL .5000000000
PLCT: X
AGAINST: T EE
PLOT: AL
AGAINST: T
PLCT: Y
AGAINST: T AT INTERVAL .2500000000
END CALCULATION WHEN MDOOT .GE. .0

```

FIVE DEGREE

T	X	Y	Z	MDUT	VCG
0	866	00	86	7255	2451
1	1733	00	17	7018	2440
2	2600	00	25	6789	2429
3	3467	00	34	6566	2417
4	4333	00	42	6355	2406
5	5200	00	50	6150	2395
6	6067	00	58	5951	2384
7	6934	00	66	5760	2373
8	7801	00	74	5598	2362
9	8667	00	82	5426	2351
10	9534	00	90	5261	2340
11	1040	00	98	5091	2329
12	1126	00	105	4917	2318
13	1213	00	112	4747	2307
14	1300	00	120	4598	2297
15	1386	00	128	4455	2287
16	1473	00	135	4317	2276
17	1560	00	142	4183	2266
18	1646	00	150	4055	2256
19	1733	00	157	3931	2245
20	1820	00	164	3811	2235
21	1906	00	171	3695	2225
22	1993	00	178	3584	2215
23	2080	00	184	3476	2205
24	2167	00	191	3373	2195
25	2253	00	198	3273	2185
26	2340	00	204	3176	2175
27	2427	00	211	3083	2166
28	2513	00	217	2993	2156
29	2600	00	223	2907	2147
30	2687	00	230	2823	2137
31	2773	00	236	2743	2128
32	2860	00	242	2655	2119
33	2947	00	248	2590	2110
34	3033	00	254	2518	2100
35	3120	00	259	2448	2091
36	3207	00	265	2380	2082
37	3293	00	271	2315	2073
38	3380	00	276	2253	2065
39	3467	00	282	2192	2059
40	3553	00	287	2134	2047
41	3640	00	293	2078	2035
42	3727	00	298	2024	2022
43	3813	00	303	1971	2010

2006.1
1998.1
1990.3
1982.5
1974.5
1966.9
1959.9
1951.9
1943.2
1937.2
1930.3
1923.5
1916.5
1909.8
1902.7
1896.4
1889.2
1883.2
1877.1
1871.1
1865.1
1859.2

18726
18256
17803
17367
16946
16539
16148
15770
15405
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25434
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VCG
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1842.3
1836.5
1831.7
1826.5
1821.5
1816.9
1811.3
1807.8
1802.5
1798.2
1794.2
1790.2
1786.4
1782.7
1778.2
1775.8
1771.6
1768.4
1765.5
1762.5
1759.6
1757.0

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24074
23954
23837
23723
23612
23509
23397
23298
23198
23109
22919
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22666
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22514
22442
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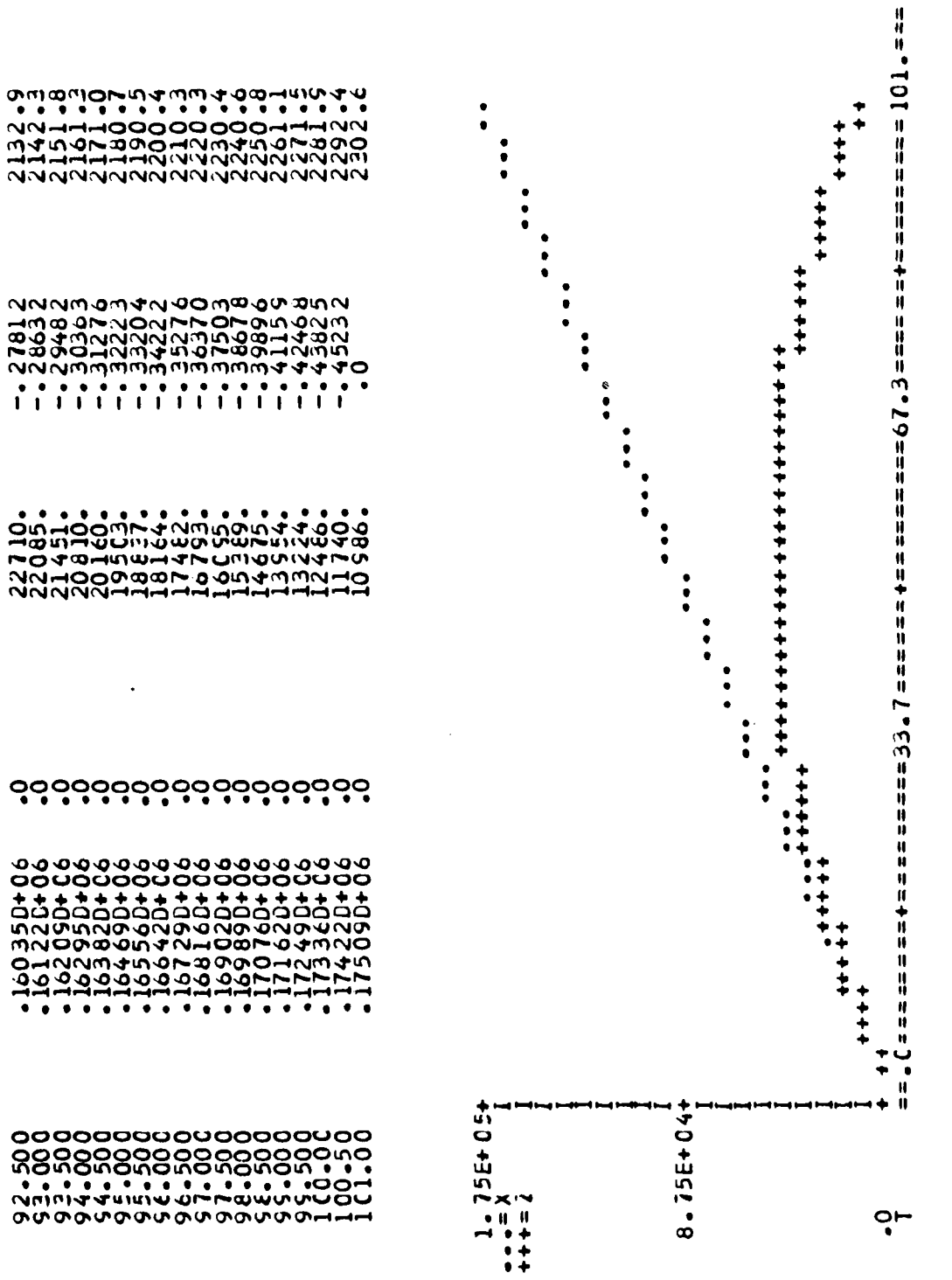
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T	X	Y	Z	MDUT	VCG
45.000	78877.	0.00	45573.	22075	1754.4
46.000	75744.	0.00	45826.	22025	1752.0
47.000	80611.	0.00	45541.	21977	1749.7
48.000	81477.	0.00	46048.	21892	1747.6
49.000	82344.	0.00	46146.	21854	1745.9
50.000	83211.	0.00	46237.	21819	1743.2
51.000	84078.	0.00	46320.	21787	1740.3
52.000	84945.	0.00	46354.	21758	1739.1
53.000	85811.	0.00	46461.	21733	1738.0
54.000	86678.	0.00	46519.	21710	1737.0
55.000	87545.	0.00	46569.	21691	1736.0
56.000	88412.	0.00	46612.	21674	1735.3
57.000	89278.	0.00	46646.	21651	1734.6
58.000	90145.	0.00	46672.	21631	1733.6
59.000	91012.	0.00	46690.	21644	1733.6
60.000	91879.	0.00	46700.	21639	1733.6
61.000	92746.	0.00	46703.	21634	1733.6
62.000	93612.	0.00	46657.	21641	1733.3
63.000	94479.	0.00	46683.	21647	1733.3
64.000	95346.	0.00	46661.	21655	1734.3
65.000	96213.	0.00	46631.	21667	1734.9
66.000	97079.	0.00	46552.	21682	1735.5
67.000	97946.	0.00	46546.	21699	1736.5
68.000	98813.	0.00	46452.	21720	1737.5
69.000	99680.	0.00	46430.	21744	1738.9
70.000	100550+06	0.00	463360.	21772	1739.5
71.000	101410+06	0.00	46281.	21802	1741.4
72.000	102280+06	0.00	46155.	21835	1743.7
73.000	103150+06	0.00	45558.	21872	1744.4
74.000	104020+06	0.00	45887.	21911	1746.6
75.000	104880+06	0.00	45769.	21954	1748.6
76.000	105750+06	0.00	45642.	22000	1750.8
77.000	106610+06	0.00	45508.	22048	1753.1
78.000	107480+06	0.00	45345.	22105	1755.6
79.000	108350+06	0.00	45214.	22153	1758.2
80.000	109220+06	0.00	45056.	22213	1761.0
81.000	110080+06	0.00	44849.	22274	1763.9
82.000	110950+06	0.00	44714.	22339	1766.5
83.000	111810+06	0.00	44531.	22406	1770.4
84.000	112680+06	0.00	44340.	22476	1773.4
85.000	113550+06	0.00	44141.	22549	1776.9
86.000	114420+06	0.00	43934.	22626	1780.5
87.000	115280+06	0.00	43719.	22705	1784.2
88.000	116150+06	0.00	43456.	22788	1788.0
89.000	117020+06	0.00		22873	1792.1
90.000	117880+06	0.00			

65.500	118750+06	0.00	43265.	2962	1796.25
65.500	119620+06	0.00	43025.	23053	1800.55
65.500	120480+06	0.00	42778.	23148	1804.55
70.500	121350+06	0.00	42523.	23245	1809.55
70.500	122220+06	0.00	42260.	23349	1814.55
71.500	123080+06	0.00	41998.	23446	1819.00
71.500	124820+06	0.00	41729.	23556	1823.00
72.500	125680+06	0.00	41421.	23665	1823.55
72.500	126550+06	0.00	41126.	23777	1823.55
73.500	127420+06	0.00	40811.	23893	1833.55
73.500	128280+06	0.00	40511.	24011	1833.55
74.500	129150+06	0.00	40263.	24132	1850.55
74.500	130020+06	0.00	39963.	24257	1850.55
75.500	130880+06	0.00	39663.	24384	1867.00
