AIRCRAFT SURVIVABILITY INDEX FOR LOW ALTITUDE PENETRATION

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ABSTRACT

The problem of determining a survivability index for an attack aircraft, penetrating a missile only defense, is formulated as an iterative linear programming model. The costs for the linear program are determined from a simplified radar detection model and a pilot visual navigation model. The costs which are determined are not functionally linear with terrain clearance and the program is solved as an iteration on a linear program, with convergence to an optimal survivability index. The survivability indices (optimal costs) computed are shown to be dependent upon the terrain and type of navigation target selected. This dependence suggests that terrain-navigation target combinations which yield high indices should be avoided when mission planning.

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I. INTRODUCTION

GENERAL. In the present conflict in Southeast Asia the United States is facing its first armed conflict since World War II in which its unquestioned right to air supremacy in the theater of action is being challenged. For the past twenty-three years in a series of "minor" confrontations with the Communist Bloc Countries, control of the air has been conceded outright, or opposed with only a token force.

As a consequence, the tactics involved in attacking a well fortified target with tactical, non-nuclear air power have been ignored. In some cases, the lessons of World War II have been forgotten or made obsolete by the rapid advance of technology which has become synonymous with the space age.

The above remarks should not be interpreted as a condemnation of the authors' military predecessors, but should be used as a barometer of the state of the art. Now there exists a large "laboratory" for evaluating the "best", "optimal", or "least expensive way" of nullifying the effectiveness of well planned, coordinated, integrated and concentrated anti-aircraft defenses. Unfortunately, the toll paid to perform these experiments has been costly in aircraft and skilled pilots.

STATEMENT OF THE PROBLEM. This paper is a beginning. It does not give a real world answer to the problem of penetrating an air defense, but it does start at the beginning of the problem by considering how the terrain and pilot navigation effect pilot-plane survival and mission success.

Simply stated the problem is: determine an optimal altitude for penetration of a missile only defense, where aircraft navigation requires a higher altitude than the missile radars will permit if detection is to be avoided. What then is the optimal aircraft altitude to maximize survivability and mission accomplishment? Can certain routes be identified in advance which have a higher survivability index?

This paper will attempt to answer these two questions within the framework of the assumptions made. Hopefully, it will provide a basis for future work in this area.

II. TERRAIN DIGITALIZATION AND RADAR DETECTION MODEL

TERRAIN DIGITALIZATION. In order to adequately pre-plan routes of approach into a given target complex, it is first necessary to reduce the terrain of Figure 1 to a vertical profile as shown in Figure 2.

There are several techniques for accomplishing this reduction, and each is dependent upon the accuracy of available maps or aerial photographs. Reference [1] provides some background of the work being done in this area. Before a solution to the aircraft penetration problem can be obtained, a satisfactory method of digitalizing the terrain must be found.

The terrain used for this study is near Tonopah, Nevada and was digitalized by the Army Map Service. The terrain was used to conduct a series of aircraft terrain following tests [2] under the auspices of Joint Task Force Two, Sandia Base, Albuquerque, New Mexico. The terrain may be seen by referring to map series V 502, two sheets, "Tonopah, Nevada", NJ-11-5 edition 2-AMS and "Goldfield, Nevada-California", NJ-11-8, edition 4-AMS, 1 to 250,000. The terrain in this study referred to as "terrain one" starts at Longitude 116° 53'30" W, Latitude 38° 39' N and ends at Longitude 116° 53' 30" W, Latitude 37° 46' N; "terrain two", starts at Longitude 116° 27' W, Latitude 38° 38' 30" N and ends at Longitude 116° 27' W, Latitude 37° 47' N. Both pieces of terrain are approximately 50 nautical miles in length.


SANTA CRUZ
Gilroy
San Martin
WATSONVILLE
WATSONVILLE MUNI
122°
37°
36°
Bells Station
HOLLISTER MUNI
Hollister
Castroville
SALINAS
MONTEREY
Carmel
NAVY MONTEREY
MONTEREY PENINSULA/NAF MONTEREY
Chualar
Gonzales
Soledad
King City
Big Sur
Los Banos
Dairyland
AZEVEDO LANDING STRIP
Dos Palos
DOS PALOS AIRPORT/30
Firebaugh
LOS BANOS
MADERA MUNI
EL PECO RANCH
Mendota
Kerman
Tranquillity
Panoche
LEMOORE
Five Points
COALINGA AIR SERVICE
COALINGA

Figure 1

MAP

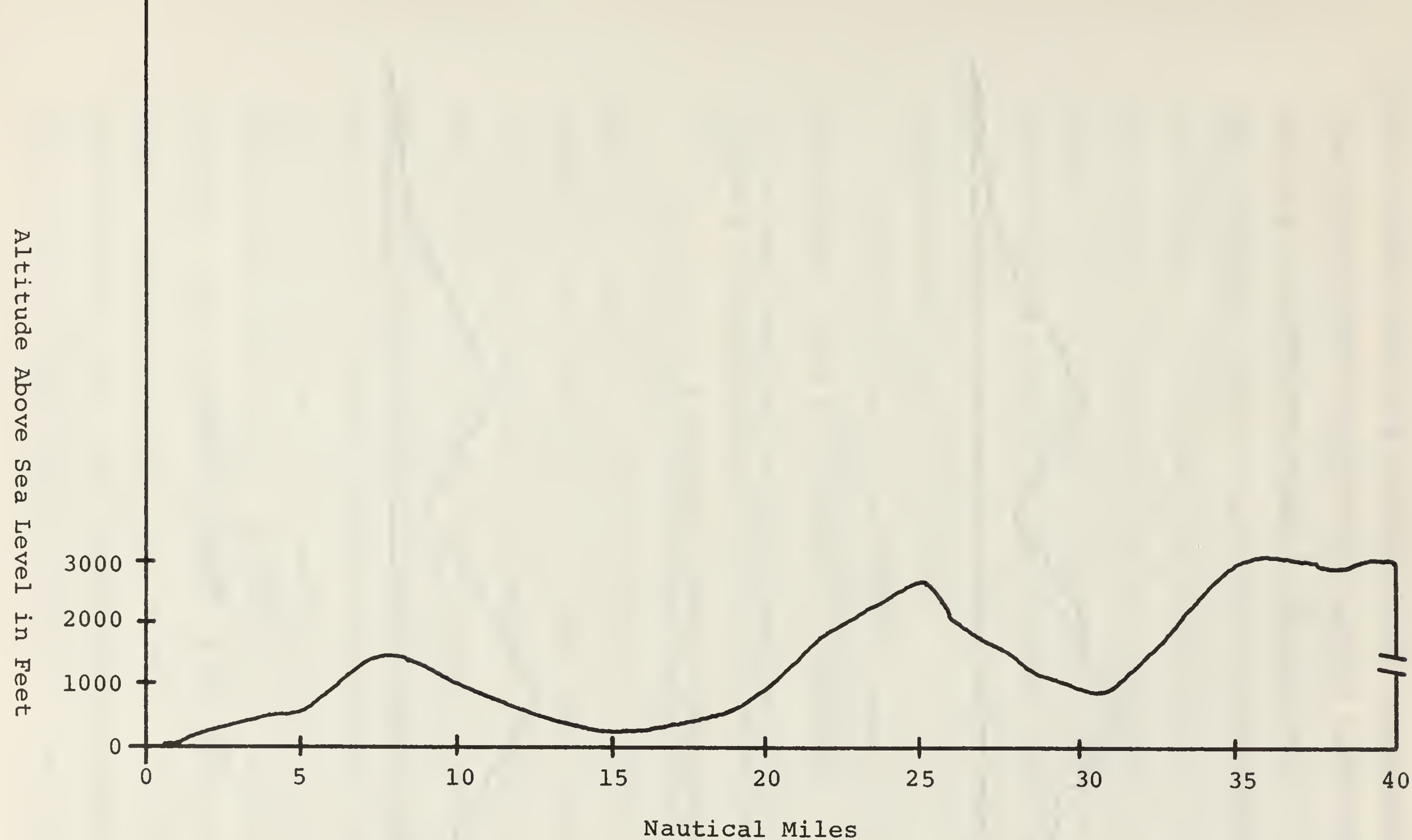


Figure 2

TERRAIN PROFILE

The terrain was digitalized in a manner similar to that shown in Figures 3 and 4. The detailed digitalization of the terrain by the Army Map Service resulted in a profile similar to Figure 3.

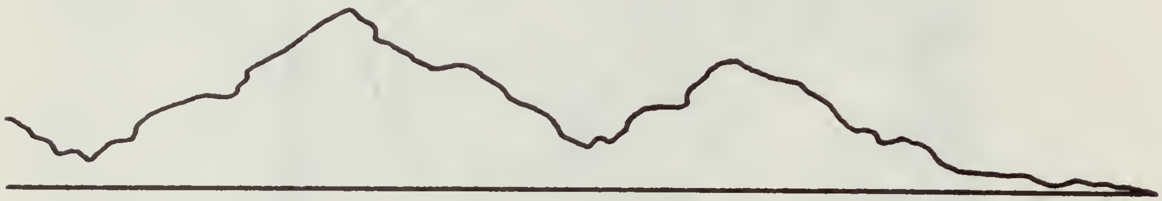


Figure 3

DETAILED TERRAIN PROFILE

The terrain profile was then simplified to its major terrain definitions as shown in Figure 4.

Figure 4

SIMPLIFIED TERRAIN PROFILE

For "terrain one" this resulted in 86 major terrain definition points and 120 points for "terrain two". The data set for each terrain is included in Appendix A.

RADAR DETECTION MODEL. The radar detection model is simple in principle. It assumes that radar energy is transmitted and received in straight lines (no refraction in earth's atmosphere) and it assumes that radar sites are distributed with a uniform probability distribution over the entire terrain; that is, it is equally likely that a radar site is located on any piece of terrain.

A block diagram of the model is shown in Figure 5 and the FORTRAN Coding is contained in Appendix B. A glossary of the more important variable names is contained in Appendix C.

The model computes the terrain visible from a point above the terrain as shown in Figure 6. In this figure, Point P is some multiple of 100 feet above the terrain point k. If P represents the location of an aircraft, then a radar located at any point on the "visible terrain" would be able to see the aircraft. The model computes the slope from point P to each terrain point on the entire 50 miles of terrain. The slopes are then compared sequentially with the slope to the last visible terrain point, looking forward and backward. When looking forward, if the slope to this terrain point is greater than the slope to the last terrain segment which could be seen, then the new terrain segment is visible from point P. When looking backward if the slope is less

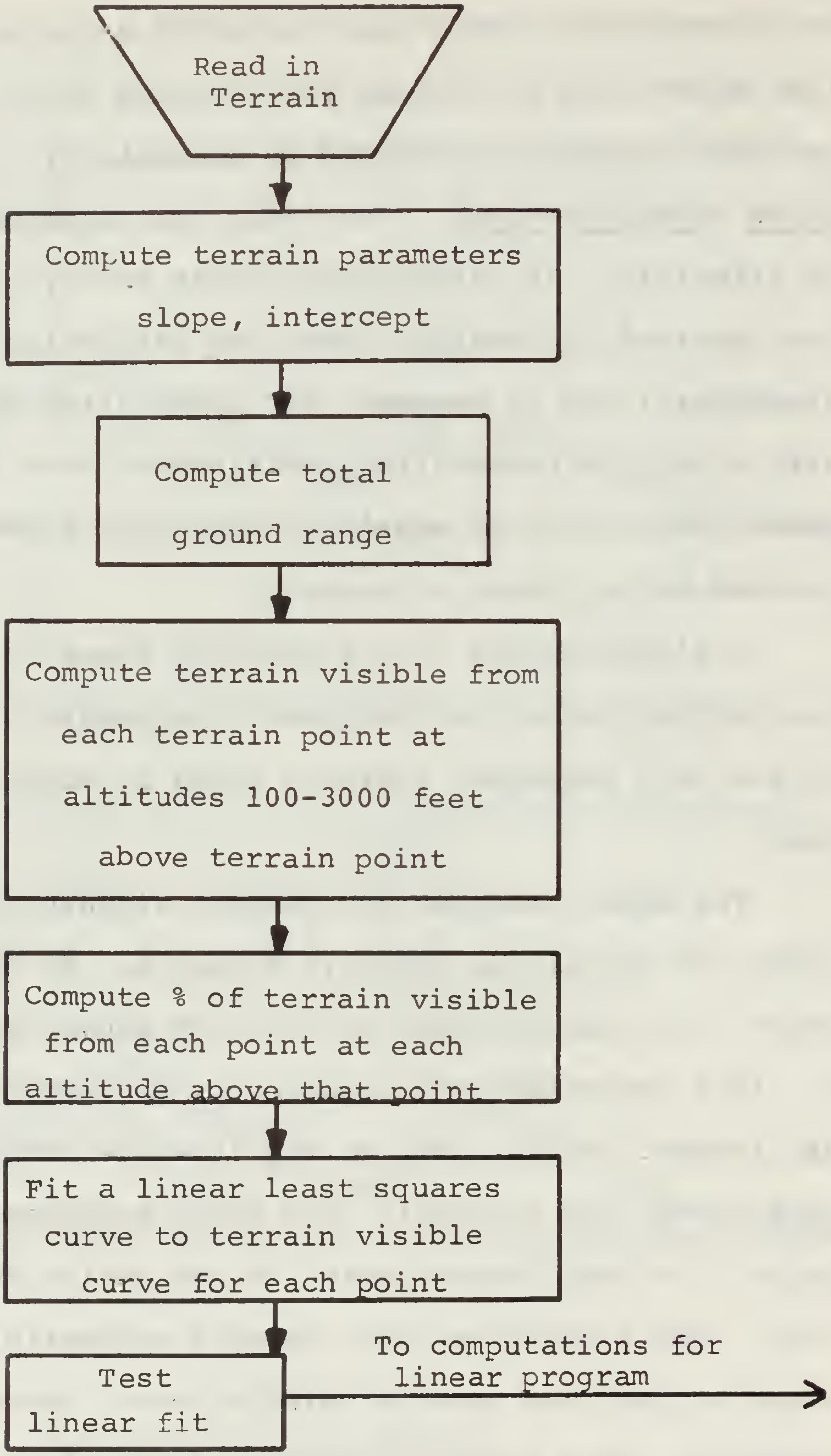


Figure 5

BLOCK DIAGRAM OF RADAR DETECTION MODEL

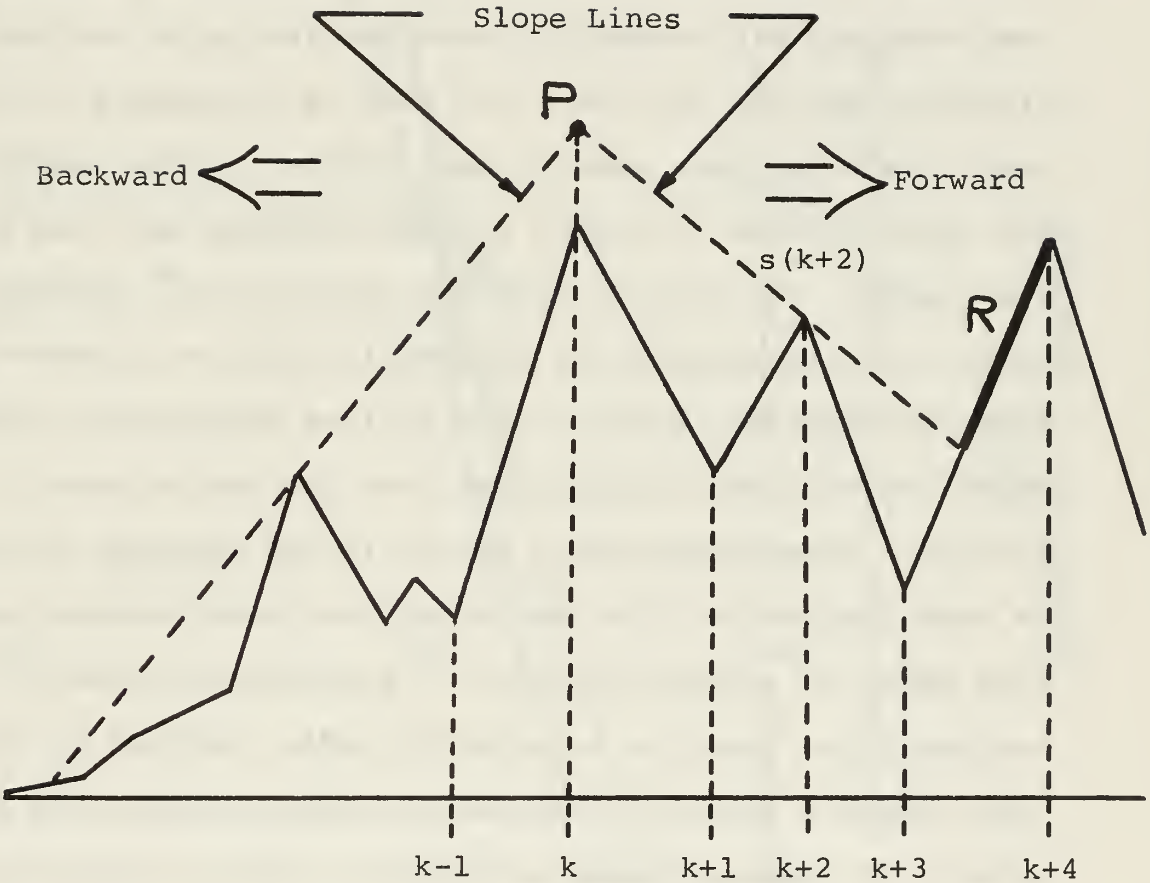


Figure 6

COMPUTATION OF VISIBLE TERRAIN

than the slope to the last visible segment, then the new segment is visible. For a terrain feature such as the one at point (k+2), which masks only a portion of the terrain between (k+3) and k+4), the model will extend the slope line s(k+2) to an intersection with (k+3) to (k+4) and compute only that portion of (k+3) to (k+4) which is visible (R in Figure 6). The length of each piece of visible terrain is them cumulatively summed for each terrain point and for each altitude from 100 feet to 3,000 feet in increments of 100 feet. Each of these sums is then divided by the length of the total terrain to obtain a number between zero and one. This number, for the i^{th} altitude above the k^{th} terrain point, then represents the probability that an aircraft at this altitude and terrain point will be detected by radars which are uniformly distributed over the entire piece of terrain. This probability, PHI(I) in the computer program, is then computed as that amount of the total terrain length from which an aircraft at the i^{th} altitude over the k^{th} terrain point could be detected by radar, divided by the total terrain length over which the radar sites could be located. It represents the probability that the enemy will locate a radar site on a piece of terrain from which the aircraft will be visible. A typical plot of this probability of detection as a function of the altitude for one terrain point is shown in Figure 7. The linear fit to the probability of detection curve is used for the generation of the inputs to the linear program which are discussed in Chapter IV.