75.500	131750+06	0.00	39364.	24514	1867.00
76.500	132620+06	0.00	38822.	24647	1874.00
76.500	133480+06	0.00	38472.	24783	1886.00
77.500	134350+06	0.00	38104.	24922	1892.00
77.500	135220+06	0.00	37728.	25063	1899.00
78.500	136080+06	0.00	37344.	25208	1906.00
78.500	136950+06	0.00	36952.	25356	1912.00
79.500	137820+06	0.00	36552.	25506	1919.55
79.500	138680+06	0.00	36144.	25659	1926.55
80.500	139550+06	0.00	35724.	25817	1933.00
80.500	140420+06	0.00	35304.	25977	1940.00
81.500	141290+06	0.00	34872.	26139	1948.00
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88.500	153420+06	0.00	27993.	28119	2056.55
88.500	154290+06	0.00	27423.	28246	2064.55
89.500	155150+06	0.00	26862.	28372	2072.55
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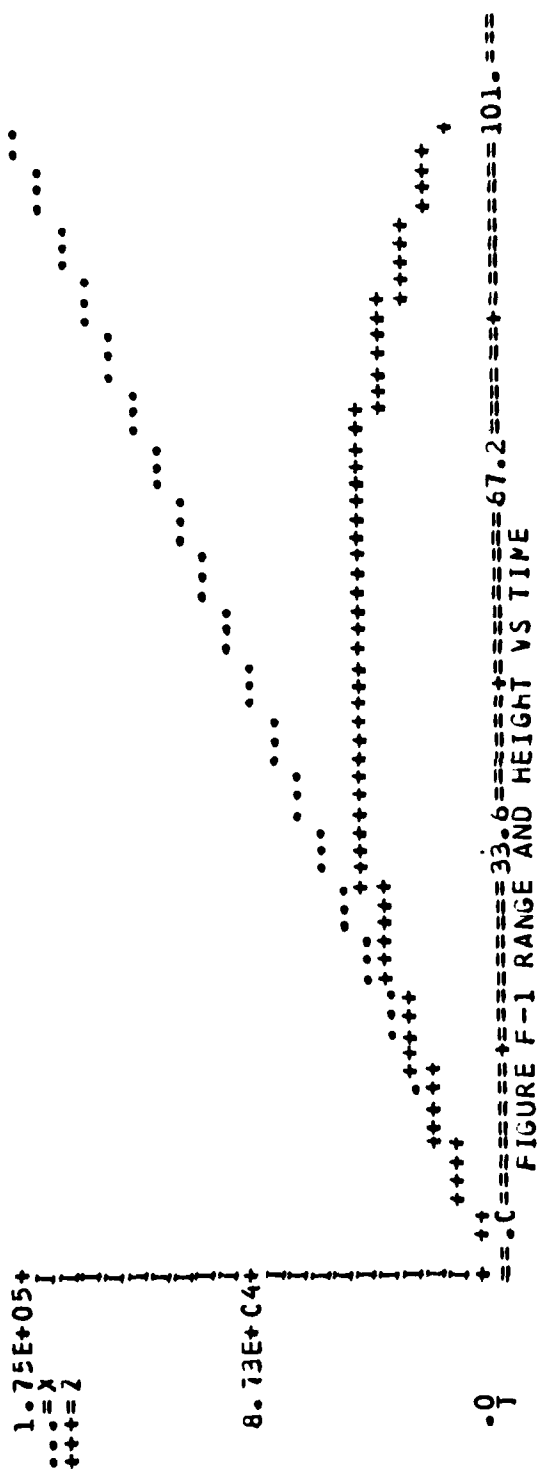
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4	5000	36405	121790-02	29310	20264	2030	5
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4	5000	45939	129010-01	34158	15789	1951	6
5	5000	46806	158350-01	34642	15427	1944	3
6	5000	47673	187360-01	35079	15074	1937	2
7	5000	48540	208030-01	35528	14735	1930	2
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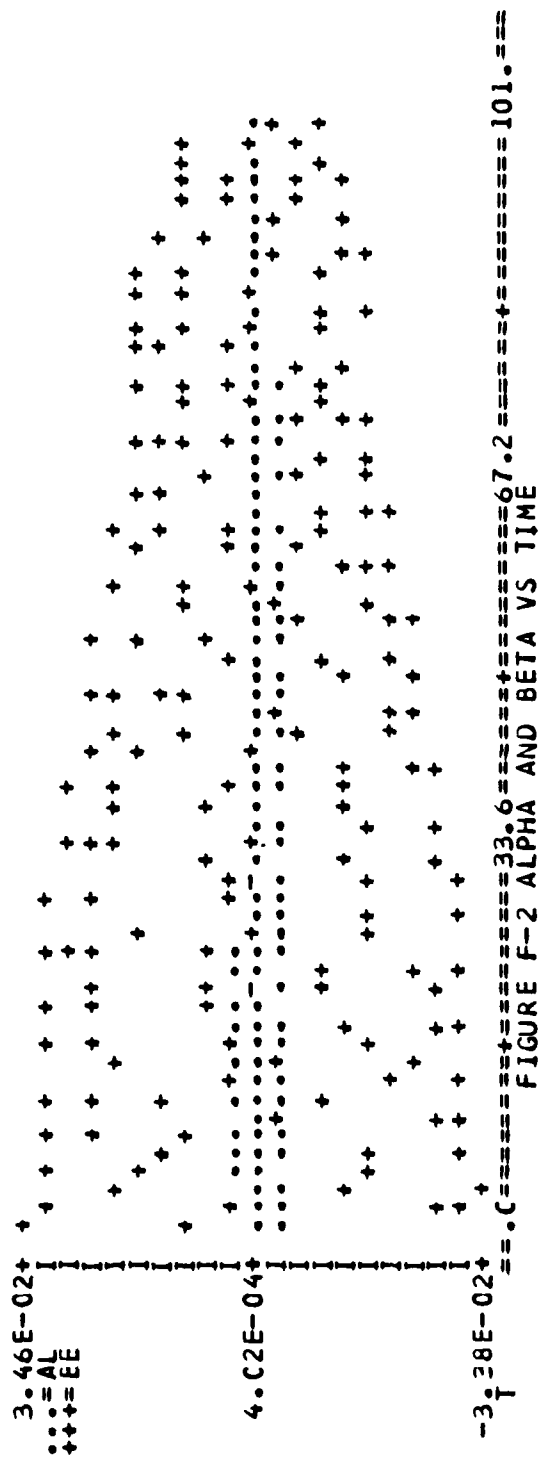
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33.500	60675.	136620-01	40968.	--	23869	1836.7
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33.500	62408.	182650-01	41559.	--	23644	1826.5
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33.500	65875.	184960-01	42646.	--	23229	1807.3
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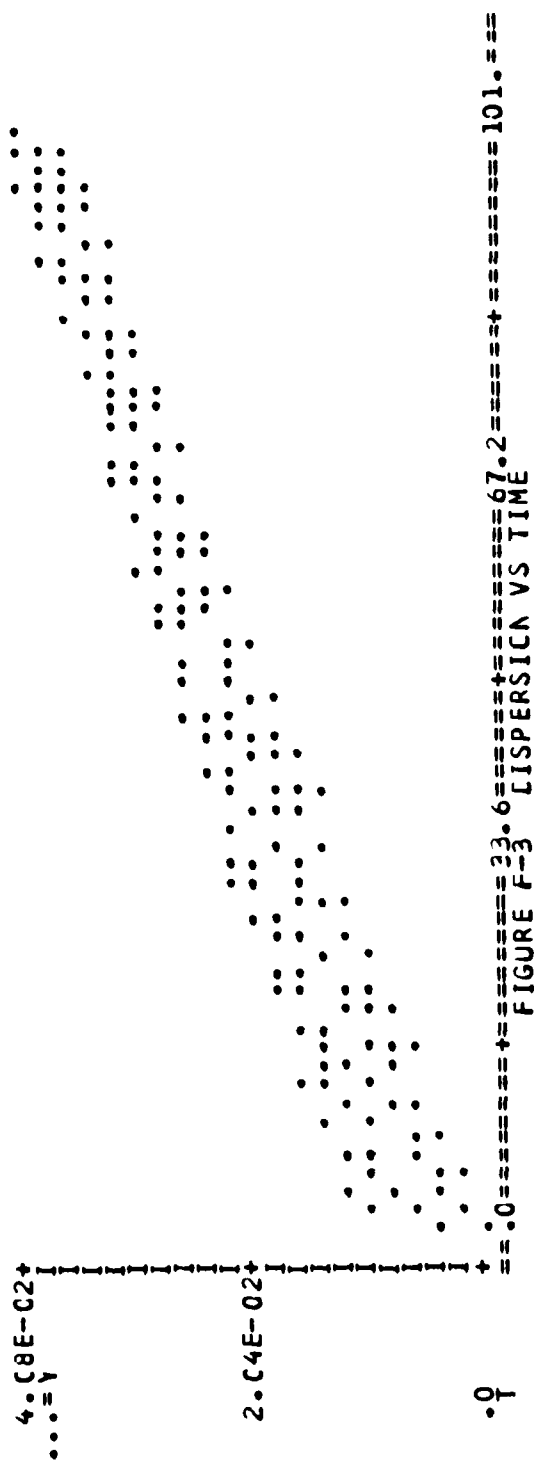
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82.000	141290+06	300860-01	33583.	26240	1948.0
82.500	142150+06	314240-01	33527.	26359	1955.5
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84.000	144750+06	365000-01	32109.	26716	1978.0
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DATA CTS /4F SUM,4HARY,4H HAR,4HD CU,4HPUT/
DATA CTS /4F 3 D,4FEG D,4HURIN,4HG BU,4HRNIN,4HG /
DATA CTS /4H ITE,4FRATE,4H UN,4HCE /
DATA CTS /4H TER,4HMINA,4HTE A,4HT TE,4HRM X,4HINST,
14HEAD C,4F OF T,4HERM,4HX2 /
DATA CTS /4H 5 C,4HIGIT,4F TIM,4HE PR,4HINT /
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DATA SYM /2F10, 2HPC, 2HIM, 2HIP, 2FIS, 2HAA, 2HTC, 2HIB,
12HRJ, 2FVC, 2HMC, 2HRI, 2HRT, 2HRC, 2PRS, 2HMM, 2FNA, 2HSS/
DATA CTS /O, 32E, 08E, 59, 1148, 29E, 56, 2460, 62E, 52, 4101, 04E, 587,
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444251, 3E, 858, 47572, 17848, 50853, 01837, 54133, 85827, 57414, 65816,
560655, 3E, 806, 63576, 37755/
ASSIGN 167 TO IER
NEXT TAC STATEMENTS ARE MINE
INTEGER R(19), CODE, SS, TYPE, DUMMY
DATA CLAMPY/1H /
DO 1 I=1, 38E3
1 LE(I)=C.
JBURN=1
START WITH AEROPACK END WITH 0 IN CCL 80
2 CALL AEROPACK
DO 3 I=1, 85E
3 LE(I)=C.
ISP=999.99
TBM=.55599
ISLN=0
J2=1
TSRB=.55555
DENSF=1.
PRESPF=1.
TEMPF=1.
CMETM=C.
SL=1.
CONTRCL CARD OPTIONS SET FOR 6DEG, SPIN, F1, STGF TRAJ ON T, FLAT TRAJ
4 REAC (5, 159) R, CCDE, SS, TYPE
4 IDGREE(I)=1
4 IRECT=R(2)
4 ITWT=1
4 IUFLEG=F(5)
4 IUNPT=1
4 ISPRT=1
4 IRSET=1

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C C

C

C C

C

C

C

C

[illegible]

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IF (IC.NE.ICN) GC TC 13
ICN=ICN+10
C(2)=ANICMS*C(2)
C(3)=ANICMS*C(3)
L=K
DO 11 I=1,7
ATM(L)=C(I)
L=L+1
11 IF (L.LE.653) GC TC 12
WRITE (6,172)
STCP
K=K+7
12 IF (C(1)-GE.0.) GO TO 9
ATM(L-7)=ABS(ATM(L-7))
NATM=K-7
GO TO 4
13 WRITE (6,172)
STCP
14 MTB=C(2)
D=FTOM*(3)
CGIB=FTCM*C(4)
ATB=FTCM2*C(5)
BTB=FTCM2*C(6)
TWIST=C(7)
15 IF (SS.EQ.DLMMY) GO TO 4
GO TO 34
16 LO=FTCM*C(1)
CE(1)=C(2)
AZC=C(3)
BC=C(4)/ANICM**2
SL=C(5)
IH2=C(6)
IH3=C(7)
GO TO 15
17 ITC=C(1)
IX1=FTCM*C(2)
IX2=FTCM*C(3)
IX3=FTCM*C(4)
IARV=C(5)
IARH=C(6)
GO TO 15
18 DEIFF=C(1)
PTFF=C(2)
XICEL=FTCM*C(3)
AZC=C(4)
LAT=C(5)
GO=FTCM*C(6)

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FDL01470
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FDU01490
FDU01500
FDU01510
FDU01520
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 FDU02390
 FDU02400

15 GO TO 15
 Q=C(1)
 TF=C(2)
 E=C(3)
 LL=FTCM*C(4)
 SL6C=C(5)
 20 GO TO 15
 TI=C(1)
 XI0=FTCM*C(2)
 XI MAX=FTCM*C(3)
 YI=FTCM*C(4)
 ZI=FTCM*C(5)
 EX1=FTCM*C(6)
 EZ1=FTCM*C(7)
 21 GO TO 15
 TMCBI=C(1)
 UMCB=FTCM*C(2)
 PHMCB=FTCM*C(3)
 THMCB=FTCM*C(4)
 EUB=FTCM*C(5)
 EPB=FTCM*C(6)
 ETB=FTCM*C(7)
 22 GO TO 15
 R2TBM=FTCM*C(1)
 RNE=FTCM*C(2)
 AE=FTCM*C(3)
 PE=C(4)/FTCM2
 RN=FTCM*C(5)
 RK=FTCM*C(6)
 23 GO TO 15
 QE(1)=C(1)
 IX2=FTCM*C(2)
 IU=FTCM*C(3)
 AZU=C(4)
 EU=C(5)
 XI MAX=FTCM*C(6)
 XI=XI MAX
 AZC=C(7)
 24 GO TO 15
 W SX(1)=AMTMS*C(1)
 W S2=AMTMS*C(2)
 WBX=AMTMS*C(3)
 WBZ=AMTMS*C(4)
 DENSF=C(5)
 PR ESF=C(6)
 TEMPF=C(7)
 CMETM=C.
 J2=1

```

25 GO TO 15
   IH2B=C(1)/DTOM
   IH3B=C(2)/DTOM
   IFUB=C(3)/FTOM
   CX1=C(4)/ANTOM**2//FTCM
   LZ1=C(5)/FTCM
   GO TO 15
26 ISI=C(1)
   ISP=C(2)
   MF=C(3)
   LE(1)=FTCM*C(4)
   CGTBM=FTCM*C(5)
   ATBM=FTI(M2*C(6))
   MDI=C(7)
   GO TO 15
27 TBM*ST=C(1)
   TBM=C(2)
   TBST=C(3)
   TB=C(4)
   TL=C(5)
   TDI=C(6)
   TEC=C(7)
   GO TO 15
28 DELTB=C(1)
   PTB=C(2)
   TCE=C(3)
   TCF=C(4)
   GO TO 15
29 TSRI=C(1)
   TSRI=C(2)
   TSRES=C(3)
   TSRES=C(4)
   RS=FTCM*C(5)
   TS CF=C(6)
   GO TO 15
30 AL CNG=C(1)
   RACS=C(2)*1000.
   ADGS=C(3)*1000.
   PACA=C(4)*1000.
   TOCAY=C(5)*1000.
   ISUN=1
   GO TO 15
31 HG IMP=C(1)/FTOM
   CMETM=1.
   COCEM=CCCE
   DO 32 I=1,162,6
   K=I+4
   READ (5,171) (CMNT(J),J=I,K)

```

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FDU022410
FDU022420
FDU022430
FDU022440
FDU022450
FDU022460
FDU022470
FDU022480
FDU022490
FDU022500
FDU022510
FDU022520
FDU022530
FDU022540
FDU022550
FDU022560
FDU022570
FDU022580
FDU022590
FDU022600
FDU022610
FDU022620
FDU022630
FDU022640
FDU022650
FDU022660
FDU022670
FDU022680
FDU022690
FDU022700
FDU022710
FDU022720
FDU022730
FDU022740
FDU022750
FDU022760
FDU022770
FDU022780
FDU022790
FDU022800
FDU022810
FDU022820
FDU022830
FDU022840
FDU022850
FDU022860
FDU022870
FDU022880

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13 IF (CMMT(I).EQ.0...AND.CMMT(I+3).EQ.0...AND.CMMT(I+4).EQ.0.) GO TO 3
   L=CMMT(I)+1
   IF (L.NE.1+I/6) GO TO 13
   CMNT(I)=HGTPDP+CMHGT(L)
   CMNT(I+5)=-1*CMNT(I+3)
   CMNT(I+3)=348.3676356*CMNT(I+4)/CMNT(I+5)
32 CMNT(I+5)=CMNT(I+5)-273.15
33 NMET=6*L
   J2=2
   GO TO 4
34 IF (Q.EC.0.) Q=1.2
   IF (BC.EC.0.) BC=MTBST/D**2
   IF (SLC.EC.0.) SL6D=1.
   IF (SL.EC.0.) SL=1.
   GOR SQ=GC#RSC
   CSC=Q**2
   J9=2
   MTBM=0.
   IF (MF.NE.0.) MTBM=MTB+MF*MDI
   TMCB=1/ACBI
   IF (TMCB.EQ.0.) TMCB=TE6
   IF (IUPLEG.NE.0.) J9=1
   IYP=1
   IF (ICLFE.NE.0.) IYP=0
   IF (IUNIT.EC.0.) GO TO 35
   PMTCF=APICF
   PDTCM=1.
   GO TO 36
35 PMTCF=1.
   PDTCM=1.
   GO TO 36
36 ITE=0
   IF (IRELUC.EQ.1) ITE=1
   IF (CMETM.EC.0.) GC TC 38
   J=1
37 I=1,NMET,6
   DO M(J)=CMNT(I)
   ATM(J+3)=CMNT(I)
   ATM(J+4)=CMNT(I+3)
   ATM(J+5)=CMNT(I+4)
   ATM(J+6)=CMNT(I+5)
   AZMWD=CMTCF*(AZ-1.0.*CMNT(I+1))
   WS=.5144444444*CMNT(I+2)
   ATM(J+1)=-WS*CCS(AZMWD)
   ATM(J+2)=WS*SIN(AZMWD)
   J=J+7
37 NATM=J-1
38 SPN=TWIST