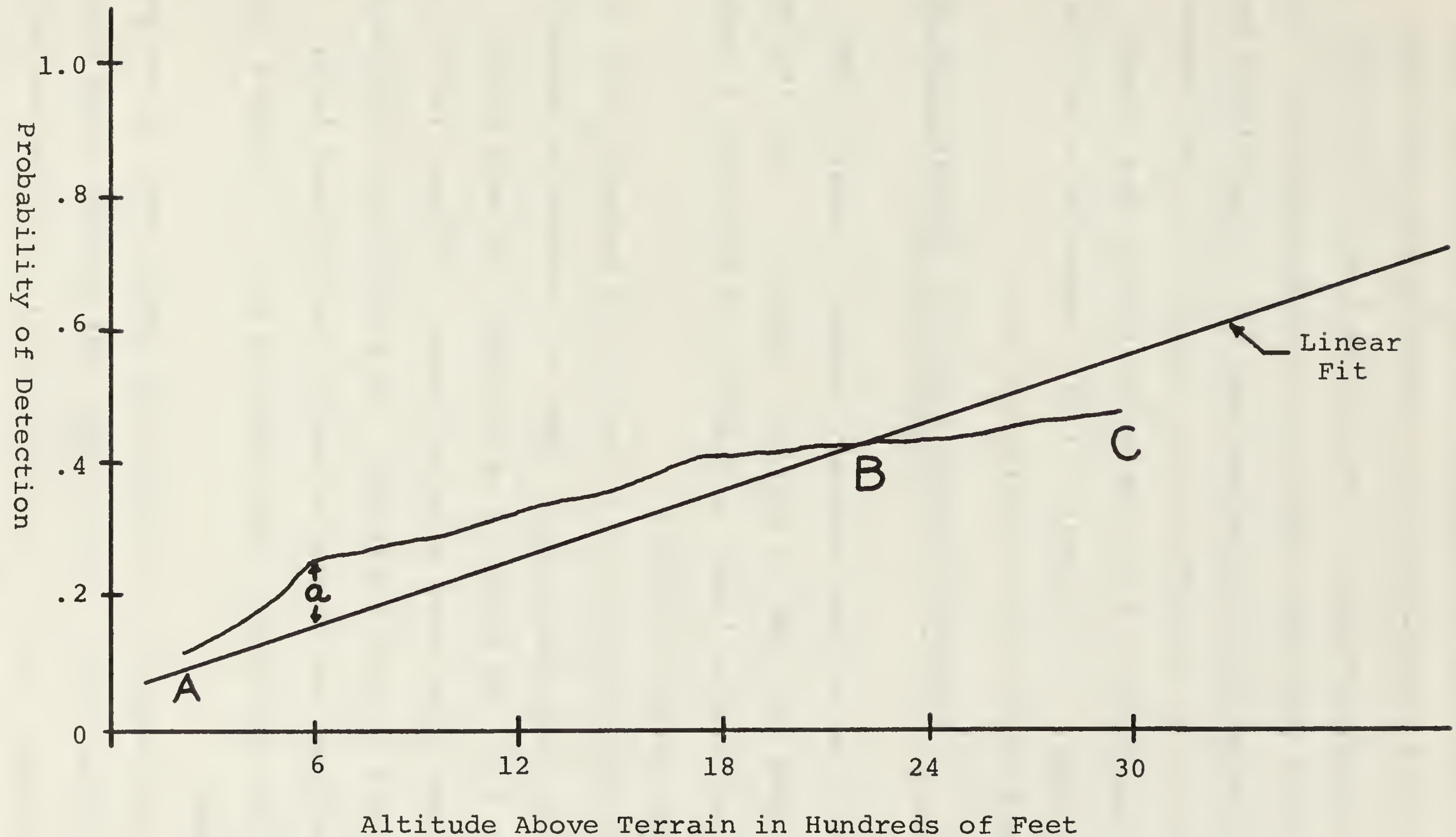


Figure 7

PROBABILITY OF DETECTION

In Figure 7, this linear fit is exaggerated to indicate how the use of this approximation was operationally justified.

Consider the region between points A and B in Figure 7; in this region the true probability of detection curve lies above the linear fit; this means that for all altitudes between A and B, an aircraft will be exposed to radar detection for some period of time above that which the linear curve specifies. To determine if this exposure is critical, the "exposed time" can be determined from

$$\text{exposed time} = \frac{(\text{distance a})(\text{total length of terrain in 50 mi.})}{\text{aircraft velocity}}.$$

The exposed time is then compared against a missile time which includes the time to acquire, identify, track the target, and the time to launch a missile and intercept a target at a minimum time of flight.

In the model this time is set at 100 seconds; this is considerably less than actual times as recorded in Operation Blue Lotus [3]. An Analysis of Variance was made on the data obtained from three Missile Control Officers for 13 aircraft attacks in this operation. No significant difference between officers was found at the 5% significance level. The mean time for the above tasks exceeded the 100 seconds used in the model.

In the interest of security the actual data is not presented in this paper. In the model the exposed times computed were less than 100 seconds for all altitudes and all terrain points; therefore since the exposure times are less than 100 seconds and 100 seconds is less than actual operational engagement times, the linear curve fit to the probability of detection curve is a valid assumption.

The validity of this linear curve fit to the probability of radar detection curve completes the radar detection model.

III. VISUAL NAVIGATION

If an aircraft survivability index for low altitude penetrations is to represent the true cost for an aircraft attacking a target, it must take into consideration the type of target the aircraft is searching for, the altitude and airspeed of the attacking aircraft, the meteorological visibility in the area of search, and the type terrain the target is located in (i.e., terrain masking).

A search of the most recent literature revealed that Dr. W. H. Bradford [4] of the Sandia Laboratory had designed a model for Joint Task Force Two, Sandia Base, Albuquerque, N.M. and Dr. June G. Brenton [5] of the Dikewood Corporation had taken the Bradford Model, made some changes and formulated the model in detail. Sharon Daniel of the Sandia Laboratory wrote the FORTRAN program listed in Appendix D.

In June, 1967, permission was obtained from JTF-2 to use the Visual Target Reconnaissance and Acquisition (VISTRAC) FORTRAN model to determine the cost due to pilot navigation for an aircraft attacking a target at low altitude and high airspeed. The model computed the probability of acquiring 25 different targets as a function of aircraft airspeed, altitude, type target, target masking angles, and meteorological visibility.

CHANGES MADE TO VISTRAC.

Brenton's model, VISTRAC, computed the cumulative probability of detecting each of the 25 targets and a final score which is the average detection of all 25 targets. Since one of the assumptions of the aircraft survivability index model was that the aircraft was searching for a specific type target, a change was made to VISTRAC to put one of the 25 targets into each of the 25 target locations. This was accomplished by reading in a new variable K22 which designated the target of interest. The four parameters height, width, length, and target's inherent contrast are then placed in each of the 25 target locations. The original locations and masking angles were kept the same, fulfilling another assumption that terrain masking is a function of target location. The final score or the average detection of the target located at the 25 positions was used as one input to the linear program. Three targets were selected for investigation. Since target inherent contrast is a major source of variation in target detection, target 10 and target 14 (Appendix E, Figures 29 and 30) were selected because they had the highest and lowest inherent contrast. Target 25 (Appendix E, Figure 33) a SAM-2 site was used because this is the type target for which a survivability index is most useful. Plots of the probabilities of detecting (Appendix E, Figures 30, 32, and 34) each of the three targets as a function of aircraft speed and altitude gives insight as to the aircraft navigation costs.

Due to errors made in aircraft navigation, intelligence reports, and/or accuracy of maps used, the pilot may find the target on the flight path or to either side. The sample deviation of target offset distances in the VISTRAC model was computed assuming the flight path as the mean. The offset distance from the flight path of one standard deviation was found to be approximately 5000 feet, and a Chi-Square goodness of fit test confirmed the normal distribution at an $\alpha = .8$.

The following sections of this chapter consist of a summary of the VISTRAC model developed by Brenton for point to point navigation. Figures 29, 31, and 33, Appendix E, are taken from reference 6 and Figure 9 is taken from reference 7.

DEFINITIONS.

$P(t)$ = the cumulative probability that a target will be acquired by an airborne observer.

Y_T = the range of unmasking of a target along the flight path.

y = ground distance from the aircraft to the target.

y_1 = the point of remasking of the target along the flight path.

y_2 = the point of unmasking of the target along the flight path.

m = the slope or rate at which the probability increases with increasing $\frac{C(t)}{C_T(t)}$ set equal to 1.9.

$C(t)$ = the target apparent contrast.

$C_T(t)$ = the target threshold contrast.

b = a constant related to human factors and is the threshold value of $\frac{C(t)}{C_T(t)}$ set equal to .62.

r_0 = the foveal line of vision from the observer to the point of the ground where his eye is fixating.

θ = the angle between the foveal line of vision and the target-observer line.

k = a human factors parameter related to the task-loading of the crew set equal to 0.015830.

v = the speed of the aircraft in feet per second.

C_0 = the target inherent contrast.

R = the slant range to the target.

V_m = the meteorological visibility.

B_B = the target's background luminance.

B_T = the target luminance.

a = the altitude of the aircraft above the target.

α = the angle the target subtends at the eye of the observer.

l = the length of the target.

w = the width of the target parallel to the flight path.

h = the height of the target.

M_A = the angle between the ground and the line from the center of the target to the aircraft.

M_T = the mask angle or the angle between the ground and the line from the center of the target to the tallest tree measured every 10 degrees around each target.

e = the offset distance of the target from the ground track.

L_A = the angle between e and a line from the center of the target to the aircraft projected on the ground.

Φ = the dip angle the observer's foveal line of vision makes with the horizontal.

ϕ = $90-\Phi$.

ρ_0 = the angular search limits of the observer.

$\dot{\rho}$ = the angular search speed of the observer.

ρ = the angle between the flight path and a line projected on the ground from the foveal line of vision.

d = the projection of the aircraft target ground distance on the ground track.

L_T = the azimuth angle from the target measured counter-clockwise from the direction of the positive x axis.

s = the number of saccades (angular jump between fixations made by the eye) in one scan from $-\rho_0$ to $+\rho_0$.

i = the scan number.

THE MATHEMATICAL MODEL.

The computer model VISTRAC assumes the Bradford [4] model and makes a change of variable $y = y_2 - tv$. Then it defines the probability of acquiring a target as

$$P(t) = 1 - \exp\left[-k\int_0^{\frac{y_2-y_1}{v}} \{\max[0,(\frac{C(t)}{C_T(t)}-b)]\}^m dt\right] , \quad (1)$$

where k is a parameter which is related to the taskloading of the crew. The point of unmasking of the target along the flight path is y_2 and the point of remasking along the flight path is y_1. The aircraft velocity is v and is given in feet per second.

The target's apparent contrast is defined as C(t) and $C_T(t)$ is the target's threshold contrast. The threshold value of $\frac{C(t)}{C_T(t)}$ is b or the contrast ratio at which the probability of acquiring the target is appreciable [4], [8], [9]. Then m is the slope or rate at which the probability increases with increasing values of $\frac{C(t)}{C_T(t)}$. $C_T(t)$, the threshold contrast, varies as a function of θ, the angle between the foveal line of vision and the target-observer line, therefore the factor $\frac{C(t)}{C_T(t)} - b$ is a function of θ.

<u>THE PARAMETER k.</u>

The parameter k is related to the observers taskloading. Brenton assumed a value k = 0.01583, based on references [4], [9]. All probabilities computed for use in the linear program use this value k. If k is decreased this implies there is an increase in taskloading of the observer which means the pilot is spending more of his time navigating and flying the aircraft and less time searching for targets. Results of test 4.4 [7], [10], [11], confirmed k = 0.01583 for the A-6A, RF-4C and F-4C for all altitudes. These three aircraft each carry a crew of two, and the A-6A side-by-side configuration permits both pilot and bombardier-navigator to see outside the cockpit equally well. The tandem configuration of the RF-4C and F-4C restricts most of the search effort to the pilot in the front cockpit. As was suspected the A-6A crew performed better, however the value k = 0.01583 gave a good fit to the data. The A-4C/E aircraft is a single piloted aircraft and therefore higher taskloading exists. A value of k = 0.012 fit the data of Test 4.4. This is a 25 percent reduction in k, implying the crew of a single seated aircraft spends one fourth less time searching for targets.

These two values of k are recommended for use in determining a survivability index, since they fit the data collected in the point-to-point navigation portion of Field Test 4.4.

For the route reconnaissance part of Test 4.4 the crews were briefed to fly a ground route made up of portions of highways and waterways. This additional taskloading required a 25 to 45 percent reduction in the value if k to give a good fit to the data. Table D1-3 of reference 7 gives a complete breakdown of k values used for type aircraft, altitudes and airspeeds.

TARGET CONTRAST.

From Koopman [4] the target apparent contrast C(t) is defined in terms of C_0 the target's inherent contrast. V_m is the meteorological visibility and R is the slant range from the aircraft to the target, which varies as a function of time. Then the target's apparent contrast is

$$C(t) = C_0 \, e^{\frac{-3.44R}{V_m}} , \qquad (2)$$

where C_0 is defined in terms of background luminance B_B, and target luminance B_T as

$$C_0 = 100\frac{B_B - B_T}{B_B} \text{ when } B_B \geq B_T \tag{3}$$

or

$$C_0 = 100\frac{B_T - B_B}{B_T} \text{ when } B_T > B_B \quad . \tag{4}$$

Because all targets were of a complex nature, the average target luminance was computed by the Sandia Laboratory [6], [7], by taking films of each target and background, then dividing them into equal grid squares and comparing each grid square with the gray scale of a known reflectance similar to the method recommended for a single-item target [12], [13], [14]. The luminance of the whole was computed as a function of the parts. Then

$$B = \frac{1}{A}[B_1A_1 + B_2A_2 + \ldots B_nA_n] \quad , \tag{5}$$

where A is the area of the whole background or target and B_nA_n is the product of the nth area and its luminance. The inherent contrast was computed using equations (3), (4), and (5).

The threshold contrast $C_T(t)$ is defined by

$$C_T(t) = \begin{cases} 1.75\sqrt{\theta} + \dfrac{18.57\theta}{\alpha^2} , & 0.8° \leq \theta \leq 90° \\ 1.57 + \dfrac{14.86}{\alpha^2} , & 0° \leq \theta \leq 0.8° \end{cases} \tag{6}$$

where θ is the angle between the observer's line of vision and the target-observer line in degrees and α is the angle subtended by the target at the eye of the observer.

If $R >> h + w + l$ where h, w, l, are the height, width and length of the target, then equation (7) is a good approximation for α. Then α is given as

$$\alpha = \frac{6876}{R}\left[\frac{h\cos M_A(l\cos L_A + w\sin L_A) + lw\sin M_A}{\pi}\right]^{\frac{1}{2}} \quad . \qquad (7)$$

The angles are given by $M_A = \sin^{-1}(\frac{a}{R})$ and $L_A = \tan^{-1}(\frac{d}{e})$ where a is the aircraft altitude above the target, e is the target offset distance from the flight path, and d is the projection of aircraft-target distance on ground track. See Figures 8 and 9.

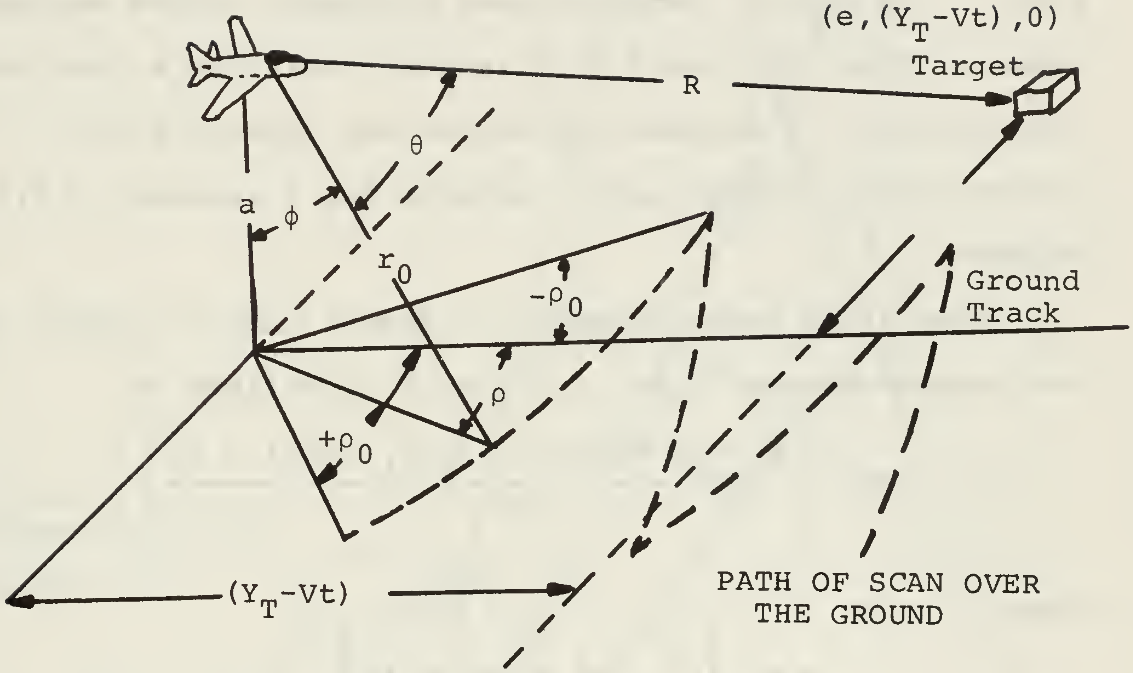
<u>The Dip Angle</u>

The dip angle Φ is defined as the angle between the observer's foveal line of vision and the horizontal. The model assumes that the dip angle is 5 degrees at the altitudes of 0 to 300 feet. It then increases linearly to 15 degrees below the horizon at 1000 feet. Above 1000 feet of altitude a dip angle of 15 degrees is assumed because of cockpit masking. The computer model uses $\phi = 90-\Phi$.

<u>Scan Pattern</u>

The model assumes that an airborne observer's foveal line of vision moves from one side the flight path to the other [5] at an angular speed $\dot{\rho} = 8.5°$ per second with limits of $\rho_0 = \pm 42.5°$ at 100 knots airspeed and decreases linearly to $\rho_0 = \pm 4.25°$ at 550 knots airspeed.