```

```

IF (IT*1.EQ.0) SPN=U0/(TWIST*D)
V(10)=T*CPH*SPN
IF (XIC.EQ.C.) XIO=XIDEL
XI=XIO
IF (XICEL.EQ.0.) XI=XIMAX
IF (IRE[UC.EQ.1]) TFN=-TF
ICNP=3
IF (IARV.EQ.0.) AND.IARH.EQ.0.) GC TC 35
IUEL=IAFV
IUAZ=IAFH
GO TO 4C
35 IUEL=QE(1)
IUAZ=AZL
4C IF (MF.NE.0.) GO TO 41
CGTBM=CTE
ATBM=ATB
41 TALPH=0.
IC1=11
IC011=11
ICCT2=12
ICCT3=13
ICCT4=14
WRITE (6,197)
I=1
IF (IDGREE(1).EQ.0) GO TO 43
DO 42 J=1,4
CTP(I)=C11(J)
42 I=I+1
43 IF (IRCT.EQ.0) GC TC 45
DO 44 J=1,4
CTP(I)=C12(J)
44 I=I+1
45 IF (IRELUC.EQ.0) GO TO 47
DO 46 J=1,4
CTP(I)=C13(J)
46 I=I+1
47 IF (IT*1.EQ.0) GC TC 49
DO 48 J=1,4
CTP(I)=C14(J)
48 I=I+1
49 IF (IUFLEG.EQ.0) GO TO 51
DO 50 J=1,4
CTP(I)=C15(J)
50 I=I+1
51 IF (ISIM.EQ.0) GO TO 53
DO 52 J=1,4
CTP(I)=C16(J)
52 I=I+1

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FDL03370
FDU03380
FDU03390
FDU03400
FDU03410
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FDU03780
FDU03790
FDU03800
FDU03810
FDU03820
FDU03830
FDU03840

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53 IF (ISFFI.EQ.0) GO TO 55
DO 54 J=1,4
CTP(I)=CT7(J)
54 IF (ISCLT.EQ.0) GC TC 57
DO 56 J=1,4
CTP(I)=CT8(J)
56 IF (ISCELR.EQ.0) GO TO 59
DO 58 J=1,4
CTP(I)=CT9(J)
58 IF (ITCACE.EQ.0) GC TC 61
DO 60 J=1,4
CTP(I)=CT10(J)
60 IF (IXIAYI.EQ.0) GC TO 63
DO 62 J=1,4
CTP(I)=CT11(J)
62 IF (ISCIQ.EQ.0) GO TO 65
DO 64 J=1,4
CTP(I)=CT12(J)
64 I=I-1
WRITE (6,198) (CTP(J),J=1,I)
ICQTT=C
WRITE (6,178) CCDE
WRITE (6,179)
PR(1)=MTEST
PR(2)=MTEM
PR(3)=MTE
PR(4)=MFI
PR(5)=MCI
PR(6)=C/FTOM
PR(7)=LE(1)/FTOM
PR(8)=CCTBM/FTCM
PR(9)=CCTB/FTOM
PR(10)=ATBM/FTCM2
PR(11)=ATB/FTOM2
PR(12)=ETBM/FTOM2
PR(13)=LL/FTOM
WRITE (6,180) (PR(I),I=1,13)
IF (ITHT.EQ.0) WRITE (6,181)
IF (ITHT.EQ.1) WRITE (6,177)
PR(1)=CE(1)
PR(2)=LC/FTCM
PR(3)=AZ

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FDU03650
FDU03660
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FDU03980
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FDU04020
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FDU04320

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FDU044330
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 FDU044780
 FDU044790
 FDU044800

PR (4) = AZC
 PR (5) = AZL
 PR (6) = EL
 PR (7) = IL/FTCM
 PR (8) = I1IST
 PR (9) = I12
 PR (10) = IH3
 PR (11) = IUEL
 PR (12) = IUAZ
 PR (13) = E
 WRITE (6,182) (PR(I),I=1,13)
 WRITE (6,183)
 PR (1) = I11
 PR (2) = I1SF
 PR (3) = R2TBM/FTCM
 PR (4) = RNE/FTOM
 PR (5) = AE/FTCM2
 PR (6) = PE*FTCM2
 PR (7) = RN/FTCM
 PR (8) = RK/FTCM
 PR (9) = RACS
 PR (10) = FLCUS
 PR (11) = FACAY
 PR (12) = TGDAY
 WRITE (6,184) (PR(I),I=1,12)
 WRITE (6,185)
 PR (1) = IEMST
 PR (2) = IEMST
 PR (3) = IEMST
 PR (4) = IE
 PR (5) = IL
 PR (6) = ILI
 PR (7) = I16
 PR (8) = I1SRIST
 PR (9) = I1SR1
 PR (10) = I1SRBST
 PR (11) = I1SRB
 PR (12) = FS/FTOM
 PR (13) = I1SCF
 WRITE (6,186) (PR(I),I=1,13)
 WRITE (6,187)
 PR (1) = I1ETFB
 PR (2) = I1ETFF
 PR (3) = I1ETFF
 PR (4) = I1ETFF
 PR (5) = I1ETFF
 PR (6) = I1ETFF
 PR (7) = I1ETFF

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PR (8) = ALCNG
PR (5) = BC*ANTOM**2
PR (10) = SL
PR (11) = SL60
PR (12) = C
PR (13) = F
WRITE (6,188) (PR(I),I=1,13)
WRITE (6,189)
PR (1) = I10
PR (2) = I11/FTOM
PR (3) = I12/FTOM
PR (4) = I13/FTOM
PR (5) = I1
PR (6) = X10/FTOM
PR (7) = X1DEL/FTOM
PR (8) = X1MAX/FTOM
PR (9) = Y1/FTOM
PR (10) = Z1/FTOM
PR (11) = EX1/FTOM
PR (12) = EZ1/FTOM
PR (13) = G0/FTOM
WRITE (6,190) (PR(I),I=1,13)
WRITE (6,191)
PR (1) = T1CB
PR (2) = L1PCB/FTOM
PR (3) = P1MCB/DTOM
PR (4) = T1MCB/DTOM
PR (5) = C
PR (6) = ELB/FTOM
PR (7) = ETE/CTOM
PR (8) = EFE/DTOM
PR (9) = L21*FTOM
PR (10) = I128*CTOM
PR (11) = I138*DTOM
PR (12) = T1FUB*FTOM
PR (13) = C
PR T=CX1*FTOM*ANTOM**2
IF (ITCNG.EQ.0) PR(11)=PRT
IF (ITCNG.NE.0) PR(13)=PRT
WRITE (6,192) (PR(I),I=1,13)
GO TO (6,67), J2
66 WRITE (6,193)
PR (1) = K1X(1)/AMTOMS
PR (2) = K2/AMTOMS
PR (3) = K1X/AMTOMS
PR (4) = K2Z/AMTOMS
PR (5) = CENSEF
PR (6) = PRESF

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66

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HDU04810
HDU04820
HDU04830
HDU04840
HDU04850
HDU04860
HDU04870
HDU04880
HDU04890
HDU04900
HDU04910
HDU04920
HDU04930
HDU04940
HDU04950
HDU04960
HDU04970
HDU04980
HDU04990
HDU05000
HDU05010
HDU05020
HDU05030
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HDU05110
HDU05120
HDU05130
HDU05140
HDU05150
HDU05160
HDU05170
HDU05180
HDU05190
HDU05200
HDU05210
HDU05220
HDU05230
HDU05240
HDU05250
HDU05260
HDU05270
HDU05280

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```

PR(7)=TEMFF
WRITE (6,154) (PR(1),I=1,7)
GO TO 65
67 WRITE (6,155) CODE#
DO 68 I=1,NATM,7
PR(1)=ATM(I)
PR(2)=ATM(I+1)/ANTOMS
PR(3)=ATM(I+2)/ANTOMS
PR(4)=ATM(I+3)
PR(5)=ATM(I+4)
PR(6)=ATM(I+5)
PR(7)=ATM(I+6)
68 WRITE (6,196) (PR(J),J=1,7)
SINLAT=SIN(LAT*CVDICR)
COSLAT=COS(LAT*CVDICR)
SINAZ=SIN(AZ*CVMTOR)
COSAZ=COS(AZ*CVMTOR)
IF (ISUN.EQ.0) GO TO 70
WPI=AINT(RACS/10000.)
AFP1=RACS-WPI*10000.
FPI=AINT(AFP1/100.)
FP2=AFP1-FPI*100.
RASD=PI/12*(WPI+FP1/60.+FP2/3600.)
WPI=AINT(RASD/10000.)
AFP1=RASD-WPI*10000.
FPI=AINT(AFP1/100.)
FP2=AFP1-FPI*100.
HAGD=PI/12*(WPI+FP1/60.+FP2/3600.)
WPI=AINT(HAGD/10000.)
AFP1=HAGD-WPI*10000.
FPI=AINT(AFP1/100.)
FP2=AFP1-FPI*100.
TOCAYD=PI/12*(WPI+FP1/60.+FP2/3600.)
WPI=AINT(TOCAY/10000.)
AFP1=TOCAY-WPI*10000.
FPI=AINT(AFP1/100.)
FP2=AFP1-FPI*100.
CECLD=CCTCR*(WPI+FP1/60.+FP2/3600.)
DEL=HAGD-RASD
IF (CEL.LT.0) DEL=DEL+TWOPHI
DEL=DEL-CVDTOR*ALONG+TCCAYC
hAT IS SIN COS SUBROUTINE?
CALL SIN COS (DECLD,SINC,COSD)
COST=SINC/CECLD
7C PPI=10000.
IF ERR=0
CM=0.

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FDU05190
FDU05200
HCU05310
FDU05320
FDU05330
FDU05340
FDU05350
FDU05360
FDU05370
FDU05380
FDU05390
FDU05400
FDU05410
FDU05420
FDU05430
FDU05440
FDU05450
FDU05460
FDU05470
FDU05480
FDU05490
FDU05500
FDU05510
FDU05520
FDU05530
FDU05540
FDU05550
FDU05560
FDU05570
FDU05580
FDU05590
FDU05600
FDU05610
FDU05620
FDU05630
FDU05640
FDU05650
FDU05660
FDU05670
FDU05680
FDU05690
FDU05700
FDU05710
FDU05720
FDU05730
FDU05740
FDU05750
FDU05760

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FDU05170
 FDU051780
 FDU051790
 FDU051800
 FDU051810
 FDU051820
 FDU051830
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 FDU051900
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 FDU051920
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 FDU052110
 FDU052120
 FDU052130
 FDU052140
 FDU052150
 FDU052160
 FDU052170
 FDU052180
 FDU052190
 FDU052200
 FDU052210
 FDU052220
 FDU052230
 FDU052240

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IF (IRC1-EC-1) GC TC 71
LAM(1)=C.
LAM(2)=C.
LAM(3)=C.
GO TO 72
71 LAM(1)=.0001458424*COSLAT*SINAZ
    LAM(2)=.0001458424*SINLAT
    LAM(3)=.0001458424*COSLAT*CGSAZ
72 JCE=1
    IF (ITCNCE-EQ.0) GO TO 74
    JCE=2
    WRITE (6,26C)
    CALL PNEST (26, QEI(1), 0, TL)
    TL=(AINT((TL+.0005)*1000.))/1000.
    ICCT1=ICCT1+1
    IF (ICCT1-NE.1) GC TO 74
73 WRITE (6,175) UMCB,XI,CCDEM,ICCT1
    IEFC=2
    CALL SPFINT (Y,CY,1)
    GO TO 4
74 I6CP=0
    IF (I3LEUR-EQ.0) GC TC 75
    ICCT1=ICCT1+100
    ICCT2=ICCT2+100
    ICCT3=ICCT3+100
    ICCT4=ICCT4+100
75 R3TBM=CGTBM-CGTB
    R3=0.
    TO=MTBM-MTB
    R1TBM=PTBM*R3TBM/TO
    RK2=RK*5
    R1TB=R1TBM-RK2*TO
    RK12=((FK**2)/12.
    R2TBSQ=R2TBM**2-RK12*TC**2
    BTB=BTEM-TO*R2TBM**2-MTB*R1TBM**2+MTBM*(R1TBM-R3TBM)**2
    RETB=LE(1)-CGTB
    RTTB=RETE-RN
    CSC=D*2
    D22=PTBST/BC
    Y(1)=MTEM
    Y(2)=TEC
    Y(3)=PC
    CONS2=(TBSI-TBMSI)/(TB-TBM)
    SINEU=(SIN(EL*CVMTOR)
    COSEU=(COS(EL*CVMTOR)
    SINAZC=SIN(AZD*CVMTOR)
    COSAZC=COS(AZD*CVMTOR)
    SINAGE=SIN(GE(1)*CVMTOR)
  
```

```

COSCE=CCS(CCE(1))*CVM(TOR)
COSAZU=CCS(AZU)*CVM(TOR)
SINAZU=SSIN(AZU)*CVM(TCR)
B=BTBM
TRCCNS=MF*CONS2*ISP/IST
DO 76 I=4,9
  Y(I)=0.
  CY(2)=1.0
  IKL=5
  IL=1
  J5=1
  J6=1
  J7=2
  IMZ=0
  IMZ1=0
  IMZ2=0
  IF (UO-NE-0.) GC TC 77
  IF (TBM.LT.C.) GO TO 81
  Y(4)=IX1
  Y(7)=IL*COSEU*COSAZL
  Y(8)=IL*SINEU
  Y(9)=-IL*SINAZU*COSEU
  IF (IX2-EQ.C.) GC TC 82
  Y(5)=IX2
  J8=1
  GO TO 78
77 Y(4)=LL*CCSCE+IX1
  Y(5)=LL*SSINCE+IX2
  Y(7)=UC*CCSCE+COSAZC+IU*COSAZU*COSEL
  Y(8)=UC*SSINCE+IU*SINEU
  Y(9)=-IL*SINAZU*COSEU+LO*CCSCE*SINAZC
  J8=2
  DY(7)=C
  DY(8)=C
  CY(9)=0
  Y(2)=TL
  IF (IT0-NE.C.) Y(2)=IT0
  DELT=1CC.
  PY(1)=Y(3)
  DPY(1)=1.0
  INN=1
78 WRITE (6,280)
  CALL RKC (DELT,2,DCA,PY,DPY,QU,INN)
  INN=2
  IF (ABS(PY(1))-Y(5)) .LT. .00001) GO TC 8C
  IF (PY(1).LT.Y(5)) GO TC 75
  DELT=Y(5)-PY(1)

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FDU066250
FDU066260
FDU066270
FDU066280
FDU066290
FDU066300
FDU066310
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FDU066370
FDU066380
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FDU066690
FDU066700
FDU066710
FDU066720

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 FD007140
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 FD007170
 FD007180
 FD007190
 FD007200

```

80 GO TO 75
   Y(3)=PY(2)
81 GO TO (E2,83), J8
   DELT=DELTB
   TIME=0.
   I2=1
   I3=1
   NEG=2
82 GO TO 135
   DELT=DELTB
   TIME=TL
   Y(2)=0.
   I2=2
   I3=2
   I4=1
   I5=1
   I6=1
   NEG=8
83 GO TO 135
   I3=3
   I4=2
   I6=2
   I7=1
   I8=1
   I9=1
   NEX=1
   J6=1
   J2=2
   I2=1
   NEG=16
   KI=0
   IF IRSI=1
     DELT=DELTB
     IF (YDI-LE-C.) GO TO 84
     DELT=DELTB
     I4=3
     I5=2
84 TIME=TC+ITO
   D3=D3+D
   I4=4
   EAR=CVMTOR*TCR*IUAZ
   EER=CVMTOR*IUEL
   SINEA=SIN(EAR)
   COSSEA=COS(EAR)
   SINEE=SIN(EER)
   COSSEE=COS(EER)
   Y(14)=COS*CO SEA
   Y(15)=SINEE
  
```