The value of $\dot{\rho}$ and ρ_0 were based on results of human factors experiments conducted in visual search [15]. It was



$$\theta = \cos^{-1}\left[\frac{r_0 \sin\phi\,[e\sin\rho + (Y_T - Vt)\cos\rho] + a^2}{r_0 R}\right]$$

$$\rho = (-1)^{i+2}(-\rho_0 + \dot{\rho}[t-si]) \;, \quad i=0,1,2,\ldots,$$

$$s = \frac{2\rho_0}{\dot{\rho}}$$

$$t = 0,1,\ldots,t_{max}$$

Figure 8

SCAN MOTION IN VISTRAC MODEL

found that visual search consisted of fixations or glimpses with durations which are distributed gamma with a mean of approximately 0.3 seconds. The angular distance between fixations is also distributed gamma with a mean of about 9.0 degrees. The angular jumps between glimpses, called saccades, range in duration from $\frac{1}{3}$ to $\frac{1}{2}$ second, therefore a continuous scan rate of 8.5 degrees per second was assumed with .5 seconds for a glimpse and .5 seconds for a saccade of 8.5 degrees.

Then θ the angle between the foveal line of vision and the target-observer line in Figure 8 is defined as

$$\theta = \cos^{-1}\left[\frac{r_0 \sin\phi[e\sin\rho + (Y_T - V_t)\cos\rho] + a^2}{r_0 R}\right], \tag{8}$$

where

$$R = \left[a^2 + e^2 + (Y_T - Vt)^2\right]^{\frac{1}{2}}, \tag{9}$$

and

$$\rho = (-1)^{i+2}\left[-\rho_0 + \dot{\rho}(t - si)\right] \quad t = 0, 1, \ldots, t_{max}, \quad s = \frac{2\rho_0}{\dot{\rho}}, \quad i = 0, 1, \ldots \left[\frac{t_{max}}{s}\right] \tag{10}$$

where t is one second intervals. Y_T is defined as the distance along the Y axis from the point where the target first becomes unmasked, to the point where the aircraft fuselage masks the target. Then t_{max} is the greatest integer value $\left[\frac{Y_T}{V} + 1.0\right]$, and s, the number of saccades in one scan, is an integer since $2\rho_0$ is always taken as a multiple of $\dot{\rho}$. One

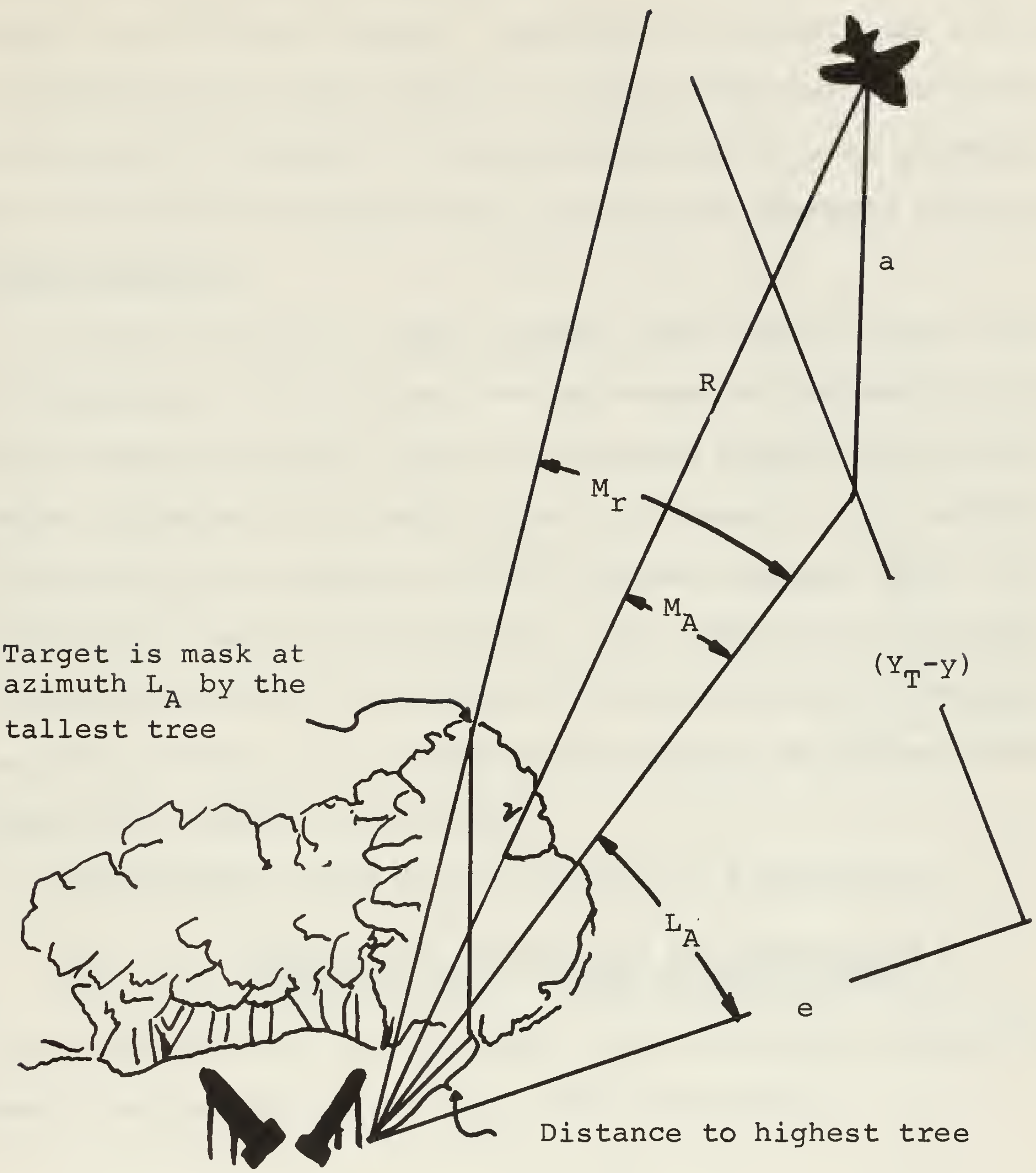


Figure 9

MASKING OF TARGET FROM OBSERVER

scan is defined as one sweep of the eyes from $-\rho_0$ to $+\rho_0$, where i is the scan number. Equation (10) starts the scan to the left of the flight path at $-\rho_0$ and moves the scan angle ρ as depicted in Figure 8. Recommendations for scan parameters as a function of airspeed are contained in Appendix D Table 5.

TARGET MASKING.

Visual search for land targets must take into consideration masking of the target area by nature of man made objects. The VISTRAC model has a table of masking angles for each 10 degree interval of azimuth around each target. Ten targets denoted with one asterisk in the Fortran computer print out have actual measured mask angles. The angles were surveyed by an engineering team, measured from the center of the target area to the tallest obstruction in each 10 degree azimuth around the target, see Figure 9.

The masking angle M_T at azimuth L_A is defined as

$$M_T = \tan^{-1}\left(\frac{\text{height of trees, hill or obstruction}}{\text{distance from target to obstruction}}\right).$$

L_T is the azimuth angle from the target measured counterclockwise from the positive x axis and is defined as

$$L_T = \tan^{-1} \frac{(Y_T - y)}{e} , \qquad (11)$$

where (Y_T-y) is the distance along the flight path from the target and e is the offset distance from the flight path.

The mask angles for the other 15 targets were estimated from high altitude vertical photographs to obtain the foliage coverage and contour maps for the terrain features. Integragration (or the computing of the probability of detection) begins when $M_A > M_T$ and continues until the aircraft passes the target, unless some M_A at an L_T is less than M_T, then integration is interrupted. Testing for the intermediate intervals of target masking is done every second.

In the computer model the aircraft is advanced to the point where the inequality $\frac{C(t)}{C_T(t)} > (b + .10)$ is satisfied (i.e., the range at which the probability of acquiring the target is appreciable). Then if the target is unmasked, integration begins. But if the target is masked, the aircraft is advanced 100 feet along the flight path and a check for target unmasking is made again. This is repeated until the target is unmasked or the aircraft has passed the target.

PROBABILITIES.

The computer model prints out the expected score for each of the 25 targets or with the changes made for the input to the linear program, it prints out the probability that the target is acquired at each of the 25 different positions using the original masking angles for that position.

$$P_i(t) = 1 - \exp\left[-k\int_0^{\frac{y_2-y_1}{v}} \{\max[0,(\frac{C(t)}{C_T(t)}-b)]\}^m dt\right], \quad i=1,2,\ldots,25 \quad . \tag{12}$$

also a final score is given as

$$\text{Final score} = \frac{1}{25}\sum_{i=1}^{25} P_i(t) \quad . \tag{13}$$

It is this final score which is used for the input to the linear program for that particular altitude, target, and airspeed.

SENSITIVITY STUDIES WITH VISTRAC.

As noted in reference [7] and [16], the model is sensitive to the target inherent contrast. In comparing the probabilities of detection, with the four target parameters (Appendix E) height, length, width and target inherent contrast, we note that the first three parameters are very similar. However, 7.9, 16.7 and 80.0 percent represent the range of the spectrum of inherent contrast. The inherent contrast is the reason for the large variations in the probabilities of detecting targets.

Another source of variation not noted in any of the VISTRAC references is the dip angle Φ. The angle Φ is assumed to be 5° below 300 feet, increasing linearly to 15° at 1000 feet and due to cockpit masking remain at 15° above 1000 feet. The angle between the foveal line of vision and the target ovserver line θ is a function of $\phi = 90-\Phi$. Koopman [8] gives a graph of the probability of detecting a target as a function of the angle θ. It can be seen that the probability of detection drops sharply with increasing values of θ.

Several computer runs were made assuming a Φ which would give a ground distance from the aircraft to the point of fixation of 5000 feet, or one standard deviation of the distribution of targets. The runs indicated an increase of 5 to 30 per cent in detections for altitudes below 1300 feet. Above 1300 feet Φ was assumed to be 15° for reasons of cockpit masking. If the observers are searching in a manner assumed by the angle Φ, then they may be able to increase their detections by searching further from the flight path. However if they are searching further from the aircraft than assumed by Φ then this may warrant a reduction in k implying an increase in the taskloading of the crews.

From a study of the probability of detection as a function of altitude (Appendix E, Figure 34) we see that detections usually increase with increases in altitude, except in the altitude range 700 to 1000 feet, where we have a slight decrease in detection with increasing altitudes.

This phenomenon is quite prevalent with targets which have inherent contrast (C_0) of 10 to 50 per cent. The reduction of the targets' apparent contrast C(t), a rise in the target's threshold contrast $C_T(t)$ and the assumed values for the dip angle all combine to offset the increases in unmasking times. Once the aircraft is above 1000 feet Φ is held constant and the targets are unmasked at a rate which offsets the reduction made by target contrasts. Then the probabilities increase until the aircraft reaches 2600 to 2800 feet where most targets have reached their maximum time of unmasking. Data collected from the road reconnaissance portion of Field Test 4.4 indicates that detections do drop off in the altitude range 700 feet to 1000 feet.

CONSTRAINTS. Consider the section of the terrain shown in Figure 10.

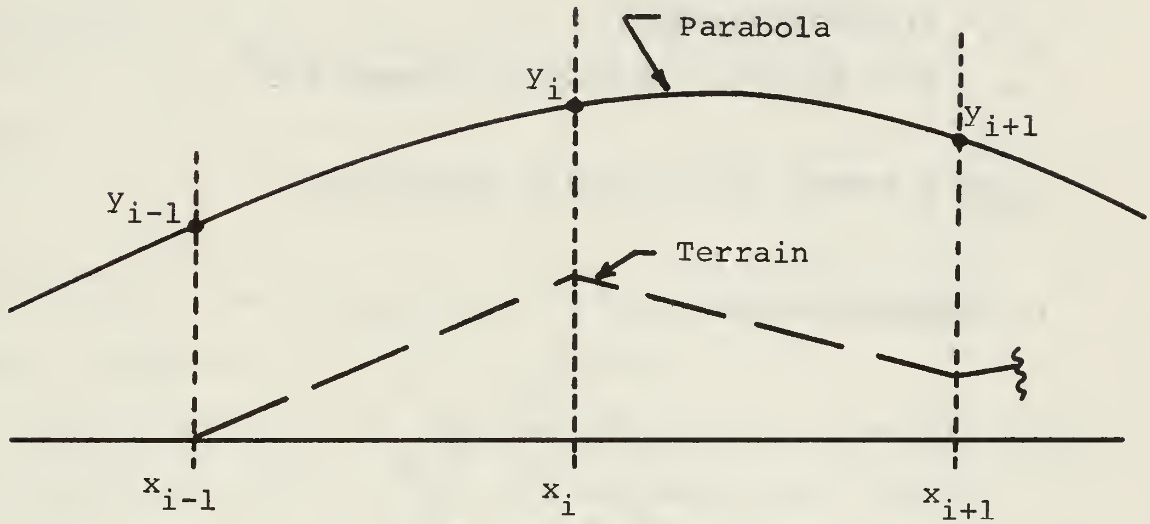


Figure 10

TERRAIN SECTION

It has been demonstrated [29], [30], that a parabola is a reasonable representation for an aircraft flight path in terrain following. Let

$$y_i = c_i + t_i \quad , \tag{1}$$

where

y_i = altitude of aircraft above sea level,

t_i = terrain altitude above sea level and

c_i = clearance of aircraft above terrain.

Now using the fact that

$$G = \frac{2v^2}{a} \frac{d^2y}{dx^2} , \qquad (2)$$

where

$G = \frac{1}{32.2}$ times the acceleration on the flight path,

v = aircraft velocity,

a = 32.2 feet per second per second and

$\frac{d^2y}{dx^2}$ = second derivative of parabola.

In addition define

$$d^+ = x_{i+1} - x_i$$

$$d^- = x_i - x_{i-1}$$

$$d^s = x_{i+1} - x_{i-1} ,$$

then take differences and assume $\frac{dy}{dx} = \frac{\Delta y}{\Delta x}$ for small Δx. The backward difference is

$$\left.\frac{dy}{dx}\right|_1 \approx \frac{y_{i-1}-y_i}{d^-} \quad . \qquad (3)$$

Similarly, the forward difference is

$$\left.\frac{dy}{dx}\right|_2 \approx \frac{y_i-y_{i+1}}{d^+} \quad . \qquad (4)$$

The second derivative for (2) is approximated by the second difference obtained by subtracting (4) from (3);

$$\frac{d^2y}{dx^2} \approx \frac{d^+y_{i-1}-d^sy_i+d^-y_{i+1}}{d^+d^-d^s} \quad . \qquad (5)$$

Substituting (1) into (5) yields

$$\frac{d^2y}{dx^2} \approx \frac{(d^+c_{i-1}-d^sc_i+d^-c_{i+1}) + (d^+t_{i-1}-d^st_i+d^-t_{i+1})}{d^+d^-d^s} \quad . \tag{6}$$

Combining (6) with (2) yields

$$\left[\frac{G^-ad^+d^-d^s}{2v^2}\right] - T_i \leq d^+c_{i-1}-d^sc_i+d^-c_{i+1} \leq \left[\frac{G^+ad^+d^-d^s}{2v^2}\right] - T_i \ , \tag{7}$$

where

$$T_i = d^+t_{i-1}-d^st_i+d^+t_{i+1} \quad . \tag{8}$$

the G^+ and G^- are the positive and negative acceleration forces respectively.

The significance of relation (7) is that it establishes two constraint equations for each terrain point; one inequality results from a bound upon the positive acceleration forces (G^+) that the pilot will sustain in conforming to his flight path and the other inequality provides the same relationship with respect to the negative accelerations (G^-) sustained at each terrain point by the pilot. The acceleration forces under consideration should not be thought of as the maximum forces which the pilot-airframe combination can sustain, but rather those forces to which a pilot on a long mission will, consciously or unconsciously, subject himself and his aircraft while following the terrain. Appendix F is the FORTRAN coding which generates the values for all parameters in relation (7) with the exception of the c_i's.

OBJECTIVE FUNCTION. To compute the costs for the linear program, consider that a linear fit has been obtained and justified for the probability of radar detection and that a non-linear function has been determined for the probability of detection of ground navigational targets by the pilot. Let $Pd(R)_{ik}$ be the probability of detection by radar at the k^{th} terrain point and the i^{th} altitude, and $Pd(n)_i$ be the probability of detection of a navigation target by the pilot at the i^{th} altitude. An unweighted linear combination of these two factors as

$$\alpha_k = \frac{Pd(R)_{ik} + (1-Pd(n)_i)}{c_k} \quad , \tag{9}$$

will then yield the "cost" per foot of terrain clearance at the k^{th} terrain point. This combination seems reasonable when it is recalled that the overall objective of the combined models was to determine a survivability index for the terrain, which also included a consideration that the mission was accomplished. The reasonableness of equation (9) becomes apparent when it is recalled that the mission can be aborted because of radar detection (plane shot down) or it could be aborted because the plane got lost and could not find its target (failed to detect the navigational target). The computation of these costs are shown in Appendix G.

A possible objective for this linear programming model is to minimize

$$T = \sum_{k=1}^{N} \alpha_k c_k \quad . \tag{10}$$

Although a proper formulation, equation (10) does not satisfy the requirements of this problem. As might be expected, the costs computed by (9) are not a linear function of terrain clearance at each terrain point. In fact, these costs when plotted by terrain point against terrain clearance, yield a figure such as the one shown in Figure 11.

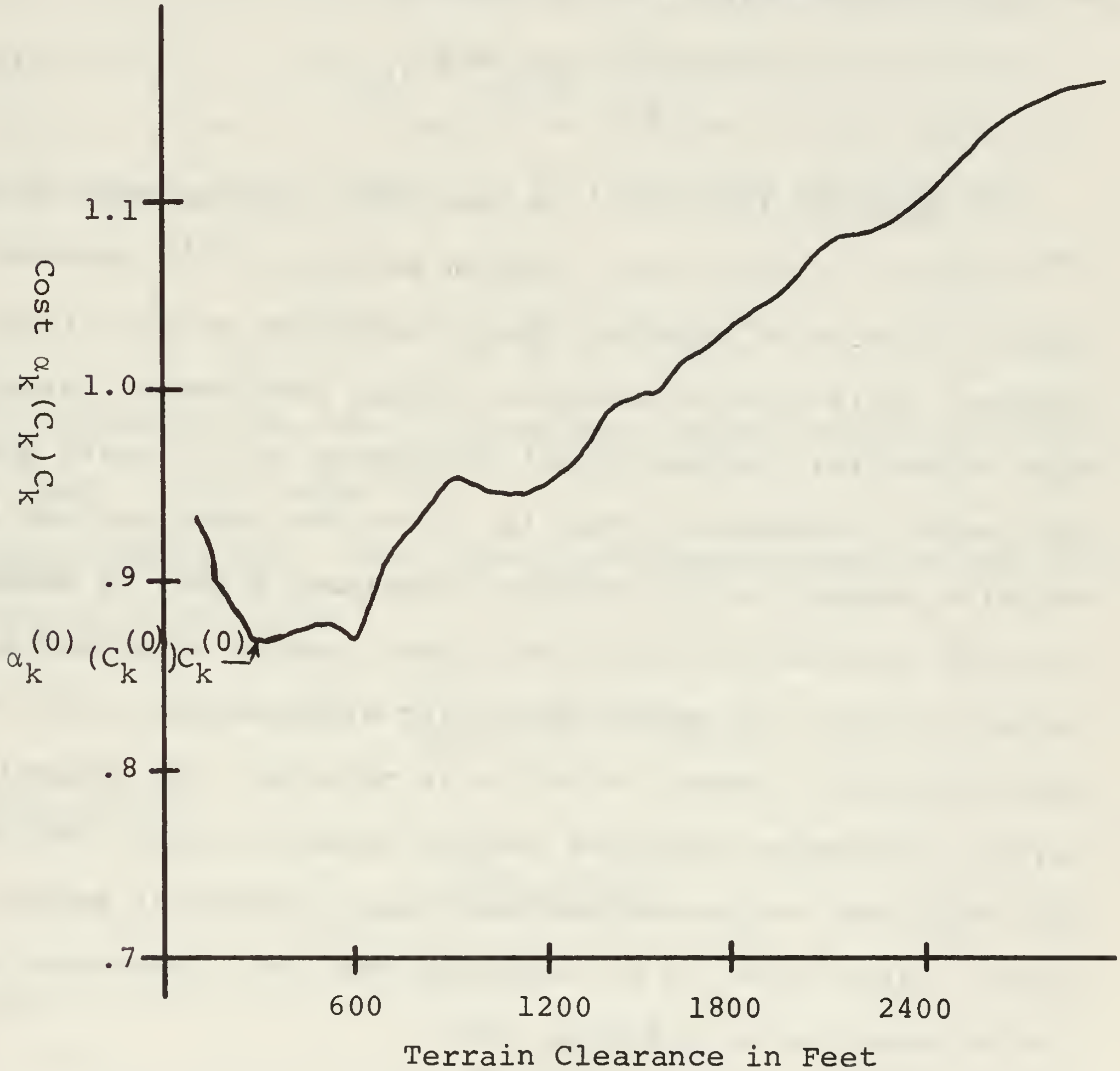


Figure 11

TYPICAL COST CURVE

These plots are similar in appearance, but functionally different at each terrain point. No attempt was made to determine their functional form at each of the terrain points. The costs are, in reality, functionally dependent upon the clearance of the aircraft above the terrain. A more reasonable objective function is to minimize

$$T^{(n)} = \sum_{k=1}^{N} \alpha_k (c_k^{(n-1)}) c_k \quad . \tag{11}$$

In equation (11), $T^{(n)}$ is the total minimum cost for the n^{th} solution of the linear program and the $c_k^{(n-1)}$ are the terrain clearances from the $(n-1)^{st}$ solution of the linear program. This type of iterative linear programming formulation allows for the functional dependence of the costs upon the terrain clearance. That is, since the costs are not linear with respect to the terrain clearance, a cost is selected for each terrain point and the linear program is solved as though the cost was known and linear with respect to the terrain clearance. When a solution is obtained, the optimal terrain clearances are then used as entering values for which new costs are determined and the linear program is solved again. Since there is no assurance that this procedure will insure convergence, relation (12)

$$\left| \frac{T^{(n)} - T^{(n-1)}}{T^{(n)}} \right| < \varepsilon \tag{12}$$

was used as a means of terminating the iterative process. Epsilon was selected as equal to .01 since preliminary runs on the Revised Simplex Algorithm indicated that a one per cent tolerance on the total optimal cost would be reasonable.

One additional constraint per terrain point is required. This constraint arises from the fact that for each terrain point examined there is some minimum cost which is the best that can be obtained at that terrain point (see minimum point on Figure 11). Since the minimum value of the objective function given by (11) would be zero due to the linear approximation of the costs, it is reasonable that the constraint

$$\alpha_k(c_k^{(n-1)})c_k \geq \alpha_k^{(o)}(c_k^{(o)})c_k^{(o)}$$

be imposed to provide the required "ground repulsion" factor at each terrain point.

<u>FINAL FORMULATION</u>. The linear programming model in its final form is to minimize

$$T^{(n)} = \sum_{k=1}^{N} \alpha_k(c_k^{(n-1)})c_k \quad ,$$

subject to

$$d^+c_{k-1} - d^s c_k + d^- c_{k+1} \leq \left[\frac{G^+ad^+d^sd^-}{2v^2}\right] - T_k \qquad k=1,2,\ldots,N$$

and

$$d^+c_{k-1} - d^s c_k + d^- c_{k+1} \geq \left[\frac{G^- ad^+d^sd^-}{2v^2}\right] - T_k \qquad k=1,2,\ldots,N$$

and

$$\alpha_k(c_k^{(n-1)})c_k \geq \alpha_k^{(o)}(c_k^{(o)})c_k^{(o)} \qquad k=1,2,\ldots,N$$

and $c_k \geq 0$ where T_k is given by (8).

With this formulation, if N is the number of terrain points after differences have been taken, then 3N constraints are needed to completely express the linear programming model.

Generation of all costs and loading of the appropriate matrices are contained in Appendix G. Appendix H is the FORTRAN coding for the Revised Simplex Algorithm used.

V. RESULTS AND DATA

GENERAL. The model was run on an IBM 360, Model 65 computer, using 512,000 core storage. When the model was originally formulated, it was intended that the linear program software, available with the above computer system, would be used, [31], [32]. However, the software available with the local system does not permit communication between the linear program and FORTRAN coding. With the objective function in the model, this communication was essential for obtaining a solution.

A Revised Simplex Algorithm was modified to handle a linear program of 75 rows and 100 columns. With three constraints required per terrain point, this meant that only 24 terrain points out of 404, in the case of terrain two, could be solved at one time. Lack of additional core space and the requirement for double precision accuracy prevented expanding the Revised Simplex Algorithm sufficiently.

It was decided to verify the model and show that the technique used was feasible on a reduced scale, and where possible extrapolate the results to larger numbers of terrain points.

TERRAIN AND TARGETS EXAMINED. A total of 48 computer runs were made using the model. Each run took more than 2.5 minutes and less than 3.5 minutes. Samples were taken from all combinations of the three variables shown in Table 1. The navigation target numbers of Table 1 are explained in Chapter III, and were chosen to provide a complete range of targets in terms of their degree of difficulty of detection as

TABLE 1

COMPUTER RUNS

Navigation Target Numbers	Terrain Points Terrain One	Terrain Points Terrain Two	Aircraft Speed in Knots
10	1- 24	1- 24	360
14	101-124	25- 48	500
25	283-306	73- 96	
		101-124	
		251-274	

navigational targets. The eight different terrains shown in Figures 12 - 19 were picked to represent difficult, moderate, and flat terrain as provided by the terrains available in terrains one and two; it should be noted that the vertical scale of these figures is twice the horizontal scale. A speed of 360 knots was selected since it is frequently an aircraft speed for the delivery of weapons and 500 knots was selected for its proximity to low altitude air defense penetration speeds. A positive acceleration (G^+) of 16.1 feet per second per second and a negative acceleration (G^-) of 32.2 feet per second per second were used for the flight path acceleration forces. These values were used as average values determined from 836 sample flights by eight type aircraft during Joint Task Force Two Test 1.0 [2], [3], in which pilots were instructed to follow the terrain as closely as they deemed possible.