```

Y(16)=CC*SEE*SINEA
ANX=0
ISPI=0
IF (Y(1C).LE..0) GC TC 85
A=ATBM
ANX=Y(1C)*A
CONS3=(ATBM-ATB)/(MTBM-MTB)
CTS=(TSFEST-TSRIST)/(TSRB-TSRI)
GCRS=GCR*FS
RNESQ2=RNES*2*.5
ISPI=1
I1=2
I8=2
NEC=16
IF (1TCNCE.EQ.0) GC TC 86
WRITE (6,270)
CALL PNEST (28,QE(1),0.,IH3)
WRITE (6,270)
CALL PNEST (20,QE(1),0.,BC)
BC=BC/ANTGM**2
BIF2=B*IF2
Y(11)=ANX*Y(14)-BIH2*SINEE*COSEA-B*IF3*SINEA
Y(12)=ANX*Y(15)+BIH2*CCSEE
Y(13)=ANX*Y(16)-BIH2*SINEE*SINEA+B*IH3*COSEA
DY(7)=0.
DY(8)=C.
DY(9)=0.
ALPE=0.
ALPG1=C.
ALPG2=C.
ALPG3=C.
T45(1)=CE(1)
T45(2)=IH2
T45(3)=IH3
T45(4)=IF
T45(5)=C.
T45(6)=SL
T45(7)=C
T45(8)=CQ*PMTOF
T45(9)=CCCE
T45(10)=ICCT4
IF (TL*CE*TE6) GO TO 85
DO 87 I=1,10
J=ITIT+I+2659
TJ(J)=T45(I)
ITIT=ITIT+10
I6DP=1
87 IF (I3LEUR.EQ.0) GC TC 139

```

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FDU07210
FDU07220
FDU07230
FDU07240
FDU07250
FDU07260
FDU07270
FDU07280
FDU07290
FDU07300
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FDU07320
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FDU07340
FDU07350
FDU07360
FDU07370
FDU07380
FDU07390
FDU07400
FDU07410
FDU07420
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FDU07570
FDU07580
FDU07590
FDU07600
FDU07610
FDU07620
FDU07630
FDU07640
FDU07650
FDU07660
FDU07670
FDU07680

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```

D22=MTTEST/BC
I6CP=0
IF (Y(10).GT..0) GC TO 88
I7=2
I8=3
NEG=9
GO TO 135
88 ISPI=0
I7=1
I8=4
I9=2
NEG=10
GO TO 135
89 ISPI=0
IF (I3CBLR-NE..0) GC TO 90
ICCT1=ICCT1+100
ICCT2=ICCT2+100
ICCT3=ICCT3+100
ICCT4=ICCT4+100
I45(10)=ICCT4
I45(5)=EC/AMTO IN**2
90 DO 91 I=1,10
J=ITIT+2655+I
I7(I)=I45(I)
I7(I)=I7(I)+10
Y(I)=MIE
DO 92 I=1,16
BURN(I)=Y(I)
GO TO 114
91 CONTINUE
IEPD=5
WRITE (6,290)
CALL SFFINT(Y,CY,1)
DELT=DELTB
PTIME=PTIE
TPRINT=Y(2)+PTB
TIME=TIME
I3=4
J6=2
IF (TCI.GT..0.) GC TC 94
GO TO 140
94 DELT=DETF
I3=5
TIME=TCI
GO TO 140
95 IFIRST=0
JBURN=2
INN=1

```

```

FDJ07690
FDJ07700
FDJ07710
FDJ07720
FDJ07730
FDJ07740
FDJ07750
FDJ07760
FDJ07770
FDJ07780
FDJ07790
FDJ07800
FDJ07810
FDJ07820
FDJ07830
FDJ07840
FDJ07850
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FDJ07900
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FDJ08020
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FDJ08040
FDJ08050
FDJ08060
FDJ08070
FDJ08080
FDJ08090
FDJ08100
FDJ08110
FDJ08120
FDJ08130
FDJ08140
FDJ08150
FDJ08160

```

```

13=6
14=2
15=1
DELT=DELTB
GO TO 140
96 JBURN=1
JEPD=5
WRITE (6,290)
CALL SPFINT (Y,CY,1)
TIME=TE
IF (AB$(TCI-TPRINT).LE..00001) GC TC 97
GO TO 14C
97 TPRINT=TPRINT+PTIME
GO TO 140
98 I3=7
I5=3
DELT=DELTFF
IF (TB$(TC.TMCB) GO TO 100
JBURN=3
GO TO 135
99 JBURN=1
JEPD=5
WRITE (6,290)
CALL SPFINT (Y,CY,1)
TIME=TAPE
I3=5
GO TO 140
100 IFIRST=C
JBURN=4
GO TO 135
101 JBURN=1
JEPD=5
WRITE (6,290)
CALL SPFINT (Y,CY,1)
DELT=DELTB
TIME=TEC
I3=8
J6=1
IF (TDI.GT.0.) GC TC 104
IF (ITE.EQ.1) GO TC 103
102 IF (TMC.EQ.TE6) GC TC 105
GO TO 14C
103 NEX=2
GO TO 148
104 DELT=DELTFF
GO TO 102
105 IF (ITCNC.NE.0) GC TC 106
ICCTI=0

```

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FDU08170
FDU08180
FDU08190
FDU08200
FDU08210
FDU08220
FDU08230
FDU08240
FDU08250
FDU08260
FDU08270
FDU08280
FDU08290
FDU08300
FDU08310
FDU08320
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FDU08360
FDU08370
FDU08380
FDU08390
FDU08400
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FDU08560
FDU08570
FDU08580
FDU08590
FDU08600
FDU08610
FDU08620
FDU08630
FDU08640

```

```

106 IF (TMCE.EQ.TE6) GC TC 107
   IEPD=5
   WRITE (4,290)
   CALL SPINT (Y,DY,1)
107 DO 108 I=1,16
108 BURN(I)=Y(I)
109 IF (13CEUR.EQ.0.AND.1TONQE.EQ.0) GC TO 110
   GO TO 112
110 ICCTI=ICCTI+1
   IF (ICCTI.NE.11) GO TO 111
   WRITE (6,175) UMCB,XI,CCDEM,ICCTI
   IEPD=2
   WRITE (6,290)
   CALL SPINT (Y,DY,1)
   GO TO 107
111 ICCT1=ICCT1+100
   ICCT2=ICCT2+100
   ICCT3=ICCT3+100
   ICCT4=ICCT4+100
112 I45(5)=BC/AMUIN**2
   I45(6)=SL
   I45(10)=ICCT4
   DO 113 I=1,10
   J=I+ITTI+2659
   IJ(J)=I45(I)
   ITTI=ITTI+1C
   DY(7)=C.
   DY(8)=C.
   DY(9)=0.
   ALPH=0.
   TAPLPH=C.
114 IF (13CF.EQ.0) GO TO 115
115 IKL=12
   D22=MTB5T/BC
   DELT=DETF
   PTIME=PTFF
   Y(1)=MTE
   CY(1)=C.
   TPRINT=ICFF
   IF (TPRINT.EQ.0.) TPRINT=PTFF+ITO
   I4=3
   I5=3
   J6=2
   NEX=1
   K1=0
   NEC=16
   I6DP=0
   IF (11CGREE(1).EQ.0) GO TO 116

```

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+DU08650
+DU08660
+DU08670
+DU08680
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FDU0\$130
FDU0\$140
FDU0\$150
FDU0\$160
FDU0\$170
FDU0\$180
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FDU0\$200
FDU0\$210
FDU0\$220
FDU0\$230
FDU0\$240
FDU0\$250
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FDU0\$550
FDU0\$560
FDU0\$570
FDU0\$580
FDU0\$590
FDU0\$600

```

I6CP=1
J5=2
INA=1
IUSA=1
JJ1=1
TST=0.14C
GO TO 14C
116 IF (V(1C).GT.0.) GC TC 117
    I7=2
    I8=3
    NEC=9
    GO TO 118
117 IF (ISFI.EQ.1) Y(10)=FCX/A
    I7=1
    I8=4
    I9=2
    NEC=10
    INA=1
    IJ4=1
    IJ6=3
    IJ8=2
    IJ10=1
    IJ12=2
    IJ14=1
    IJ16=2
    IJ18=1
    IJ20=2
    IJ22=1
    IJ24=2
    IJ26=1
    IJ28=2
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FDU05990
FDU10000
FDU10010
FDU10020
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FDU10050
FDU10060
FDU10070
FDU10080

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123  T1=PP1
      PP1=PP2
      PP2=T1
      IF (Y(2).NE.JL) GO TO 124
      PRPP1=PP1
      PRPP2=PP2
      PP1=PP2
      PP2=PP1
      PP1=PP1
      PP2=PP2
      GO TO 125
124  T1=DEL1*Y/D
      PP1=(PP1-PRPP1)/T1
      PRPP1=PP1
      PRPP2=(PP2-PRPP2)/T1
      PP2=PP2
      GO TO (126,141), IEXIT
125  GO TO (126,141), IEXIT
126  IF (ISTIM.EQ.0) GO TO 128
      IF (ABS(T1-Y(2)).LE..00001) GO TO 130
      IF (K1.EC.1) GO TO 127
      IF (Y(2).GT.T1) GO TO 127
      GO TO 145
127  DEL1=T1-Y(2)
      K1=1
      GO TO (140,119), J11
128  IF (XIAVI.EQ.0) GO TO 131
      IF (ABS(XI-Y(4)).LE..00001) GO TO 130
      IF (K1.EC.1) GO TO 129
      IF (Y(4).GT.XI) GO TO 129
      GO TO 145
129  DEL1=(XI-Y(4))/Y(7)
      K1=1
      GO TO (140,119), J11
130  IF (XIEL.EQ.0) GO TO 137
      IF (ABS(XIMAX-XI).LT.(XIDEL/10.)).OR.XI.GT.XIMAX) GO TO 137
      IFC=5
      WRITE (6,290)
      CALL SPINT (Y,DY,1)
      XI=XIDEL*XI
      DEL1=DEL1B
      K1=0
      IF (15.EC.4) GO TO 145
      DEL1=DEL1FF
      GO TO 145
131  YP=Y(5)
      IF (1YP.GT.0) YP=EC
      IF (Y(2).EQ.0) GO TO 132
      IF (ABS(YP-Y1).LE..00001) GO TO 137

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FDU10090
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FDU10490
FDU10500
FDU10510
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FDU10560

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132 IF (K1.EC.1) GO TO 136
    GO TO (133,135), J5
133 IF (Y(8).GE.0.) GO TO 134
    WRITE (6,176) CODE,ICOT1
    IEPC=3
    WRITE (6,25C)
    CALL SFFINT (Y,DY,1)
    GO TO 4
134 IF (YP.L1.Y1) GO TC 145
    GO TO 136
135 IF (Y(8).GT.0.) GO TO 145
    IF (YP.GT.Y1) GO TO 145
136 DELT=(Y1-YP)/Y(8)
    K1=1
    GO TO (140,119), J1
137 IEFC=5
    NEX=4
    J7=1
    IF (ITE.EC.1) GC TC 138
    WRITE (6,25C)
    CALL SFFINT (Y,DY,1)
    GO TO 4
138 NEX=5
    J7=2
    WRITE (6,25C)
    CALL SFFINT (Y,DY,1)
    GO TO 152
139 INN=1
    IUSA=2
    JJ1=1
    WRITE RKC (DELTA,NEQ,DER,Y,DY,QQ,INN)
    CALL RKC (DELTA,NEQ,DER,Y,DY,QQ,INN)
    INN=2
    IEXIT=2
    GO TO 120
141 GO TO (142,56,55,1G1), JBURN
142 GO TO (143,126), J5
143 IF (ABS(Y(2)-TIME).LE..00001)GOTC(82,83,53,100,95,98,100,105,
    101), J1
    IF (Y(2)+DELT.GT.TIME) GOTO 1443
    IF (Y(2)+DELT.LT.TIME+.00001) GOTO 144
    IF (Y(2)-TIME-Y(2))-10.E-15*TIME
    101), J1
1443 GOTC (14C,119), JJ1
    IF (NEC.GT.5) GO TO 126
144 IF (NEC.GT.5) GO TO 126
145 GO TO (140,146,119), J6
146 IF (ABS(Y(2)-TPRINT).LE..00001) GC TC 147
    K2=0
    IF (Y(2)+DELT.LT.TPRINT) GC TO (140,119), JJ1

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HDU1C570
 HDU1C580
 HDU1C590
 HDU1C600
 HDU1C610
 HDU1C620
 HDU1C630
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 HDU1C1000
 HDU1C1010
 HDU1C1020
 HDU1C1030
 HDU1C1040

K2=1
 SOC=DEL7
 DELI=TFPRINT-Y(2)
 GO TO (140,119), JJ1
 147 IEPO=5
 WRITE (6,290)
 CALL SFFINT (Y,DY,1)
 TPRINT=TPRINT+PTIME
 IF (K2-EC.0) GO TO (140,119), JJ1
 DEL7=SCC
 K2=0
 GO TO (140,119), JJ1
 148 LN=LN/PNTOF
 PHI=PHI*CTGM/PDTGM
 THETA=TFETA*DTOM/PCTGM
 TO=UMCE-LN
 TI=PHACE-PHI
 T2=THMCE-THETA
 IF (TFN.LT.0.) GO TO 149
 T3=TO*(TFN-TF)/(LNN-UN)
 T4=T1*(F3N-IH3)/(PHIN-PHI)
 T5=T2*(F2N-IH2)/(TFETAN-THETA)
 GO TO 150
 149 T3=TO*IFL8
 T4=T1*IF3B
 T5=T2*IF2B
 TFA=ABS(TFN)
 150 IF (ABS(TO).LT.EUB.AND.ABS(T1).LT.EFB.AND.AES(T2).LT.ETB) GO TO 151
 TFA=TF
 H2N=IH2
 H3N=IH3
 LNN=UN
 PHIN=PHI
 THETAN=THETA
 TF=TFN+T3
 IH2=H2N+T5
 IH3=H3N+T4
 ICC1=ICCT+1
 IF (ICCT.EQ.10) GO TO 73
 ICC1=ICCT+10
 ICC12=ICCT+10
 ICC13=ICCT+10
 ICC14=ICCT+10
 GO TO 72
 151 NEX=1
 IF (TMCE.EC.TE6) GO TO 105
 GO TO (140,119), JJ1

FDU111650
FDU111660
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FDU112520

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152 IF (IXIAYI.EQ.0) GC TC 154
    YP=EC
    IF (IYF.EC.0) YP=Y(5)
    IF (ABS(VI-YP).LE.EX1) GO TC 165
153 YP=Y(5)
    IF (IYF.AE.0) YP=EC
    TO=VI-YP
    XYI=YP
    GO TO 156
154 IF (ABS(Y(4)-XI).LE.EX1) GC TO 165
155 TO=XI-Y(4)
    XYI=Y(4)
156 T2=ZI-Y(6)
    IF (CM.AE.0.) GC TC 164
    T1=TO*CX1
    T3=T2*LZ1
157 XM=Y(4)
    IF (IXIAYI.EQ.0) GO TO 158
    YP=EC
    IF (IYF.EQ.0) YP=Y(5)
    XM=YP
158 IF (JCCF-1) 159,159,160
159 CM=BC
    BC=BC+I1
    GO TO 161
160 CM=CE(1)
    CE(1)=CE(1)+T1
    IUEL=QE(1)
161 SLM=SL
    ZM=Y(6)
    SL=SL+I1
    IF (I3CCUR.EQ.0.ANC.ITCNQE.EQ.0) GO TO 162
    TF=N--TF
    Y(10)=SFN*TWOPHI
    GO TO 72
162 DO 163 I=1,16
163 Y(1)=ELFN(I)
    GO TO 105
164 CQE=QE(1)
    IF (JCCF.EQ.1) CQE=BC
    T1=TO*(CM-CQE)/(XM-XYI)
    T3=0
    IF (ABS(ZM-Y(6)).LT..00000001) GO TC 157
    T3=T2*(SLM-SL)/(ZM-Y(6))
    GO TO 157
165 IF (ABS(Y(6)-ZI).LT.EZ1) GC TO 166
    IF (IXIAYI.EQ.0) GC TO 155
    GO TO 153

```



```

5 IF (TS7-LE-0.) GC TC 12
6 TSSTAR=TR*TF+(PE-PA)*AE
  VT=Y(8)
  VTSQ=V1**2+V2**2+V3**2
  VT=SQRT(VTSQ)
  MACH=VT/VAS
  IF (16DP-EQ.1) GO TC 7
  GO TO (15,19,20,13), I5
7 VDCIX=V1*Y(14)+V2*Y(15)+V3*Y(16)
  COISA=VDCIX/VT
  IF (ABS(COISA)-LE.1.0005) GO TO 8
  WRITE (6,55) Y(2), COISA, CODE, ICCT1
  GO TO IER, (56)
8 IF (ABS(COISA)-LE.1.) GC TO 10
  COISA=1.
  ALPHA=C.
  GO TO 11
9 COISA=-1.145926535
  ALPHA=-1.145926535
  GO TO 11
10 ALPHAS=AS AFCCCS
  ALPHA=ARCS(COISA)
11 ALFSQ=ALPHA**2
  TALPH=ALPSC
  GO TO (15,19,20,13), I5
12 TSSTAR=0.
  DY(1)=C
  GO TO 6
13 V1=Y(7)-MSX(1)
  V3=Y(5)-MSZ
  GO TO 5
14 V1=Y(7)-MBX
  V3=Y(5)-MBZ
  GO TO 5
15 WRITE (6,57)
  CALL PNEST (2, MACH, TALPH, KDB)
  GO TO (16,21), I6
16 WRITE (6,57)
  CALL PNEST (9, MACH, TALPH, F)
  F=FFTCN
  TO=(GC*TSSTAR-DENS*C22*KDB*VTSQ)/Y(1)-GO*SINCE-F*COISQ
  DY(9)=0.
  IF (TC-GL.0.) GO TC 17
  DY(7)=C.
  DY(8)=C.
  GO TO 18
17 DY(7)=TC*COISQ

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C

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18 DY(8)=TC* SINQE
   DY(4)=Y(7)
   DY(5)=Y(8)
   CY(6)=Y(5)
   GO TO 33
19 DY(1)=AL1/(TL-TDI)
20 WRITE (6,57)
   CALL PNEST (4,MACH,TALPH,KDB)
21 TO=Y(5)+REARTH
   R=SQRT(Y(4)**2+TO**2+Y(6)**2)
   T1=GORSC/R**3
   G1=T1*Y(4)
   G2=T1*TC
   G3=T1*Y(6)
   NU1=-LAM(1)*Y(8)-LAM(2)*Y(9)
   NU2=LAM(1)*Y(7)+LAM(3)*Y(9)
   NU3=LAM(2)*Y(7)-LAM(3)*Y(8)
   T4=GC*TSIAR
   GO TO (22,27), I7
22 WRITE (6,57)
   CALL PNEST (3,MACH,TALPH,DKDB)
   DKDBA=DKDB*ALP SQ
   T1=DENS*LC22
   T2=DENS*DSQ
   WRITE (6,57)
   CALL PNEST (IKL,MACH,TALPH,KL)
   CALL PNEST (IO,MACH,TALPH,KM)
   RE=RETE-R3
   XC=LE(1)-RE
   TO=(CGIE-XCC)/D
   KM=KM-IC*(KL+KDB)
   GO TO (23,27), IS
23 T1=-T1*(KLB+DKDBA)*VT
   WRITE (6,57)
   CALL PNEST (6,MACH,TALPH,KS)
   T3=T10*KS*V/8
   X1CH1=Y(15)*Y(13)-Y(16)*Y(12)
   X2CH2=Y(16)*Y(11)-Y(14)*Y(13)
   X3CH3=Y(14)*Y(12)-Y(15)*Y(11)
   RT=RTTE-R3
   CALL PNEST (8,MACH,TALPH,KH)
   T11=DENS*D44
   T7=-DY(1)*RE*RT
   DY(10)=C.
   HDX=0.
   V1CX1=V2*Y(16)-V3*Y(15)
   V2CX2=V3*Y(14)-V1*Y(16)

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V3CX3=Y1*Y(15)-V2*Y(14)
DO 24 I=7,9
DY(1)=C
24 CY(I+4)=0
XD=X*Y(14)**2+Y(15)**2+Y(16)**2
IF (XDX.LE-1.0005) GO TO (25,26,28,30), 18
WRITE (6,54) Y(2), XDX, CCDE, ICOT1
GO TO IER, (56)
25 T2=T2*KL*SL6D
T5=T10*KK*VI
T6=T11*KH*VI
CY(7)=(T1*V1+T2*(VTSQ*Y(14)-VDOTX*V1)+T3*X1CH1+T4*Y(14))/Y(1)-G1
1 CY(8)=(T1*V2+T2*(VTSQ*Y(15)-VDOTX*V2)+T3*X2CH2+T4*Y(15))/Y(1)-G2
1 +NU2+LY(8)
DY(5)=(T1*V3+T2*(VTSQ*Y(16)-VDOTX*V3)+T3*X3CH3+T4*Y(16))/Y(1)-G3
1 +NU3+LY(9)
DY(4)=Y(7)
DY(5)=Y(8)
CY(6)=Y(9)
HDXX1=FLX*Y(14)
HDXX2=FLX*Y(15)
HDXX3=FLX*Y(16)
DY(11)=T5*V1CX1+(T6*(HDXX1-Y(11))-T7*(Y(11)-HDXX1))/B+DY(11)
DY(12)=T5*V2CX2+(T6*(HDXX2-Y(12))-T7*(Y(12)-HDXX2))/B+DY(12)
DY(13)=T5*V3CX3+(T6*(HDXX3-Y(13))-T7*(Y(13)-HDXX3))/B+DY(13)
DY(14)=-X1CF1/B
DY(15)=-X2CF2/B
DY(16)=-X3CF3/B
GO TO 26
26 HDX=Y(11)*Y(14)+Y(12)*Y(15)+Y(13)*Y(16)
T9=HDX/A
WRITE (6,57)
CALL PNEST (13, MACF, TALPH, KF)
KF=KF*TICT*Y(1)
CALL PNEST (44, MACF, TALPH, KTA)
KTA=KTA*ALPSQ
CALL PNEST (15, MACF, TALPH, KT)
KT=KT*KTA
TK=T11*TS*KT
CALL PNEST (41, MACF, TALPH, KLA)
KLA=KLA*ALPSQ
KL=KL*KLA
CALL PNEST (42, MACF, TALPH, KMA)
KMA=KMA*ALPSQ
KM=KM*KMA
CALL PNEST (43, MACF, TALPH, KHA)
KHA=KHA*ALPSQ