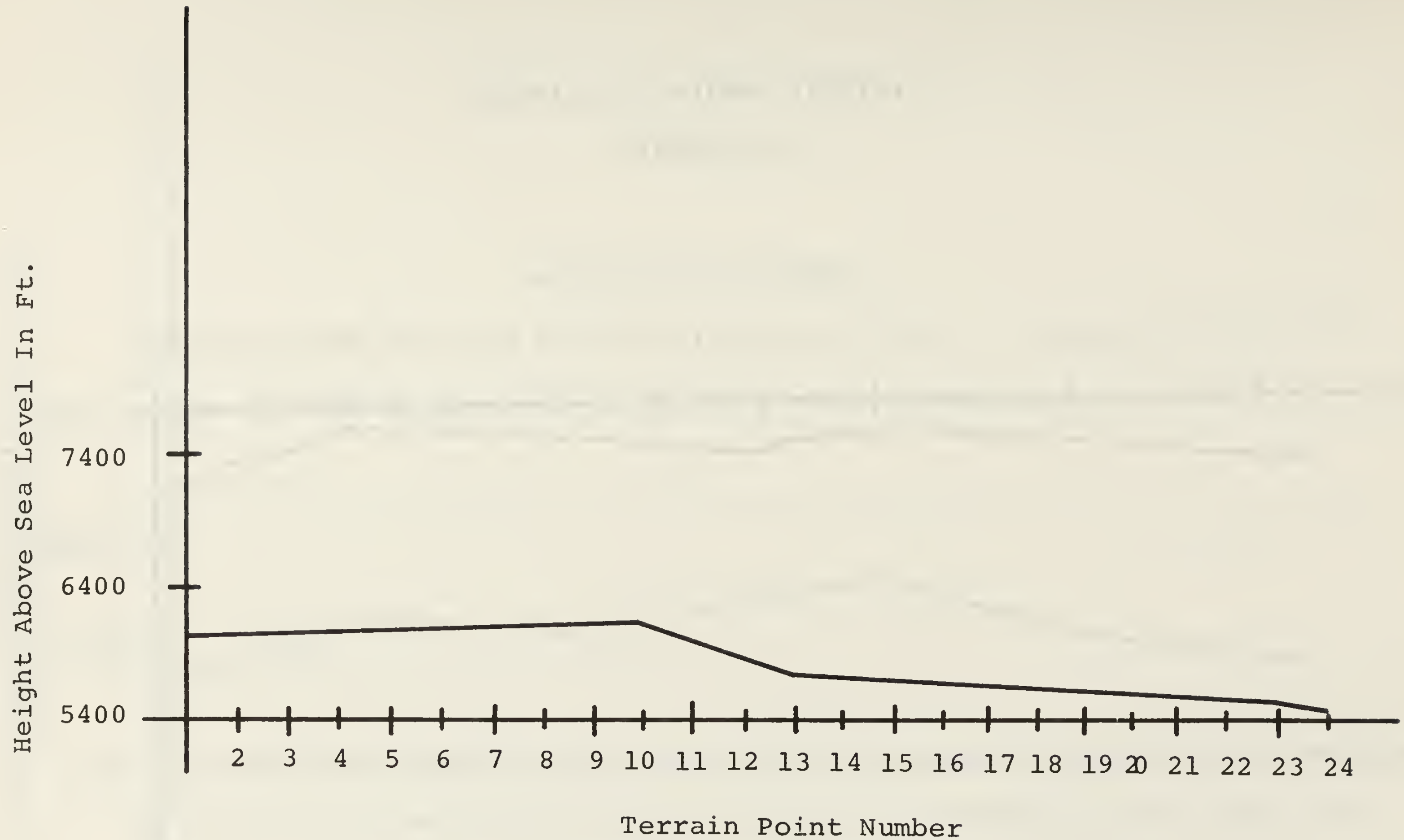


Figure 12

TERRAIN #1, POINTS 1-24

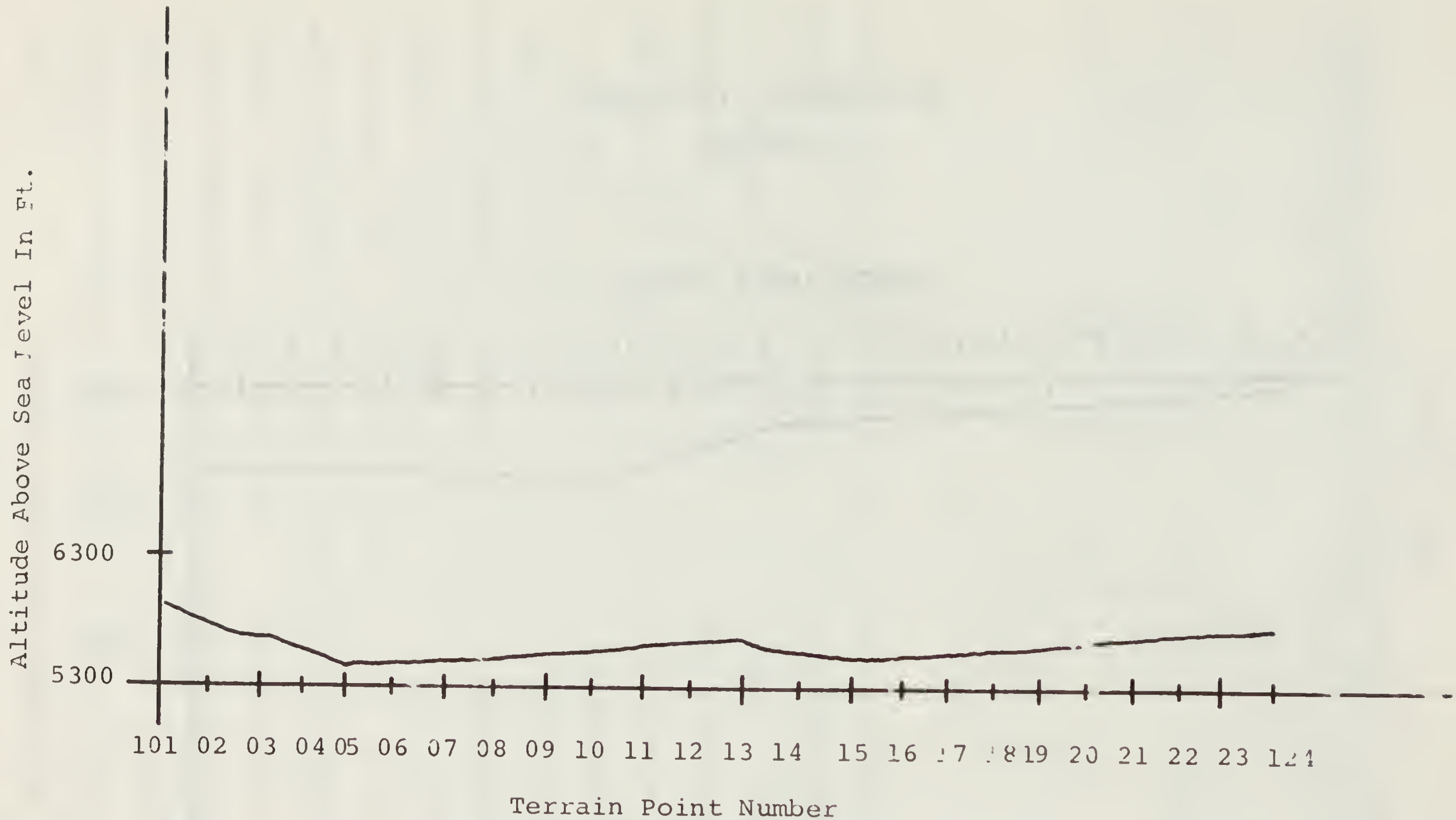


Figure 13

TERRAIN #1, POINTS 101-124

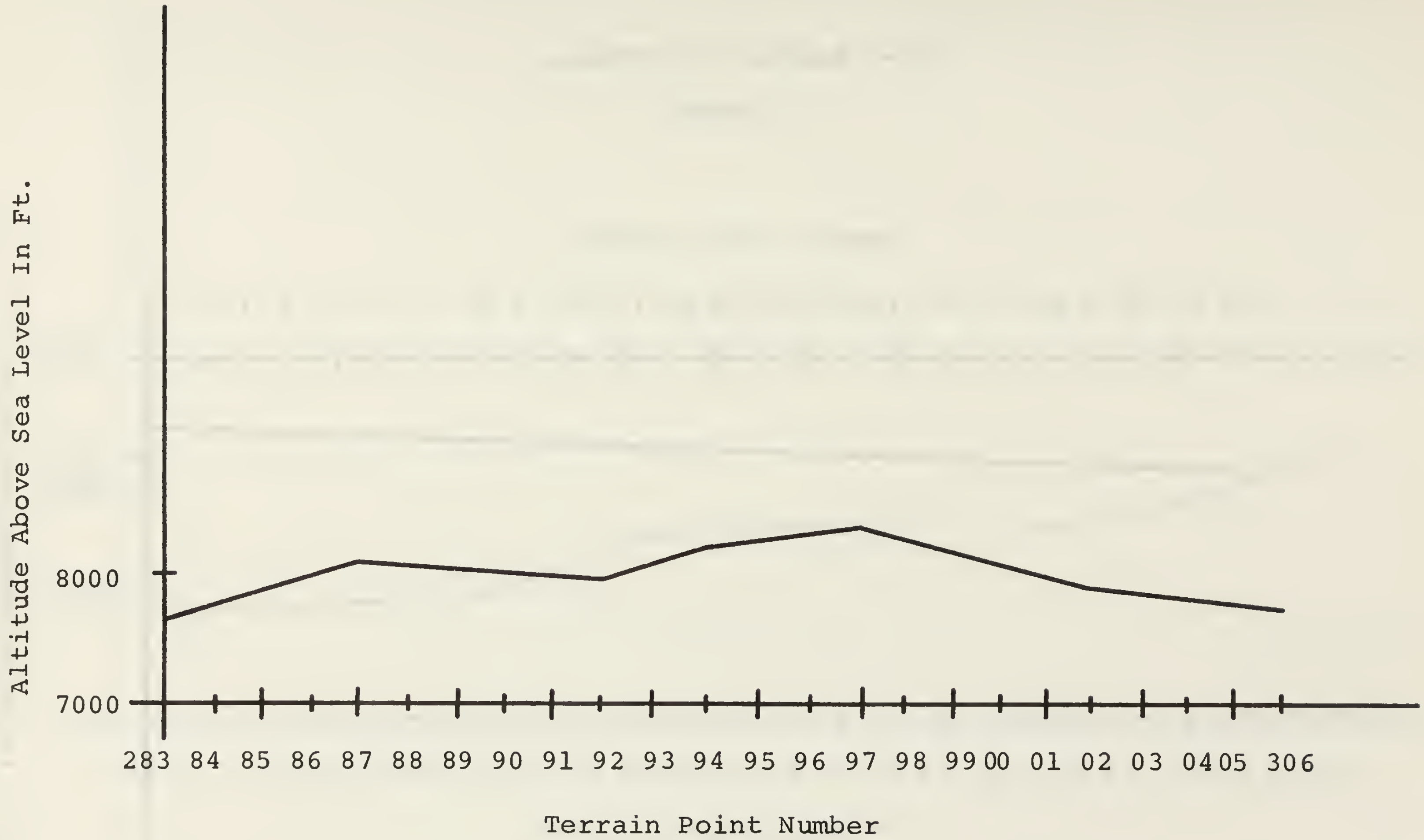


Figure 14

TERRAIN #1, POINTS 283-306

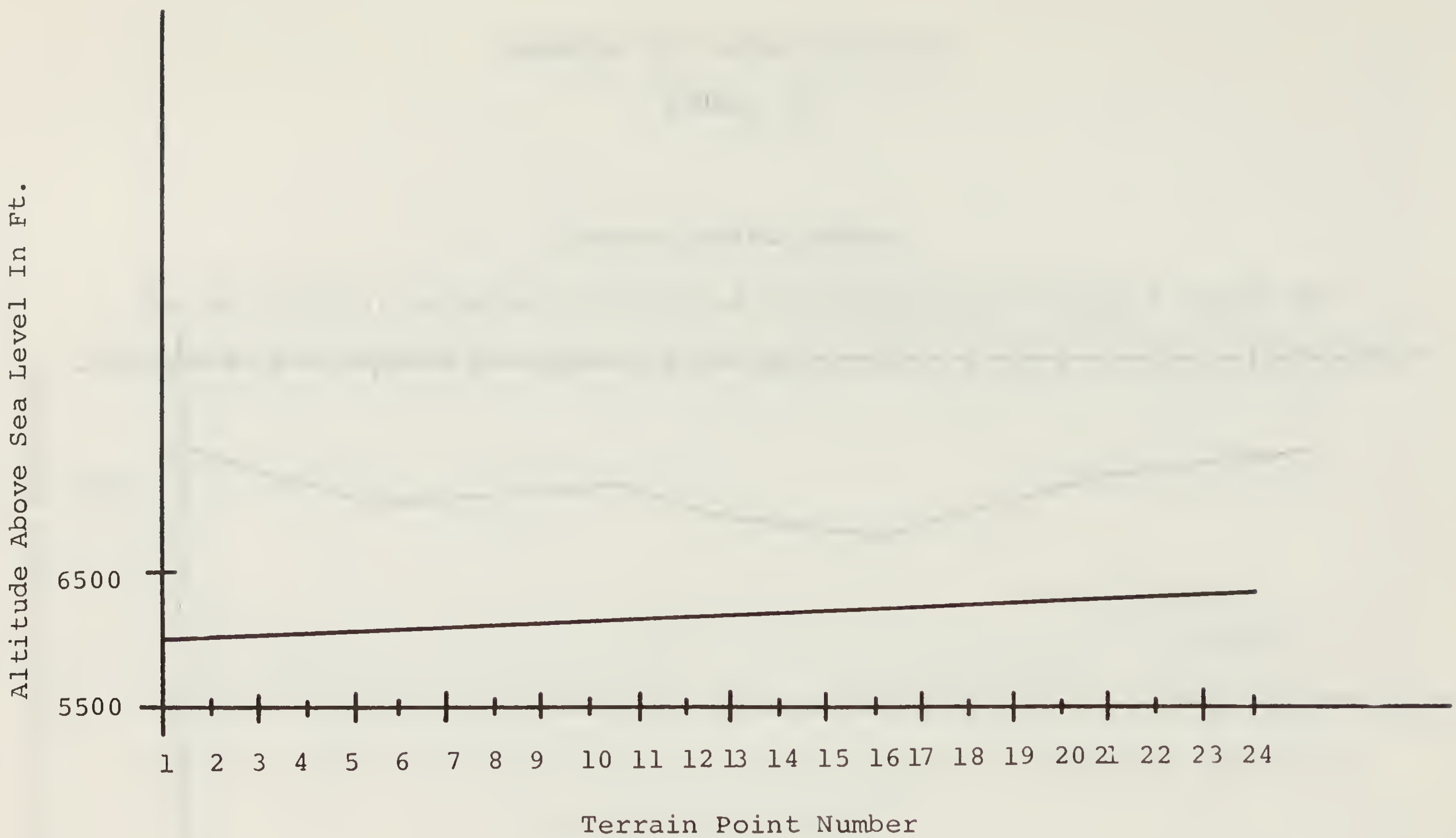


Figure 15

TERRAIN #2, POINTS 1-24

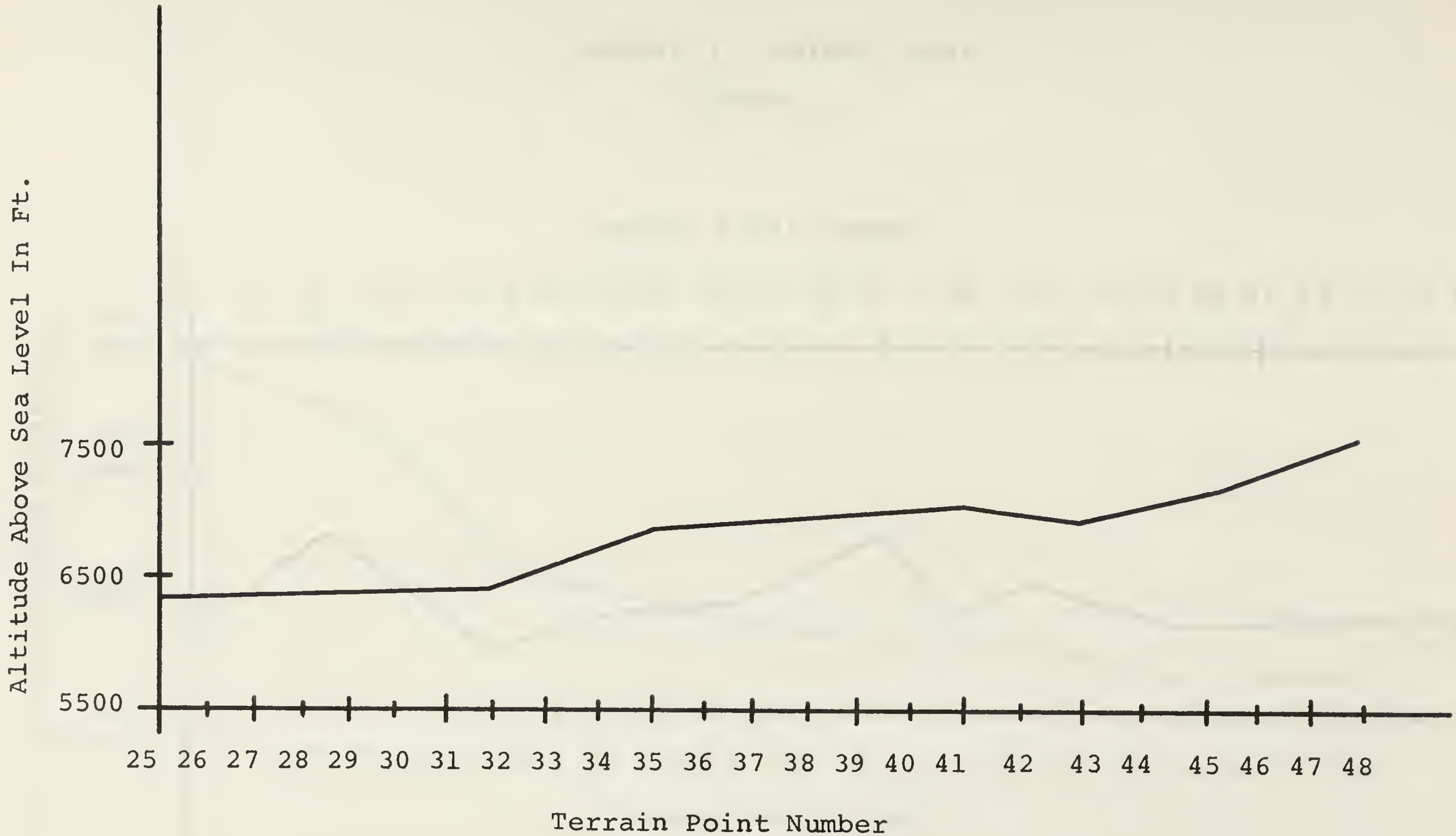


Figure 16

TERRAIN #2, 25-48

Figure 17

TERRAIN #2, POINTS 73-96

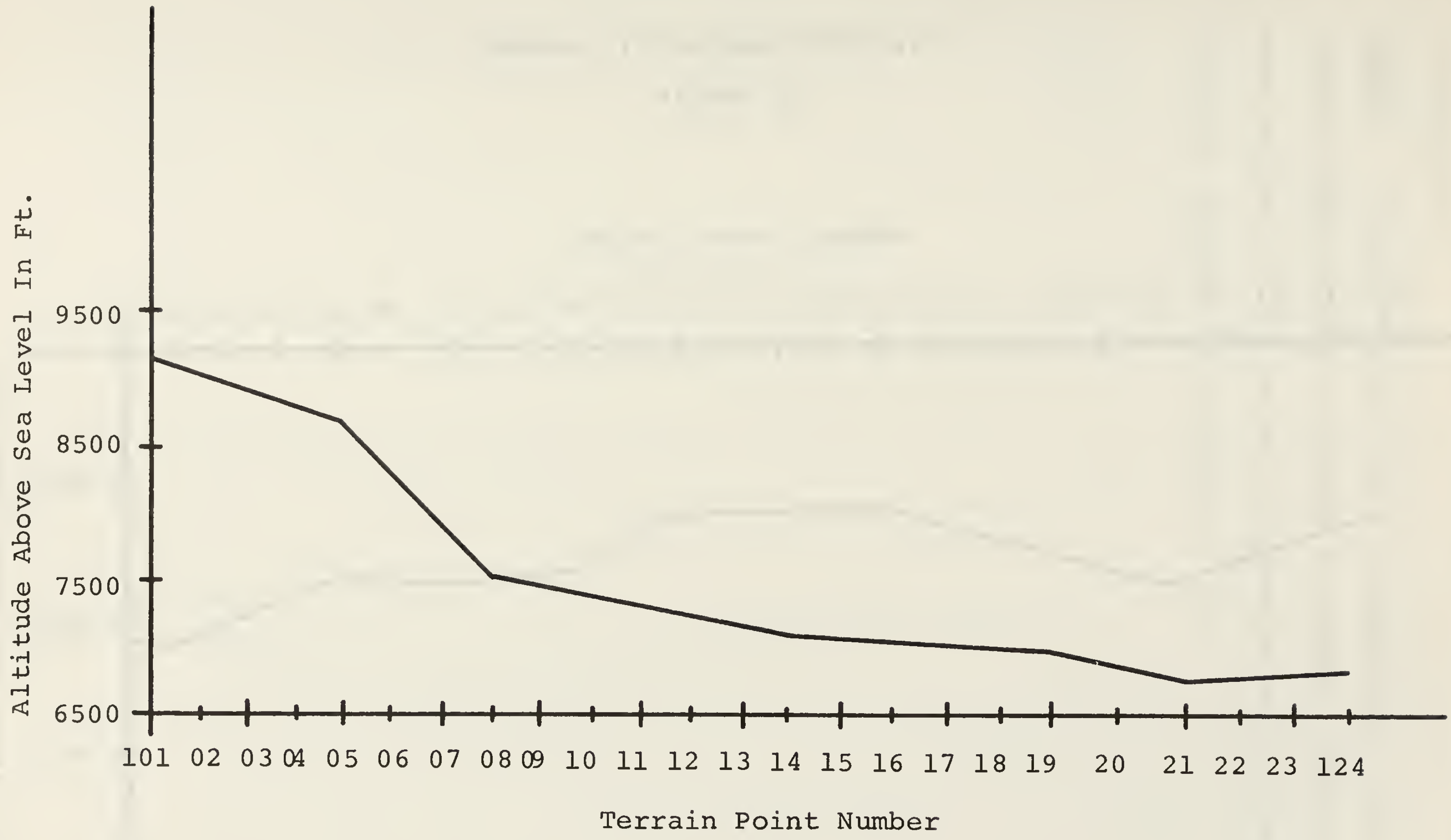


Figure 18

TERRAIN #2, POINTS 101-124

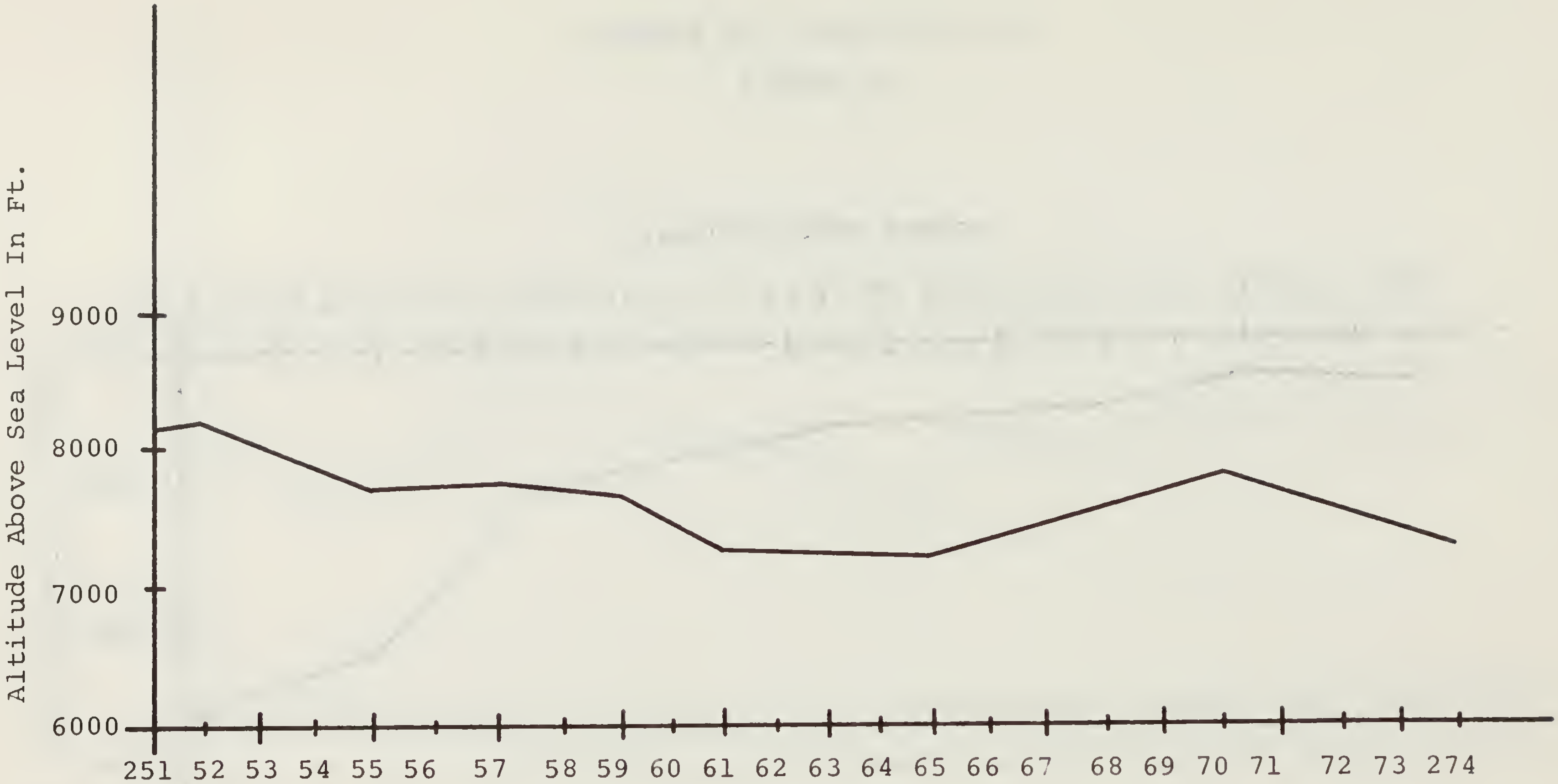


Figure 19

TERRAIN #2, POINTS 251-274

DATA. Data obtained from the 48 computer runs is contained in Appendix I.

RESULTS. Using selected data of Appendix I and plotting terrain clearances for optimal clearance without acceleration constraints and the terrain clearances with acceleration constraints, results in Figures 20 - 27.