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FDU14870
FDU14880

27 KH=KH+KFA
28 CALL PNEST (17,MACH,TALPH,KA)
KA=KA+T11*VT*19
CALL PNEST (24,MACH,TALPH,KE)
KE=KE+T10*E*VT*SQ
AM=(Y(22)-TSRI)*CTS+ISRIST
CALL PNEST (25,AM,TALPH,TS)
TS=TS+CTS*TS
TO=-KA+KE+TS
T12=DY(1)*RNESQ2*TS
DY(7)=-KF*VICX1
DY(8)=-KF*V2CX2
DY(9)=-KF*V3CX3
TO=T12=TC+T12
DY(11)=TK*(VDOIX*Y(14)-V1)+Y(14)*T0T12
DY(12)=TK*(VDOIX*Y(15)-V2)+Y(15)*T0T12
DY(13)=TK*(VDOIX*Y(16)-V3)+Y(16)*T0T12
GO TO 25
29 GO TO (25,26,28,30), 18
2E DKDB=0.
DY(7)=0.
DY(8)=0.
DY(9)=0.
TO=-DEN* (C22*(KDB+CKDB)*VT
CU SAE=CCS(SCRT(ALPE))
CU SAVT=CSAE/VT
ALP1=I4*(V1*CO SAVT+ALPQ1)
ALP2=I4*(V2*CO SAVT+ALPQ2)
ALP3=I4*(V3*CO SAVT+ALPQ3)
DY(7)=(ALP1+T0*V1)/Y(1)-G1+NU1+DY(7)
DY(8)=(ALP2+T0*V2)/Y(1)-G2+NU2+DY(8)
DY(9)=(ALP3+T0*V3)/Y(1)-G3+NU3+DY(9)
DY(5)=Y(6)
DY(6)=Y(9)
GO TO 30
30 WRITE (6,57)
CALL PNEST (13,MACH,TALPH,KF)
CALL PNEST (15,MACH,TALPH,KT)
CALL PNEST (44,MACH,TALPH,KTO)
KT=KT+KTC*ALPE
CALL PNEST (42,MACH,TALPH,KMA)
KM=KM+KMA*ALPE
CALL PNEST (41,MACH,TALPH,KLA)
KL=KL+KLA*ALPE
CALL PNEST (43,MACH,TALPH,KHA)
CALL PNEST (8,MACH,TALPH,KF)
KH=KH+KFA*ALPE

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 HDU15360

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TO=KL*KF*VTSQ/Y(10)
TO=TO+LSC*KF*KI*Y(10)
TO=TO*VTSQ*TO
ALPA=A*KL/TO
ALPE=Y(1)*DSQ*KI/TO
T2=T2*KL
IF (IKL-EC-12) GC TC 31
ALPQ1=T1*(V2*DY(9)-V3*DY(8))+ALPB*(V2*G2-V3*G2)
ALPQ2=T1*(V3*DY(7)-V1*DY(9))+ALPB*(V3*G1-V1*G3)
ALPQ3=T1*(V1*DY(8)-V2*DY(7))+ALPB*(V1*G2-V2*G1)
GO TO 32
31 ALPQ1=V2*V1/VTSQ
    ALPQ2=-1.*V2*2/VTSQ
    ALPQ3=V2*V3/VTSQ
32 ALPE=ALPQ1*2+ALPQ2*2+ALPQ3*2
    OKCB=DKCB*ALPE*CSQ
    T1=T2*SL*VTSQ
    T2=T1*KF*Y(10)*G
    TALPH=ALPE
    ALPE1=ALPQ2*V3-ALPQ3*V2
    ALPE2=ALPQ3*V1-ALPQ1*V3
    ALPE3=ALPQ1*V2-ALPQ2*V1
    RMASS=1./Y(1)
    DY(7)=(T1*ALPQ1+T2*ALPE1)*RMASS
    DY(8)=(T1*ALPQ2+T2*ALPE2)*RMASS
    DY(9)=(T1*ALPQ3+T2*ALPE3)*RMASS
    CALL PNEST(17,MACH,TALPH,KA)
    DY(10)=-T1*0*D*KA*V1*Y(10)/A
    GO TO 25
33 IE PD=5
    IF (IFIRST.EQ.1) CALL SPRINT (Y,DY,1)
34 RETURN
35 EC=Y(5)+REARTH-TO
    GO TO (36,42),J2
36 T1=Y(8)+Y(7)*Y(4)/TO
    T2=REARTH*EC
    GP=REARTH*EC/T2
    IF (EC.GT.90000.) GC TC 41
    IF (GPF.LE.PA(1)) GC TC 42
37 IF (GPF.LE.HA(IMZ+2)) GO TO 38
    IMZ=IMZ+1
    GO TO 37
38 IF (GPF.GE.PA(IMZ+1)) GO TO 39
    IMZ=IMZ+1
    GO TO 38
39 TEMP=TP(IMZ+1)+ALM(IMZ+1)*(GPH-HA(IMZ+1))
  
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CV(3)=(-.03416315474*Y(3)*RSQ*TI1)/(TEMP*TI2**2)
PA=Y(3)*22.48085431*PRESF
DENS=(Y(3)/TEMP)*.7680191702*DENSF
TEMP=TEMP*TEMPF
4C VAS=20.4680276*SQRT(TEMP)
GO TO (4,13,14), I4
41 GPF=EC
GO TO 31
42 IMZ=0
GO TO 35
43 TO=EC*AMTOF
IF (TO.LE.0.) GC IC 46 GO TO 45
44 IMZ1=IMZ1+7
IF (IMZ1.LT.NATM) GC TO 44
WRITE (6,52)
GO TO IER, (56)
45 IMZ1=IMZ1-7
GO TO 45
46 IMZ1=0
47 TI=(TO-ATM(IMZ1+1))/(ATM(IMZ1+8)-ATM(IMZ1+1))
WBX=ATM(IMZ1+2)+TI*(ATM(IMZ1+9)-ATM(IMZ1+2))
WSX(1)=WBX
WSZ=ATM(IMZ1+3)+TI*(ATM(IMZ1+10)-ATM(IMZ1+3))
WBZ=WSZ
IF (TO.LE.0.) GO TO 50
48 IMZ2=IMZ2+7
IF (IMZ2.LT.NATM) GO TO 48
WRITE (6,53)
GO TO IER, (56)
49 IMZ2=IMZ2-7
GO TO 49
50 IMZ2=0
51 TI=(TO-ATM(IMZ2+4))/(ATM(IMZ2+11)-ATM(IMZ2+4))
TEMP=ATM(IMZ2+7)+TI*(ATM(IMZ2+14)-ATM(IMZ2+7))
DENS=(ATM(IMZ2+5)+TI*(ATM(IMZ2+12)-ATM(IMZ2+5)))*.002204022622
PA=(ATM(IMZ2+6)+TI*(ATM(IMZ2+13)-ATM(IMZ2+6)))*22.48085431
GO TO 4C
52 FURMAT (24H EXCEEDS METRG FOR WINDS)
53 FURMAT (42H ERROR METRC EXCEEDED FOR DENSITY AND TEMP)
54 FURMAT (15H ROUND TUNELED 12F10.3,A5,15)
55 FURMAT (27H ALPHA VDX GREATER THAN V1 12F10.3,A5,15)
57 FURMAT (21H GONE TC PAEST FM DER)
  
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AE2=ALFC2
AE3=ALPC3
GO TO 4
3 IF (A.G1.0.) T1=HD X/(TWCPHI*A)
T2=RTCC*ALPHA
AE1=Y(14)
AE2=Y(15)
AE3=Y(16)
4 IF (T2.G1.0.) GO TO 5
PSI=0.
GO TO 6
5 T3=(V1*AE3-V3*AE1)*VT
T4=V1*(V1*AE2-V2*AE1)-V3*(V2*AE3-V3*AE2)
IF (T3.NE.0..OR.T4.NE.0.) GO TO 500
PSI=0.
GO TO 6
50C PSI=ATAN2(T3,T4)
IF (PSI.GE.0.) GO TO 6
PSI=TWCPHI+PSI
6 PSI=RTCC*PSI
IF (T6CF.EC.1) GO TO 7
T3=KDB+[KCB
GO TO 8
7 T3=KDB+[KCB
8 IF (T1.G1.2C.) GO TO 9
TJ (IT+1)=0.0
TJ (IT+12)=0.0
GO TO 10
9 T6=CENS*[C33/Y(1)
T4=T6*(KL-KI*(Y(1)*C22/A))
T5=T6*(KL-TI*KI*(Y(1)*C22/B))
T6=KM*[CENS*[C22*D33/B
T7=TWUPFI*T1*D*A/(B*VT)
SDY=2.*T4/T5
SGY=T7*T2/(4.*T6)
IDY=0
IGY=0
IF (1.-/SGY.LT.1.) GC TC 10
IDY=1
IGY=1
GO TO 11
1C IF (1.-/SGY.LE.SDY*(2.-SDY)) GO TO 11
IDY=1
IGY=1
11 IF (IGY.EQ.1) GO TO 12
SGY=TJ(IT+1)
ENCCDE (10,58,TJ(IT+1)) JSGY
GO TO 13
C

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HDU16340
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12 SGY=TJ(I1+11)
13 ENCODE (10,59,TJ(I1+11))SGY
13 IF (ICY.EQ.1) GC TC 14
14 SDY=TJ(I1+12)
14 ENCODE (10,58,TJ(I1+12))SDY
14 GO TO 15
15 SDY=TJ(I1+12)
15 ENCODE (10,59,TJ(I1+12))SDY
15 TJ(I1+1)=Y(2)
15 TJ(I1+2)=PMTOF*Y(4)
15 TJ(I1+3)=PMTOF*YP
15 JAH=0
15 TJ(I1+4)=PMTOF*Y(6)
15 TJ(I1+5)=LN
15 TJ(I1+6)=PHI
15 TJ(I1+7)=T-ETA
15 TJ(I1+8)=T1
15 TJ(I1+9)=T2
15 TJ(I1+14)=ICOT1
15 TJ(I1+10)=PSI
15 TJ(I1+13)=CODE
15 IT=I1+14
15 IF (I6CP.EQ.0) GO TO 25
15 TJ(I1+84)=Y(2)
15 IF (ISLN.EQ.1) GC TC 16
15 TJ(I1+842)=0.
15 GO TO 22
16 TLFA=DEL+7.2720521E-5*Y(2)+(Y(4)*SINA2+Y(6)*COSAZ)/(REART*CSLAT
16 )
16 IF (TLFA-PI.GE.0.) GC TC 17
16 TMERID=TLHA
16 GO TO 19
17 IF (TLFA-TWOPHI.GE.0.) GO TO 18
17 TMERID=TWOPHI-TLFA
17 GO TO 19
18 TMERID=TLHA-TWOPHI
18 SINH=SINLAT*SIND+CSLAT*COSD*COS(TMERID)
18 H=ASIN(SINH)
18 Z=ARCCOS((SIND-SINLAT*SINH)/(CSLAT*COS(P)))
18 IF (TLFA-PI.LT.0.) GO TO 20
18 IF (TLFA-TWOPHI.GE.0.) GO TO 20
18 THE=PI2-Z
18 GO TO 21
19 THE=Z-PI-PI2
19 PH=PI2-P
19 CALL SINCCS (PH,SINH,CCSPF)
19 SINPH=SIN(PH)
19 COSPH=CCS(PF)

```

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FDU16810
FDU16820
FDU16830
FDU16840
FDU16850
FDU16860
FDU16870
FDU16880
FDU16890
FDU16900
FDU16910
FDU16920
FDU16930
FDU16940
FDU16950
FDU16960
FDU16970
FDU16980
FDU16990
FDU17000
FDU17010
FDU17020
FDU17030
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FDU17290
FDU17300
FDU17310
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FDU17640
FDU17650
FDU17660
FDU17670
FDU17680
FDU17690
FDU17700
FDU17710
FDU17720
FDU17730
FDU17740
FDU17750
FDU17760

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C      CALL SIACOS (THE,SINTH,COSTH)
      SINTH=SIN(TP)
      COSTH=COS(TP)
      S1=COSAZ2*SINPH*SINTH+SINAZ*SINPH*CCSTH
      S2=COSAZ2*SINPH*CCSTH-SINAZ*SINPH*SINTH
      S3=COSAZ2*RTOD*ASIN(S1*Y(14)+S2*Y(15)+S3*Y(16))
22  T1=Y(14)
      T2=Y(16)
      TJ(TT+644)=RTOD*ATAN2(T2,T1)
      T1=SQR(T1*2+T2*2)
      T2=Y(15)
      TJ(TT+643)=RTOD*ATAN2(T2,T1)
      IF (PP1.NE.10000.) GO TO 23
      GO TO 24
23  T1=-(T5*PP1-T7*T4+PPP1)/(2.*PP1-T7)*1000.
      T2=-(T5*PP2-T7*T4+PPP2)/(2.*PP2-T7)*1000.
      ENCCDE (40,60,TJ(TT+845),T1,T2,PP1,PP2
      TJ(TT+845)=T1
      TJ(TT+846)=T2
      TJ(TT+847)=PP1
      TJ(TT+848)=PP2
      TJ(TT+849)=TSTAR
      TJ(TT+850)=Y(1)
      TJ(TT+851)=8/FTOM2
      TJ(TT+852)=XDX
      TJ(TT+853)=CODE
      TJ(TT+854)=ICOT2
      TJ(TT+14)
25  IF (ISPR1.EQ.0) GO TO 26
      TJ(TT+1667)=Y(2)
      TJ(TT+1668)=PMICF*Y(7)
      TJ(TT+1669)=PMICF*Y(8)
      TJ(TT+1670)=PMICF*Y(9)
      TJ(TT+1671)=PMICF*Y(7)
      TJ(TT+1672)=PMICF*Y(8)
      TJ(TT+1673)=PMICF*Y(9)
      TJ(TT+1674)=2.546475085*T3
      TJ(TT+1675)=MACH
      TJ(TT+1676)=Y(1)
      TJ(TT+1677)=PMICF*VT
      TJ(TT+1678)=CODE
      TJ(TT+1679)=ICCT3
      IF (ISLIG.EQ.1) GO TO 54
27  IF (ICCT1.EC.IC1) GC TO 28
      ICNP=ICCT1
28  IF (ICNP.GE.56) GO TO 291

```

```

25 GO TO (252,29), J7
   ICNP=ICNP+1
291 GO TO (57,57,57,46,57), NEX
   JAH=1 3C
292 IF (JAF.EC.1) GO TO 45
   K=27
3C IF (PMTCF.EC.1.) K=14
   II=0
   J=2
   KI=K
   KII=KI+12
   IF (IYF.EQ.0) GC TC 31
   WRITE (6,61) (HEAD(I),I=1,13)
   GU TO 32
31 WRITE (6,61) (HEAD(I),I=157,169)
32 WRITE (6,62) (HEAD(I),I=KI,KII)
33 WRITE (6,63)
   J=J+1
34 KI=II+1
   KII=KI+12
   WRITE (6,64) (TJ(I),I=KI,KII)
   J=J+1
   IF (J.EC.58) GO TO 36
   IF (II.EC.II+14) GO TO 35
   II=II+14
   IF (TJ(II).EQ.TJ(II+14)) GC TO 34
   GU TO 33
35 WRITE (6,63)
36 GO TO (31,41), J7
37 IF (TJ(53).EQ.0) GO TO 40
   IF (J.AE.58) WRITE (6,63)
   II=84
   J=2
   KI=K+35
   KII=KI+12
   WRITE (6,61) (HEAD(I),I=40,52)
   WRITE (6,62) (HEAD(I),I=KI,KII)
38 WRITE (6,63)
   J=J+1
39 KII=II+13
   WRITE (6,65) (TJ(I),I=II,KII)
   J=J+1
   IF (J.EC.58) GC TO 40
   IF (II.EC.II-827) GC TC 40
   II=II+14
   IF (TJ(II-1).EQ.TJ(II+13)) GO TO 39
   GU TO 38

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FDU17770
FDU17780
FDU17790
FDU17800
FDU17810
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FDU18060
FDU18070
FDU18080
FDU18090
FDU18100
FDU18110
FDU18120
FDU18130
FDU18140
FDU18150
FDU18160
FDU18170
FDU18180
FDU18190
FDU18200
FDU18210
FDU18220
FDU18230
FDU18240

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40 IT=0
41 GO TO 42
42 IF (Y(2).LT.TE6) GC TC 37
43 IF (I6CF.EQ.1) GO TO 37
44 IF (ISFF1.EQ.0) GO TO 45
45 IF (J.NE.58) WRITE (6,63)
46 II=1681
47 J=2
48 K=105
49 IF (PMTCF.EQ.1.) K=92
50 KI=K+12
51 WRITE (6,61) (HEAD(I),I=79,91)
52 WRITE (6,62) (HEAD(I),I=K,KII)
53 WRITE (6,63)
54 J=J+1
55 IF (IJ(1652).EQ.0.) GC TO 45
56 KI=II+12
57 WRITE (6,66) (TJ(I),I=II,KII)
58 J=J+1
59 IF (J.EQ.58) GO TO 45
60 IF (II.EQ.11-1667) GC TC 45
61 II=II+14
62 IF (IJ(II-1).EQ.TJ(II+13)) GO TO 44
63 GO TO 43
64 IT=0
65 ICNP=3
66 J7=2
67 GO TO (57,57,57,46,57), NEX
68 WRITE (6,63)
69 II=270C
70 J=2
71 KI=144
72 IF (PMTCF.EQ.1.) KI=131
73 KI=KI+12
74 WRITE (6,61) (HEAD(I),I=118,130)
75 WRITE (6,62) (HEAD(I),I=KI,KII)
76 WRITE (6,63)
77 J=J+1
78 IF (IJ(2709).EQ.0.) GC TO 49
79 KI=II+5
80 WRITE (6,67) (TJ(I),I=II,KII)
81 J=J+1
82 IF (I177.EQ.0) GC TC 48
83 IF (I177.EQ.11-2690) GC TO 49
84 II=II+1C
85 IF (IJ(II-1).EQ.TJ(II+9)) GO TC 48
86 GO TO 47
87 IT=0

```

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FDU18250
FDU18260
FDU18270
FDU18280
FDU18290
FDU18300
FDU18310
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FDU18670
FDU18680
FDU18690
FDU18700
FDU18710
FDU18720

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[illegible]

FDU2C170
FDU2C180
FDU2C190
FDU2C200
FDU2C210
FDU2C220
FDU2C230
FDU2C240
FDU2C250
FDU2C260
FDU2C270
FDU2C280
FDU2C290
FDU2C300
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FDU2C510
FDU2C520
FDU2C530
FDU2C540
FDU2C550
FDU2C560
FDU2C570
FDU2C580
FDU2C590
FDU2C600
FDU2C610
FDU2C620
FDU2C630
FDU2C640

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N=I+7
BR=AM
K=E(I+1)+1.+FLOAT(I)
IF (B(I).EQ.2.) GO TO 4
DO 1 J=N,K,6
IF (BR.LE.B(J)) GO TO 3
1 CONTINUE
2 WRITE (6,11) II,BR
J=J-1
IF (B(I+1).EQ.2.) J=J-15
WRITE (6,10) (B(I),I=J,K)
GO TO 1ER(167)
3 R=B(J-5)+ER*(B(J-4)+BR*(B(J-3)+BR*(B(J-2)+BR*B(J-1))))
4 RETURN
A2=ALPHA
N=N+13
K=K-15
DO 5 J=N,K,19
IF (BR.GE.B(J).AND.BR.LE.B(J+19)) GO TO 6
5 CONTINUE
GO TO 2
6 JS=J-3
DO 5 I=1,2
K=JS
KK=K-14
DO 7 L=KK,K,2
IF (A2.GE.B(L).AND.A2.LE.B(L+2)) GO TO 8
7 CONTINUE
WRITE (6,12) A2,II,BR
GO TO 2
8 RA(I)=E(L+1)+(B(L-1)-B(L+1))*(A2-B(L+2))/(B(L)-B(L+2))
9 JS=JS+15
R=RA(2)+(BR-B(J+19))*(RA(1)-RA(2))/(B(J)-B(J+19))
RETURN
10 FORMAT (6E15.8)
11 FORMAT (20H AERO EXCEEDED CODE=,I4,12H BREAK PCINT,E15.8)
12 FORMAT (10H ALPHA2 OF,E15.8,9H FOR TYPE,I4,12H BREAK PCINT,E15.8)
167 RETURN
END
ROUTINE COA (PY,DPY)
DIMENSION PY(2),DPY(2)
COMMON /BDH/ REARTH,GC,AMTOMS,PO,AMTOD,FTCM,ANTOM,KTOD,
1 CTOM,TWCPHI,AMTOKN,AMTGMH,FTOM2,CVDTOR,CVMTOR,RSQ
2 HA(25),TM(25),ALP(25),HEAD(169)
J=2
T2=REARTH+PY(1)
GPH=REARTH+PY(1)/T2
1 IF (GPH.LE.ALP(J)) GC TO 2

```


LIST OF REFERENCES

1. Etkin, Bernard, Dynamics of Flight, Wiley and Sons, 1959.
2. Norden Systems United Technologies Report 1313-R-0015, Wind Tunnel Test Report, by M.R.Fink, 19 September 1980.
3. American Institute of Aeronautics and Astronautics Report 81-0278R, Aerodynamic Properties of an Advanced Indirect Fire System Projectile, by M. R. Fink, 27 February 1981.
4. Ballistics Research Laboratories Report 1077, Jump Due To Aerodynamic Assymetry of a Missile With Varying Roll Rate, by C.H. Murphy and J.W. Bradley, May 1959.
5. Fuhs, A.E. and Tillotson, K.D., "Test of a Probe Used to Sense Alt itude Through Measurement of Pressure", Journal of Spacecraft and Rockets, Volume 21, Number 3 page 225, May-June 1984.
6. Norden Systems United Technologies Report X36123, Advanced Indirect Fire Systems: An Overview, by B.J. Horias, February 1983.

BIBLIOGRAPHY

American Institute of Aeronautics and Astronautics Report 81-0278R, Aerodynamic Properties of an Advanced Indirect Fire Systems Projectile, by M.R. Fink, 27 February 1981.

Babister, A.W., Aircraft Stability and Control, Permagon Press, 1961.

Ballistics Research Laboratories Report , HTRAJ Users Guide, by R.F. Lieske and J. Hurff, January 1973.

Ballistics Research Laboratories Report 1244, Equations of Motion of a Rigid Projectile, by R.F. Lieske and R.L. McCoy, March 1964.

Ballistics Research Laboratories Report 1216, Free Flight Motion of Symmetric Missiles, by C.H. Murphy, March 1964.

Ballistics Research Laboratories Report 1077, Jump Due To Aerodynamic Assymetry of a Missile With Varying Roll Rate, by C.H. Murphy and J.W. Bradley, May 1959.

Etkin, B., Dynamics of Flight, Wiley and Sons, 1959.

Fuhs, A.E. and Tillotson, K.D., "Test of a Probe Used to Sense Altitude Through Measurement of Pressure", Journal of Spacecraft and Rockets, Volume 21, Number 3, May-June 1984.

Norden Systems United Technologies Report 1313-R-0015, Wind Tunnel Test Report, by M.R. Fink, 19 September 1980.

Norden Systems United Technologies Report X36123, Advanced Indirect Fire System, An Overview, by B.J. Horias, February 1983.

Norden Systems United Technologies Report 1313-12-0045, Design of a Thrust Drag Control Loop, by S. Yang, 3 April 1981.

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