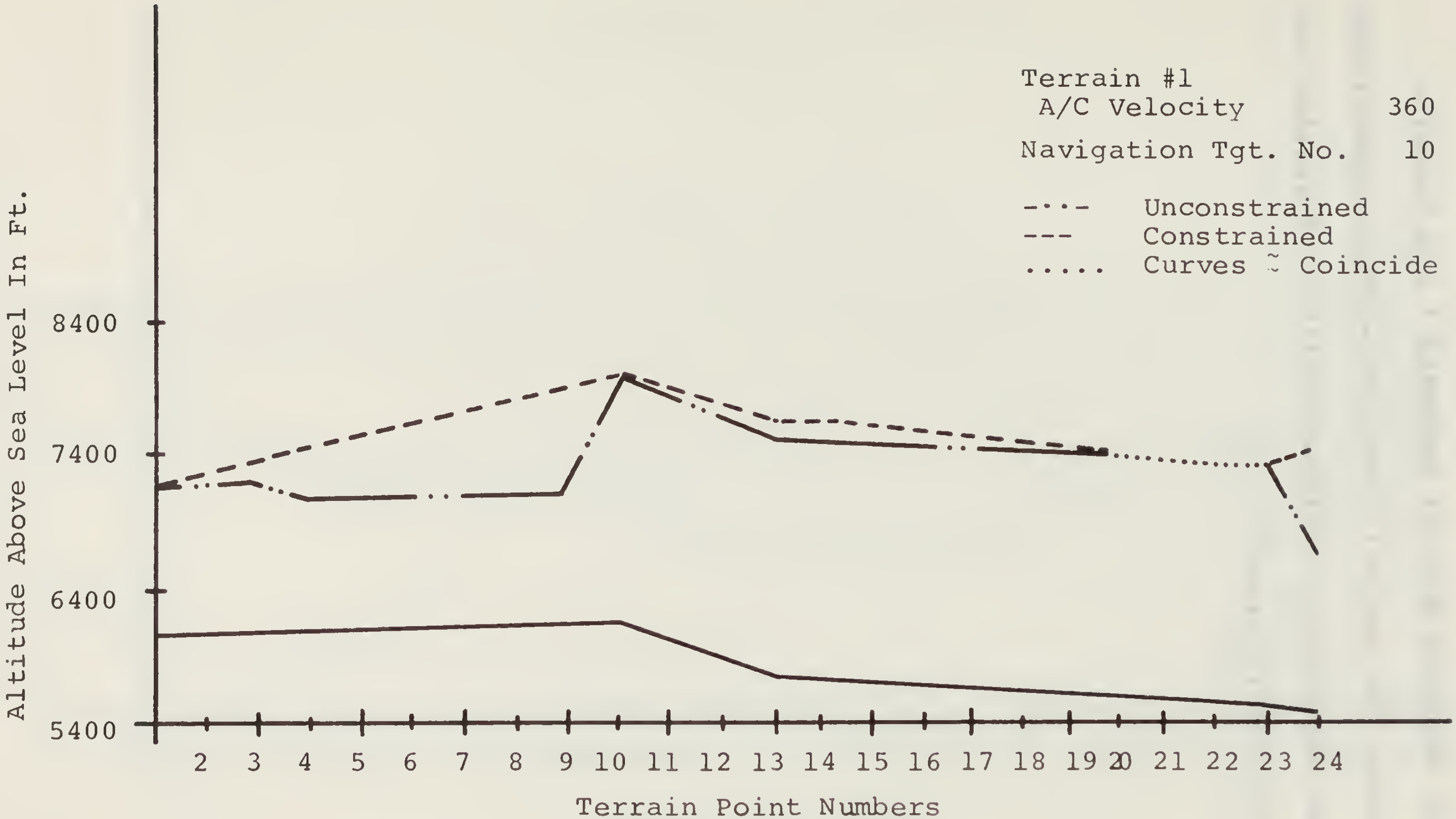


Figure 20

CONSTRAINED AND NON-CONSTRAINED FLIGHT PATHS

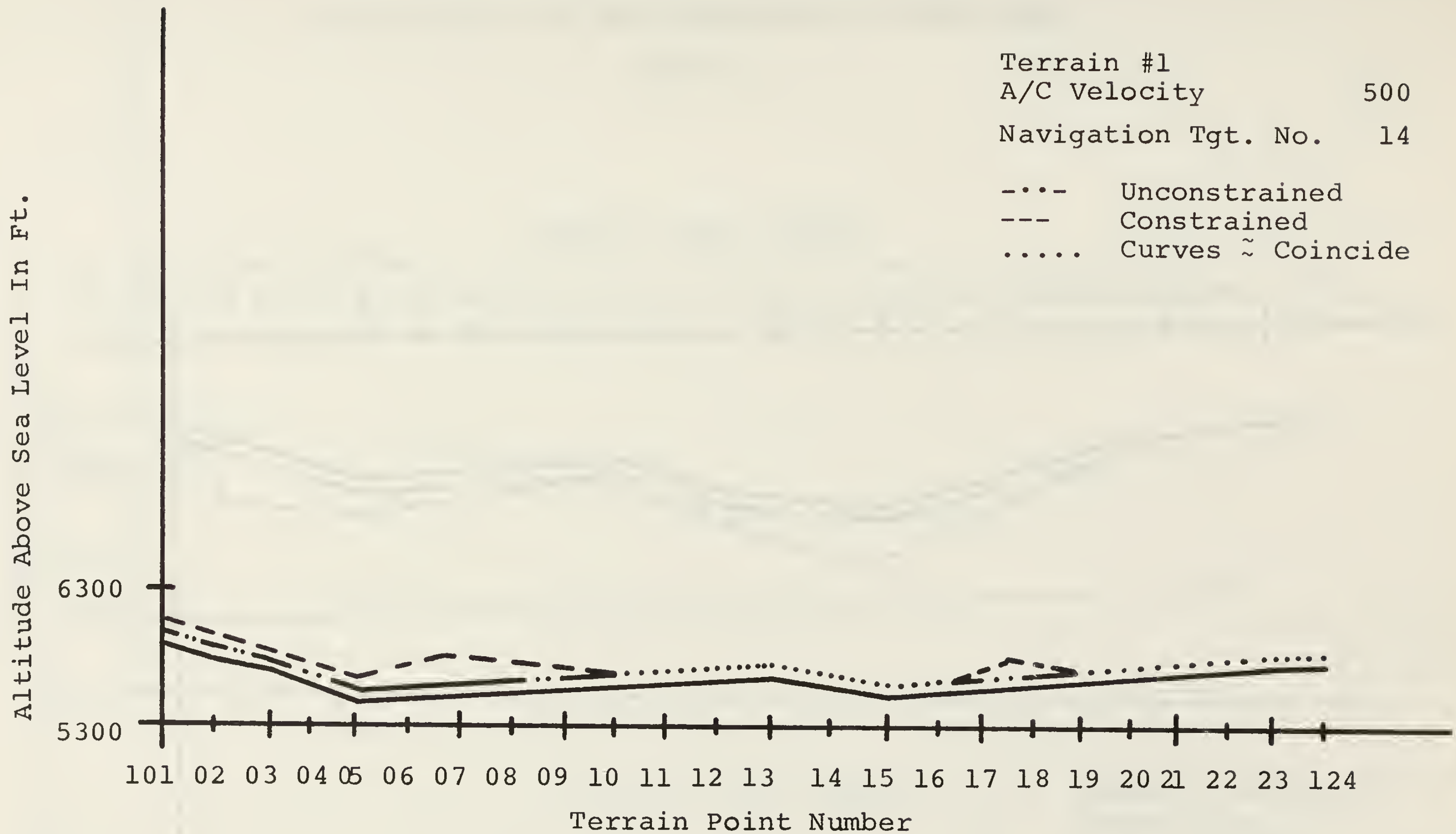


Figure 21

CONSTRAINED AND NON-CONSTRAINED FLIGHT PATHS

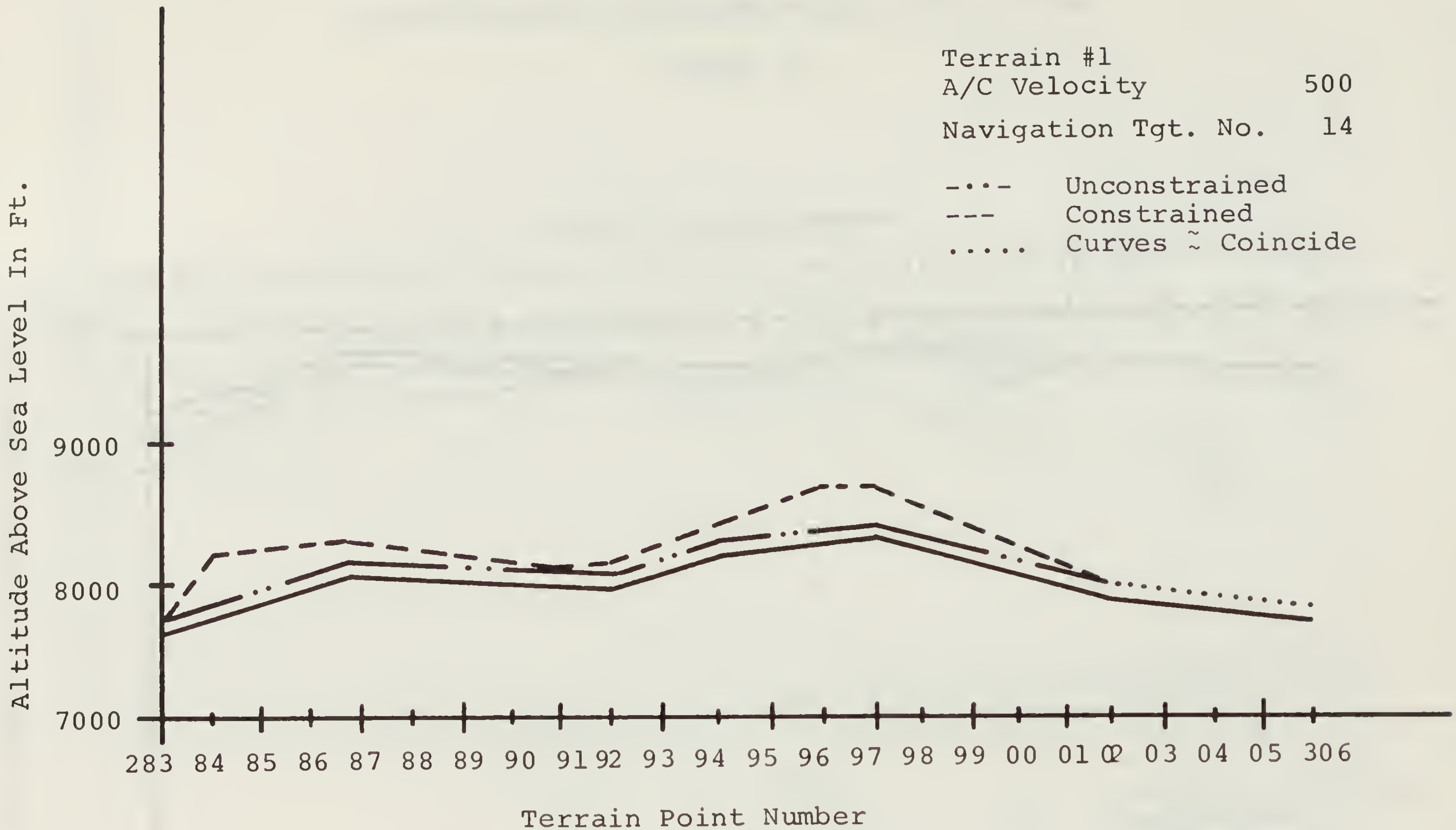


Figure 22

CONSTRAINED AND NON-CONSTRAINED FLIGHT PATHS

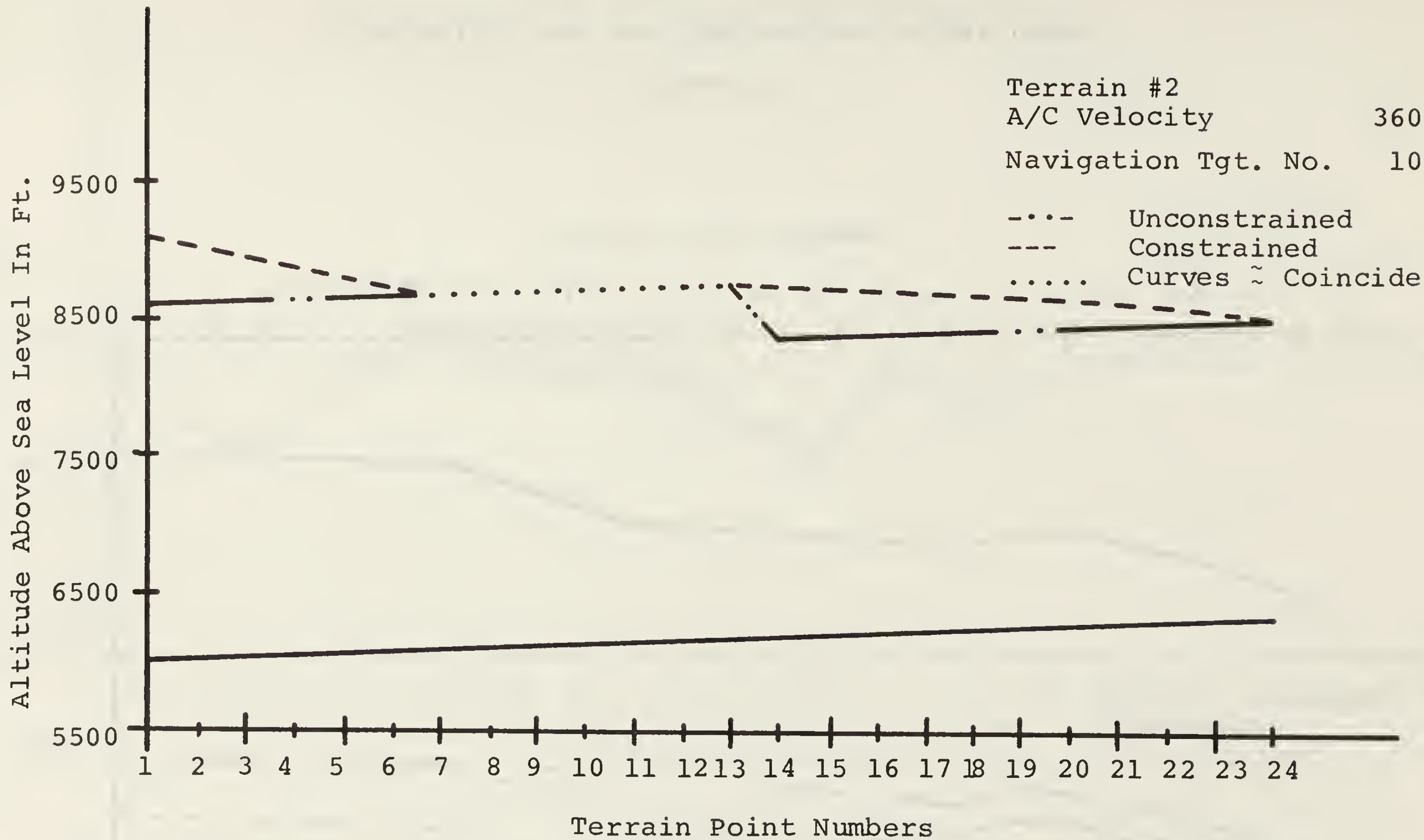


Figure 23

CONSTRAINED AND NON-CONSTRAINED FLIGHT PATHS

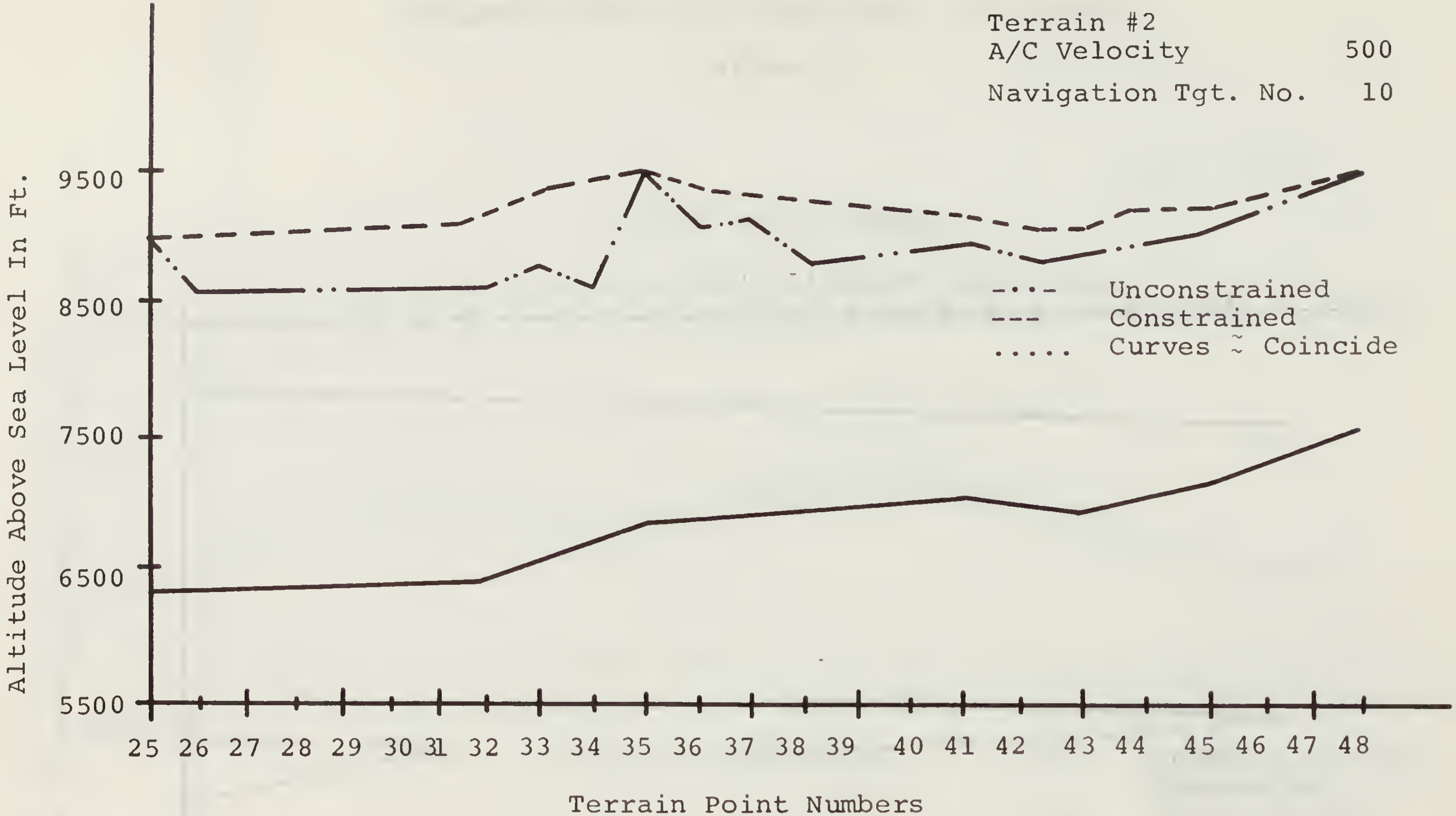


Figure 24

CONSTRAINED AND NON-CONSTRAINED FLIGHT PATHS

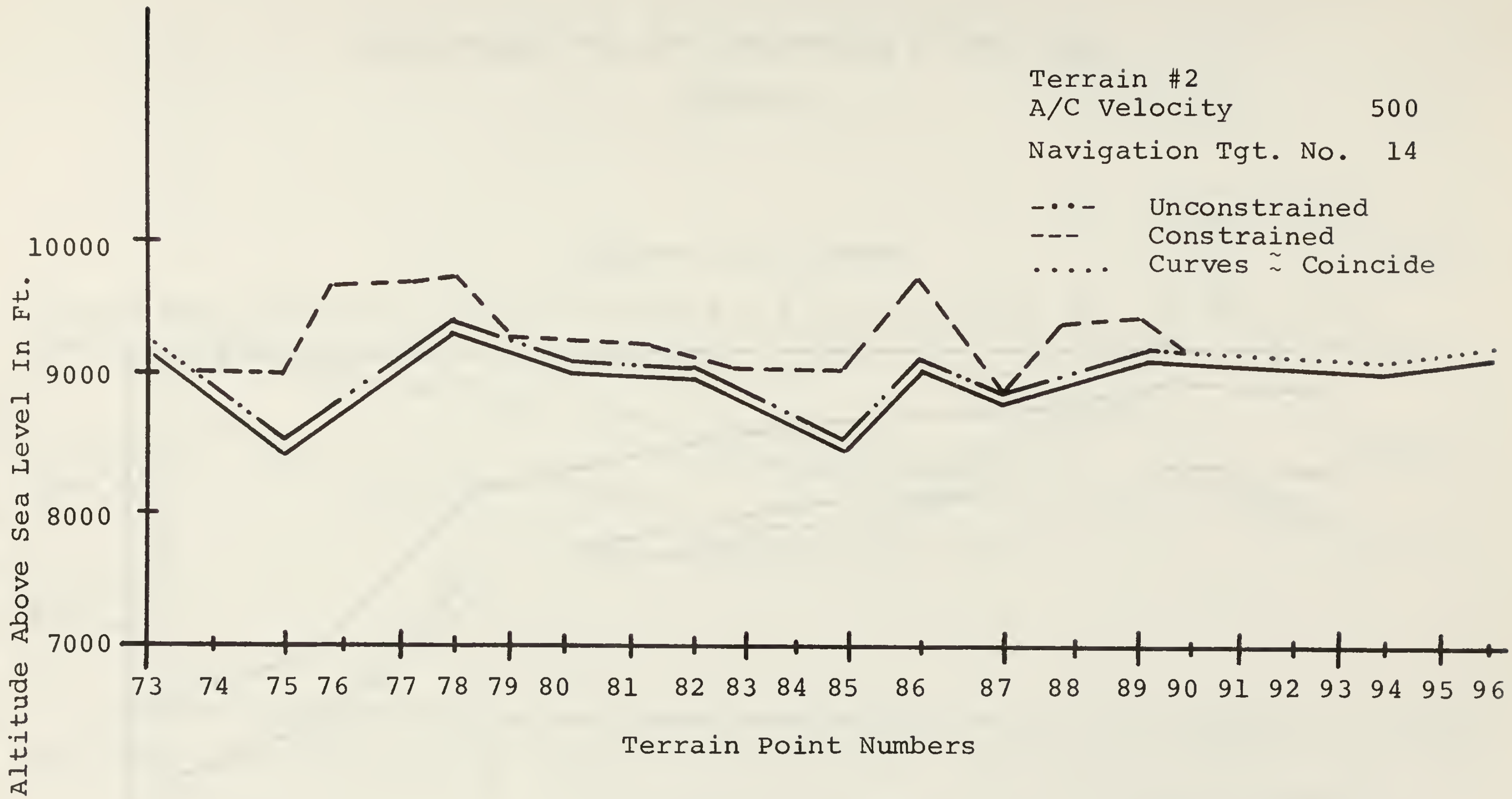


Figure 25

CONSTRAINED AND NON-CONSTRAINED FLIGHT PATHS

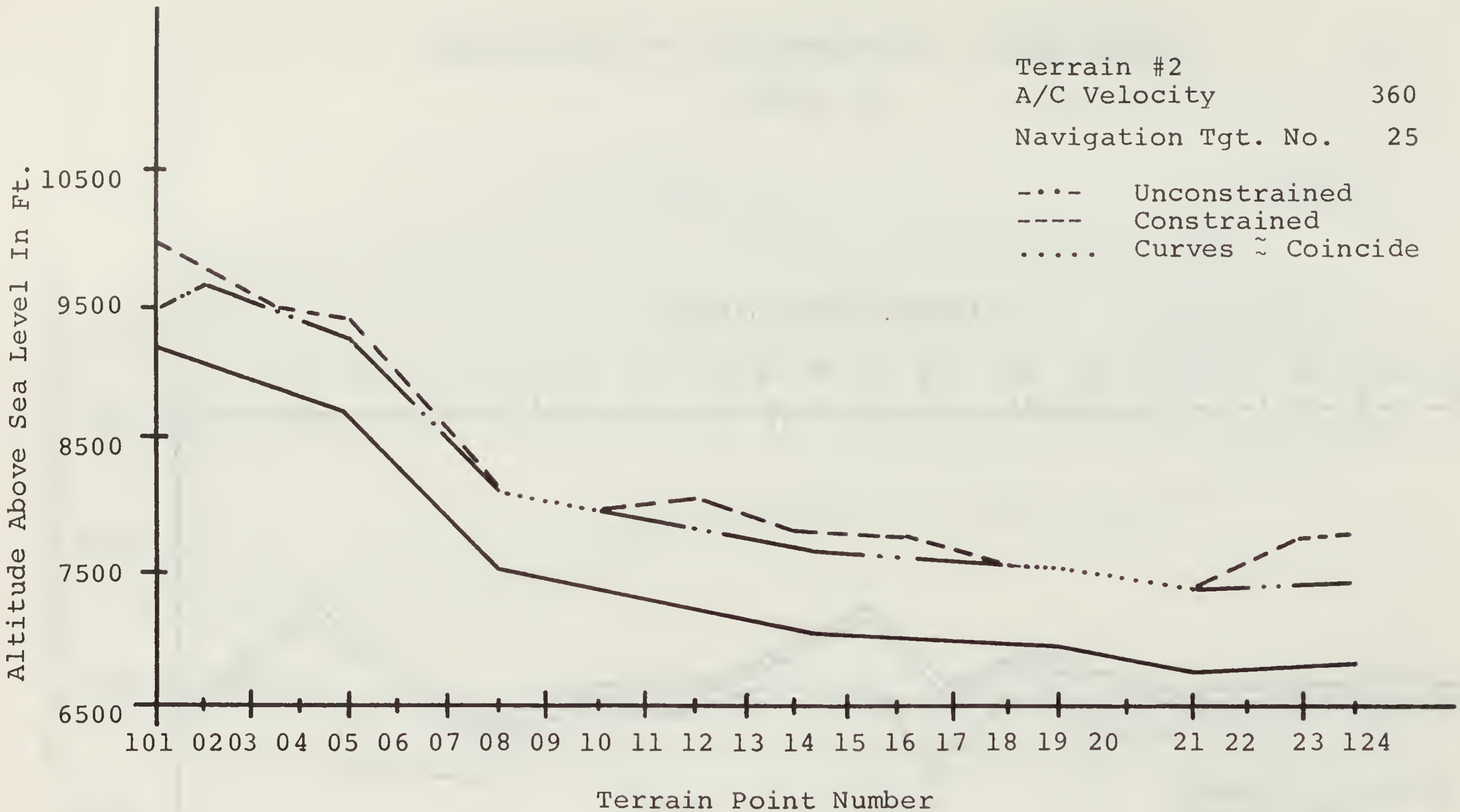


Figure 26

CONSTRAINED AND NON-CONSTRAINED FLIGHT PATHS

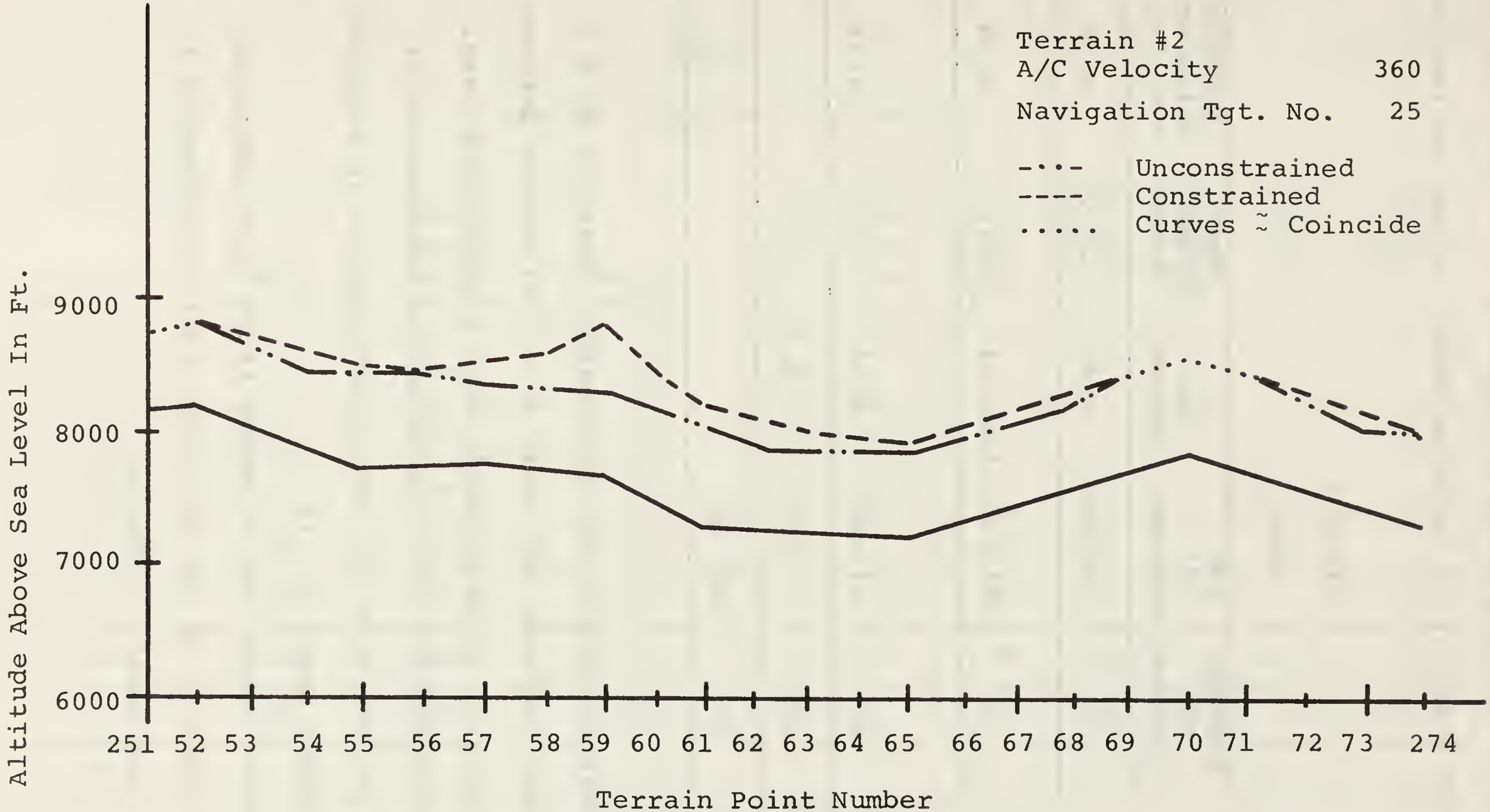


Figure 27

CONSTRAINED AND NON-CONSTRAINED FLIGHT PATHS

Using the cost data table of Appendix I as the input to a fixed factor Analysis of Variance Model, gives the results of Table 2.

TABLE 2

ANOVA

Source	Degrees of Freedom	Sum of Squares	Mean Square	Mean Square Error	F-Table Value at α = .001
Terrain	7	59.38	8.48	23.21	4.99
Navigation Target	2	3813.88	1906.94	5220.	9.34
Terrain Target Interaction	14	14.62	1.04	3.51	4.22
Error	24	8.76	.365		
Total	47	3896.64			

These results permit the hypotheses: There is no difference between terrains and there is no difference between navigation targets, to be rejected at a significance level of .1%. The hypothesis, that there are no interaction effects among the terrains and navigation targets is accepted at a significance level of .1%.

If A Duncan Range Test on Means After Experimentation [33] is then applied to the cost data table of Appendix I, the computations result in Table 3.

TABLE 3

DUNCAN RANGE TEST ON MEANS

Means	P	Table Statistic	Mean Square Error Correct.	Test Statistic	Diff Mean Test 8	Diff Mean Test 7	Diff Mean Test 6	Diff Mean Test 5	Diff Mean Test 4	Diff Mean Test 3	Diff Mean Test 2
14.59	8	3.34	.2465	.82	3.39						
15.27	7	3.31	.2465	.82	2.71	3.36					
15.99	6	3.28	.2465	.81	1.99	2.68	2.92				
16.63	5	3.22	.2465	.79	1.35	1.96	2.24	2.25			
16.84	4	3.15	.2465	.78	1.14	1.32	1.52	1.57	2.04		
17.51	3	3.07	.2465	.76	.44	1.1	.88	.85	1.36	1.4	
17.95	2	2.92	.2465	.62	.03	-	.67	.21	.64	.72	.66
17.98											

$$\text{Mean Square Error Correction} = \sqrt{\frac{\text{ANOVA MSE}}{\text{\# Points in Col.}}} = .2465$$

Test Statistic = Table Statistic x .2465

The data and calculations of Table 3 permit the terrain samples to be ranked from most difficult to least difficult as shown in Table 4.

TABLE 4

TERRAIN DIFFICULTY

Ranking by Difficulty	Terrain Number	Terrain Points
1	2	73- 96
	1	101-124
	1	283-306
2	2	251-274
	2	101-124
3	1	1- 24
4	2	25- 48
5	2	1- 24

Using the same procedure on the row means results in a ranking of 14, 25, 10 for the navigation target numbers.

VI. CONCLUSIONS

GENERAL. The problem of modeling a complex military function such as penetrating an air defense system is monumental. It is not a task which can be accomplished within a few weeks, but will take the combined efforts of several people for months.

The above facts are not startling, but are added only so that the reader might be aware that the more specific conclusions presented are applicable only within the context of the assumptions made and are not offered as an exact answer to any real world problem. Rather, the conclusions are used to suggest technique and encourage further work in this area.

SPECIFIC.

a. If Figures 20 through 27 are examined closely, it can be seen that the use of a parabola curve fit between three successive terrain points, as an approximation of aircraft flight with acceleration constraints, is reasonably valid. Only the solution shown in Figure 25 is questionable, in that the peak at point 259 is unexplained by the terrain or the no acceleration constraint curve. The only explanation which can be offered for this deviation is that the Revised Simplex Algorithm used does not solve for all solutions to the linear program, but only gives the first it obtains. Additional verification of this parabola fitting technique is given in [30]. All flight paths, as recommended by the linear program, are feasible and would appear to be more precise than an aviator could fly while terrain following. It is concluded that this technique is adequate for the purpose of determining a survivability index. The concept could be improved by building more "pilot anticipation" into the constraints. At present, the "pilot sees ahead and behind" only one terrain point. This lack of anticipation is evidenced by the sharp "maneuvers" shown in Figure 23, at points 76, 86 and 88.

b. In Test 1.0 conducted by Joint Task Force Two [2], the pilots were instructed to follow the terrain as closely and at as low an altitude as possible. Subject to these instructions the pilots, on the average, pulled one negative g and one-half positive g, while terrain following. Thus, when considering the same terrain, these two accelerations can be considered as upper and lower bounds on acceleration. To determine the sensitivity of the optimal cost to these accelerations, three additional computer runs were made on terrain two, points 73-96, speed 500 knots, navigation target 14 and acceleration pairs of (+.5, -.5), (+.25, -.5), and (+.01, -.01). For the first two pairs the optimal cost was reduced from an initial value of 25.89 to 25.52 and 24.72. However, when the acceleration forces were reduced to the last pair (essentially a level flight condition) the cost increased to 25.62, a figure which was still less than that due to the more severe acceleration restraints imposed by Test 1.0.

This would at least appear to be cursory evidence that it is not desirable to "follow terrain as closely as possible and at as low an altitude as possible", if the cost to the pilot-aircraft is to be minimized. Further work on the sensitivity of the optimal cost to these acceleration constraints might provide an optimal rule of thumb for briefing pilots on penetration missions, that is "Enter IP at an altitude of "Y" feet, maintain altitude between "Y_1" and "Y_2" feet and perform all maneuvers between "+g" and "-g"." This type of briefing gives the pilot maximum flexibility while flying his mission, but lets him know that if he exceeds the parameters given, he does so at the risk of decreasing his survivability.

c. With the exception of terrain two, points 1 to 24 and 25 to 48 which are exceptionally flat, all other terrain examined for an average navigational target, such as target 25, showed that the unconstrained optimal terrain clearance was between 300 and 700 feet. These figures are in conflict with recent testing procedures [34], [35], [36] for air defense penetration techniques. These tests have shown considerable concern for altitudes less than these figures.

It would appear that operational testing with penetrations being made at clearances in this new range are desirable for comparisons with previous or future low altitude results.

d. The assumption of a uniform distribution of radar sites (missile batteries) is unrealistic. Terrain analysis to select "most likely" radar sites must be incorporated into the model. Then radar costs for terrain points and altitudes

used in tests involving an aircraft-pilot combination, and when the pilot is task loaded with a mission and a point to point navigation requirement.

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APPENDIX A

TERRAIN DATA SETS

	Terrain Number 1		Terrain Number 2	
Point No.	X Coordinate	Y Coordinate	X Coordinate	Y Coordinate
1	-99999984.	6066.	-99999984.	6000.
2	0.0	6066	0.0	6000.
3	6706.	6123.	21800.	6410.
4	9078.	5757.	24200.	6840.
5	19087.	5426.	28800.	7010.
6	30000.	5258.	30600.	6920.
7	48854.	5310.	32500.	7150.
8	52714.	5556.	34700.	7550.
9	56446.	5978.	36700.	6960.
10	58837.	6097.	40500.	7080.
11	60886.	6075.	41200.	7290.
12	62200.	5890.	43900.	7400.
13	65245.	6048.	44800.	7140.
14	68374.	5819.	46300.	7420.
15	72325.	6374.	48600.	7550.
16	78000.	5450.	49300.	7840.
17	84023.	5630.	50400.	7680.
18	85762.	5504.	52800.	8370.
19	92782.	5793.	53700.	9160.
20	97683.	6096.	55400.	9180.
21	98753.	6342.	57400.	8450.
22	100321.	6494.	59900.	9290.
23	101633.	6389.	61500.	9050.
24	105080.	6617.	63400.	8940.
25	106600.	6430.	65600.	8440.
26	115811.	6164.	66700.	9010.
27	118118.	6461.	67900.	8780.
28	120900.	6230.	69900.	9070.
29	127540.	6353.	73400.	9030.
30	132802.	6980.	76700.	9200.
31	134531.	7806.	79000.	9150.
32	137891.	6821.	81800.	8680.
33	142800.	6610.	84000.	7520.
34	147709.	6649.	89100.	7030.
35	149151.	6880.	92200.	6960.
36	150589.	6685.	94200.	6770.
37	158059.	7098.	96500.	6820.
38	159925.	7826.	101900.	6700.
39	161609.	7328.	104600.	7070.
40	163974.	7618.	106000.	6930.
41	165000.	7400.	108200.	7200.
42	167890.	7628.	110200.	7100.
43	172800.	7300.	112100.	7200
44	178700.	6750.	113600.	6820.
45	182901.	7403.	116300.	6870.

Terrain Data Sets (Cont'd)

Point No.	Terrain Number 1 X Coordinate	Terrain Number 1 Y Coordinate	Terrain Number 2 X Coordinate	Terrain Number 2 Y Coordinate
46	184000.	7180.	118200.	6820.
47	186736.	7342.	120000.	6510.
48	189200.	6700.	133800.	6250.
49	196703.	7114.	134900.	6390.
50	200620.	7202.	138700.	6450.
51	202852.	7150.	143600.	7050.
52	205523.	7539.	145600.	6960.
53	206652.	7309.	148500.	6980.
54	210233.	7883.	151900.	6950.
55	212183.	7950.	154400.	7660.
56	214161.	7324.	156000.	7130.
57	219152.	8045.	158400.	7090.
58	222800.	7940.	159600.	7530.
59	224400.	8160.	161400.	7280.
60	226653.	8312.	162900.	7270.
61	230139.	7868.	164000.	7730.
62	242244.	7244.	166000.	6860.
63	244497.	7423.	169800.	6640.
64	246100.	7130.	171000.	6830.
65	251296.	7068.	174000.	6870.
66	257179.	6792.	176200.	7140.
67	259793.	6919.	178500.	7530.
68	262358.	6750.	179800.	7580.
69	264328.	7021.	181900.	7530.
70	265230.	7460.	182800.	7730.
71	265927.	7496.	184500.	7730.
72	268257.	7028.	185200.	7970.
73	275105.	6983.	186900.	7380.
74	279714.	7203.	189100.	7890.
75	281700.	7300.	191000.	7300.
76	285209.	8045.	192200.	7690.
77	286963.	8012.	194500.	8210.
78	288463.	7770.	195400.	7850.
79	290001.	7265.	199800.	8200.
80	291700.	7162.	202200.	7720.
81	294290.	7363.	204000.	7740.
82	295721.	7773.	205800.	7650.
83	297609.	7534.	207200.	7280.
84	300001.	7600.	210200.	7210.
85	302107.	7627.	211800.	7470.
86	999999744.	7627.	214300.	7820.
87			217700.	7270.
88			221900.	7180.
89			224100.	6890.
90			226400.	7250.
91			228700.	7210.

Terrain Number 2

Point No.	X Coordinate	Y Coordinate
92	233100.	7590.
93	237600.	7080.
94	239900.	7340.
95	243300.	7190.
96	246900.	8260.
97	250000.	7390.
98	252900.	8070.
99	255000.	8150.
100	258500.	7720.
101	260400.	7160.
102	262000.	7570.
103	267900.	6020.
104	269300.	6000.
105	272200.	6930.
106	274900.	6830.
107	276800.	6610.
108	278800.	7050.
109	280300.	6960.
110	281900.	7510.
111	283300.	7680.
112	285100.	6840.
113	289400.	8000.
114	293900.	7450.
115	294900.	7670.
116	298500.	7130.
117	301500.	7290.
118	305400.	6900.
119	317213.	6723.
120	9999999.	6723.

APPENDIX B

Radar Detection Model

```
      IMPLICIT REAL*8(A-H,O-Z),INTEGER*4(I-N)
      DIMENSION  TX(120),TY(120),TB(120),TP(120),AH( 30),S(
     1120),VR(30),GR(120),TC(30),PHI(30),DIFF(30),YYY(30),
     2TTX(999),TTY(999),DPLUS(999),DMIN(999),DS(999),T(999),
     3CO(999),CU(999),CL(999),EXPTI(30),C2(120),COST(999),
     4TS(120),PD(30),ALPHA(24,30),TLPHA(24,30)
      COMMON A(75,100),B(75),X(75),P(75),Y(75),E(75,75),Z(10
     10),DDT(100),ZJ(100),PINV(75,75),XI(75),TOL(10),ERR(10
     2),RUN(8),ZZ(3),TERR(8),KB(100),JH(75),INFIX(10),KCUT(1
     30),IOFIX(16)
      READ 2000,NT,NAP,K1,V,EPSI,GPOS,GNEG,MIST
 2000 FORMAT(3I4,5F10.4)
      READ 2001,((TX(I),TY(I)),I=1,NT)
 2001 FORMAT( 2F10.0)
      READ 9965,(PD(I),I=1,NAP)
 9965 FORMAT(F10.4)
      NTT=NT-1
 9944 DO 9943 I=1,100
      DO 9943 J=1,50
 9943 A(I,J)=0.
      DO 2002 J=2,NTT
      TS(J)=(TY(J)-TY(J-1))/(TX(J)-TX(J-1))
      TP(J)=1.+TS(J)**2
      TB(J)=TY(J)-TS(J)*TX(J)
 2002 CONTINUE
      TT=0.
      NTP=1
      DO 2 I=3,NTT
      NTP=NTP+1
      GR(NTP)=DSQRT((TX(I)-TX(I-1))**2+(TY(I)-TY(I-1))**2)
      TT=TT+GR(NTP)
    2 CONTINUE
      DO 15 K=2,NTT
      DO 50 I=1,NAP
      VR(I)=0.
      BB=I
      AH(I)=TY(K)+BB*100.
      IF(K.EQ.NTT) GO TO 555
      L=K+1
      DO 5 J=L,NTT
   22 S(J)=(TY(J)-AH(I))/(TX(J)-TX(K))
    5 CONTINUE
  555 IF(K.EQ.2) GO TO 557
      ITP=K-1
      DO 556 J=2,ITP
```

```
 24  S(J)=(A  (I)-TY(J))/(TX(K)-  (I))
555  CONTINUE
557  IF(K.EQ.2) GO TO 691
     IF(K.EQ.NTT) GO TO 6
     IF(K.NE.2.AND.K.NE.NTT) VR(I)  R( )+ R(K-1)
     GO TO 9
691  VR(I)=GR(K)
  9  GS=10.E20
     DO 559 N=L,NTT
101  IF(S(N).GT.GS) GO TO 13
     IF(N.NE.L) GO TO 559
 21  GS=S(N)
     GO TO 559
 13  X1=(TY(N)-TS(N)*TX(N)+GS*TX(K)-AH(I))/(GS-TS(N))
     Y1=TY(N)+TS(N)*X1-TS(N)*TX(N)
     GS=S(N)
     R=DSQRT((TY(N)-Y1)**2+(TX(N)-X1)**2)
     VR(I)=VR(I)+R
559  CONTINUE
     IF(K.EQ.2) GO TO 66
     IF(K.NE.NTT) GO TO 558
692  VR(I)=GR(NTT-1)
558  GLS=-10.E20
     ITB=K-2
     DO 560 J=1,ITB
     M=K-J
 40  IF(S(M).LT.GLS) GO TO 55
     IF(J.NE.1) GO TO 560
 52  GLS=S(M)
     GO TO 560
 55  X1=(TY(M)-TS(M+1)*TX(M)-AH(I)+GLS*TX(K))/(GLS-TS(M+1))
     Y1=TY(M)+TS(M+1)*(X1-TX(M))
     GLS=S(M)
     R=DSQRT((TY(M)-Y1)**2+(X1-TX(M))**2)
     VR(I)=VR(I)+R
560  CONTINUE
 66  FHI(I)=VR(I)/TT
 50  CONTINUE
 74  DO 90 JJ=1,NAP
     TC(JJ)=AH(JJ)-TY(K)
 90  CONTINUE
C    LINEAR LEAST SQUARES FIT
     YX=0.
     AN=NAP
     SUMX=0.
```

```
      SUMY=C.
      SUMXZ=0.
      DO 333 I=1,NAP
      YX=YX+TC(I)*PHI(I)
      SUMX=SUMX+TC(I)
      SUMY=SUMY+PHI(I)
      SUMXZ=SUMXZ+TC(I)**2
  333 CONTINUE
      C2(K)=(AN*YX-SUMX*SUMY)/(AN*SUMXZ-SUMX**2)
      C1=(SUMY-C2(K)*SUMX)/AN
      DO 334 I=1,NAP
      YYY(I)=C2(K)*TC(I)+C1
  334 CONTINUE
      DO 789 IL=1,NAP
      DIFF(IL)=(PHI(IL)-YYY(IL))*TT
      IF(DIFF(IL).EQ.0.) GO TO 1777
      EXPTI(IL)=DIFF(IL)/V
      IF(EXPTI(IL).GT.MIST)GO TO 1000
      GO TO 789
 1000 PRINT 1001,IL,K,EXPTI(IL)
 1001 FORMAT(2X,'LINEAR FIT BAD AT ALTITUDE',I5,
     1'TERRAIN POINT',I4,'EXPOSED TIME EQUALS',F12.4)
 1777 EXPTI(IL)=0.
  789 CONTINUE
      PRINT 1073
 1073 FORMAT(1H1)
      PRINT 1002, K,TX(K),TY(K)
 1002 FORMAT(2X,'TERRAIN POINT',(I4),15X,'X COORDINATE',F10.
     10,15X,'Y COORDINATE',F10.0,//)
      PRINT 1074
 1074 FORMAT(34X,'PHI',37X,'YYY',32X,'EXPOSED TIME',//)
      PRINT 1003,(PHI(I),YYY(I),EXPTI(I),I=1,NAP)
 1003 FORMAT(20X,F20.7,20X,F20.7,20X,F20.7)
   15 CONTINUE
```

APPENDIX C

FORTRAN GLOSSARY - In Order of Occurrence

TX(I)	X COORDINATE OF i^{th} TERRAIN POINT.
TY(I)	Y COORDINATE OF i^{th} TERRAIN POINT.
TB(I)	Y INTERCEPT OF i^{th} TERRAIN PIECE.
TP(I)	ONE PLUS THE SLOPE OF THE i^{th} TERRAIN PIECE SQUARED.
AH(I)	ALTITUDE OF AIRCRAFT ABOVE SEA LEVEL FOR i^{th} INCREMENT.
S(I)	SLOPE OF THE LINE OF SIGHT FROM AIRCRAFT TO i^{th} TERRAIN POINT.
VR(I)	TERRAIN VISIBLE AT i^{th} ALTITUDE.
GR(I)	LENGTH OF THE i^{th} PIECE OF TERRAIN.
TC(I)	TERRAIN CLEARANCE AT THE i^{th} INCREMENT.
PHI(I)	RADAR PROBABILITY OF DETECTION FOR THE i^{th} ALTITUDE INCREMENT.
DIFF(I)	THE INCREMENTAL LENGTH USED TO BREAK UP THE DISTANCE BETWEEN TWO MAJOR TERRAIN POINTS, WHEN TAKING DIFFERENCES.
YYY(I)	RADAR PROBABILITY OF DETECTION FOR LINEAR FIT TO PHI(I) FOR THE i^{th} ALTITUDE INCREMENT.
TTX(I)	X COORDINATE OF i^{th} TERRAIN POINT AFTER DIFFERENCING.
TTY(I)	Y COORDINATE OF i^{th} TERRAIN POINT AFTER DIFFERENCING.
DPLUS(I), DMIN(I), DS(I)	USED IN DIFFERENCING, SEE DEFINITION OF d+, d-, d^s IN CHAPTER IV.
T(I)	SEE DEFINITION CHAPTER IV.
CO(I)	DS(I).

CU(I)	POSITIVE ACCELERATION CONSTRAINT AT i^{th} TERRAIN POINT.
CL(I)	NEGATIVE ACCELERATION CONSTRAINT AT i^{th} TERRAIN POINT.
EXPTI(I)	EXPECTED TIME EXPOSED AT i^{th} ALTITUDE INCREMENT DUE TO USE OF LINEAR FIT TO RADAR PROBABILITY OF DETECTION.
C2(I)	SLOPE OF LINEAR FIT TO RADAR PROBABILITY OF DETECTION CURVE AT i^{th} MAJOR TERRAIN POINT.
COST(I)	SLOPE OF LINEAR FIT TO RADAR PROBABILITY OF DETECTION CURVE AT i^{th} TERRAIN POINT.
TS(I)	SLOPE OF THE i^{th} TERRAIN PIECE.
PD(I)	PROBABILITY OF DETECTION OF NAVIGATION TARGET AT i^{th} ALTITUDE INCREMENT. INPUT FROM NAVIGATION MODEL.
ALPHA(I,J)	COST MATRIX FOR COST PER FOOT OF TERRAIN CLEARANCE FOR BOTH NAVIGATION AND RADAR AT i^{th} TERRAIN POINT AND j^{th} ALTITUDE INCREMENT.
TLPHA(I,J)	SAME AS ALPHA(I,J) EXCEPT COST IS PER 100 FEET OF TERRAIN CLEARANCE.
A(I,J)	MATRIX FOR LINEAR PROGRAM. ROW ONE IS COST ROW, SUCCEEDING ROWS ARE FOR CONSTRAINTS.
B(I)	CONSTRAINT VALUE FOR i^{th} ROW OF A(I,J).
NT	NUMBER OF MAJOR TERRAIN POINTS. MAXIMUM IS NOW 120.
NAP	NUMBER OF ALTITUDE INCREMENTS. MAXIMUM IS NOW 30, 100 FOOT INCREMENTS.
K1	ONE LESS THAN THE NUMBER OF THE TERRAIN POINT ON WHICH THE LINEAR PROGRAM WILL BASE THE MINIMAL COST.
V	VELOCITY OF THE AIRCRAFT IN FEET PER SECOND.
EPSI	EPSILON TO WHICH LINEAR PROGRAM COST WILL CONVERGE.

GPOS	POSITIVE G'S PILOT WILL CAUSE AIRPLANE TO EXPERIENCE.
GNEG	NEGATIVE G'S PILOT WILL CAUSE AIRPLANE TO EXPERIENCE.
MIST	MISSILE TIME REQUIRED TO ACQUIRE, IDENTIFY, TRACK, LAUNCH AND INTERCEPT. USED IN TEST FOR EXPOSURE TIME.
GS	GREATEST SLOPE, USED IN DETERMINING IF A PIECE OF TERRAIN IS VISIBLE WHEN LOOKING FORWARD.
GLS	SMALLEST SLOPE, USED IN DETERMINING IF A PIECE OF TERRAIN IS VISIBLE WHEN LOOKING BACKWARD.
PROG	LINEAR PROGRAM.
ZJ(I)	THE OPTIMAL COST OF THE i^{th} LINEAR PROGRAM SOLUTION. $T^{(n)}$ IN FORMULATION CHAPTER IV.

APPENDIX D

RECOMMENDED VISTRAC PARAMETERS

TABLE 5

The following angular search parameters are recommended for all altitudes with RDOT ($\dot{\rho}$) = 8.5° per second.

Airspeeds (VT)/sec. Knots	Feet	RZERO(ρ_0) Degrees	NMOD(s)	Width of One Scan Degrees
100	169.0	42.5	10	85.0
150	253.0	38.25	9	76.5
200	338.0	34.00	8	68.0
250	422.0	32.75	7	59.5
300	507.0	25.5	6	51.0
350	591.0	21.25	5	42.5
400	676.0	17.0	4	34.0
450	760.0	12.75	3	25.5
500	845.0	8.5	2	17.0
550	929.0	4.25	1	8.5
Above		4.25	1	8.5

LIST OF VARIABLES IN VISTRAC

Arrays

ANGM	Table of masking angles (M_T) at every 10° of azimuth.
COTAR	Table of target inherent contrast (C_0).
CLEG	Table of flight coordinates.
TARCOR	Table of target coordinates.
DIMTAR	Table target dimensions (h,w,l).
NTARG	Table of target names.
SVM	Table of meterorological visibility (leg 1, leg 2).
IANG	Table of azimuth angle from the target measured counterclockwise from the direction of positive x axis (L_T).

Data Card 1

BEE	Always read in at .62 (b).
BM	1.9 (m).
CAY	0.015830 (k for crew of two) or 0.0120 (k crew of one).
TINC	Time interval for integration (t=1.0) seconds.

Data Card 2

NSET	The number of altitude runs.
KTAR	The number of targets in the program (25).

Data Card 3

RZERO	The angular search limits of the observer (ρ_0).
RDOT	The angular search speed of the observer ($\dot{\rho}$=8.5) per second.
NMOD	The number of saccades in one scan (s).

Data Card 4

VT   Aircraft speed in feet per second (table 5).

ALT   Aircraft altitude in feet.

Other Variables

E   Target offset distance (e).

AY   Y distance from target.

TL   Target length (l).

W   Target width (w).

H   Target height (h).

RO   Slant range of foveal line of vision (r_0).

RT   Slant range (R).

TESTY   Trial maximum y distance from target.

SAVEY   Value for which probability of acquiring target is not greater than zero.

DECY   Stepping increment to determine point of foliage unmasking.

DELY   Tolerance limit on AY.

AL   Azimuth to target (L_A).

AM   Elevation angle from target to aircraft (M_A).

NSCAN   The scan number (i).

THETA   Angle of observer's foveal line of vision to target (θ).

VT   Aircraft velocity in feet per second (v).

K22   Number of target of interest.

Subroutines

1. TIMEQ

This routine evaluates the inequality:

$$C_o \, e^{-\frac{5.66(10^{-4})RT}{VM}} >$$

$$0.973 + \frac{0.195(10^{-6})*RT^2\pi}{H*COS(AM)(L*COS(AL) + W*SIN(AL)) + L*W*SIN(AM)} + 0.1$$

2. SETIND

This routine sets up the "sign convention" for azimuth to target and locates the M_T for the value L_T (closest to L_A).

3. SETT

The time required for the aircraft to come abreast of the target from the point of unmasking is calculated and an array of time intervals for integration is stored.

(t=0 unmasking to t_{max} remasking).

4. FOFXC

Using the circular scanning process FOFXC evaluates θ, R, and the function $\left[\frac{C(t)}{C_T(t)} - b\right]^m$, also called function CT.

5. Function CT

This function selects and evaluates:

$$C_T = 1.75\sqrt{\theta} + \frac{18.75}{\alpha^2}, 0.8 \leq \theta \leq 90°$$

or

$$C_T = 1.57 + \frac{14.86}{\alpha^2}, 0 \leq \theta \leq 0.8$$

6. GQUAD

This program uses a sixteen point Gauss's Quadrature Formula for finding the value of a definite integral. FOFXC is called to evaluate the function being integrated.

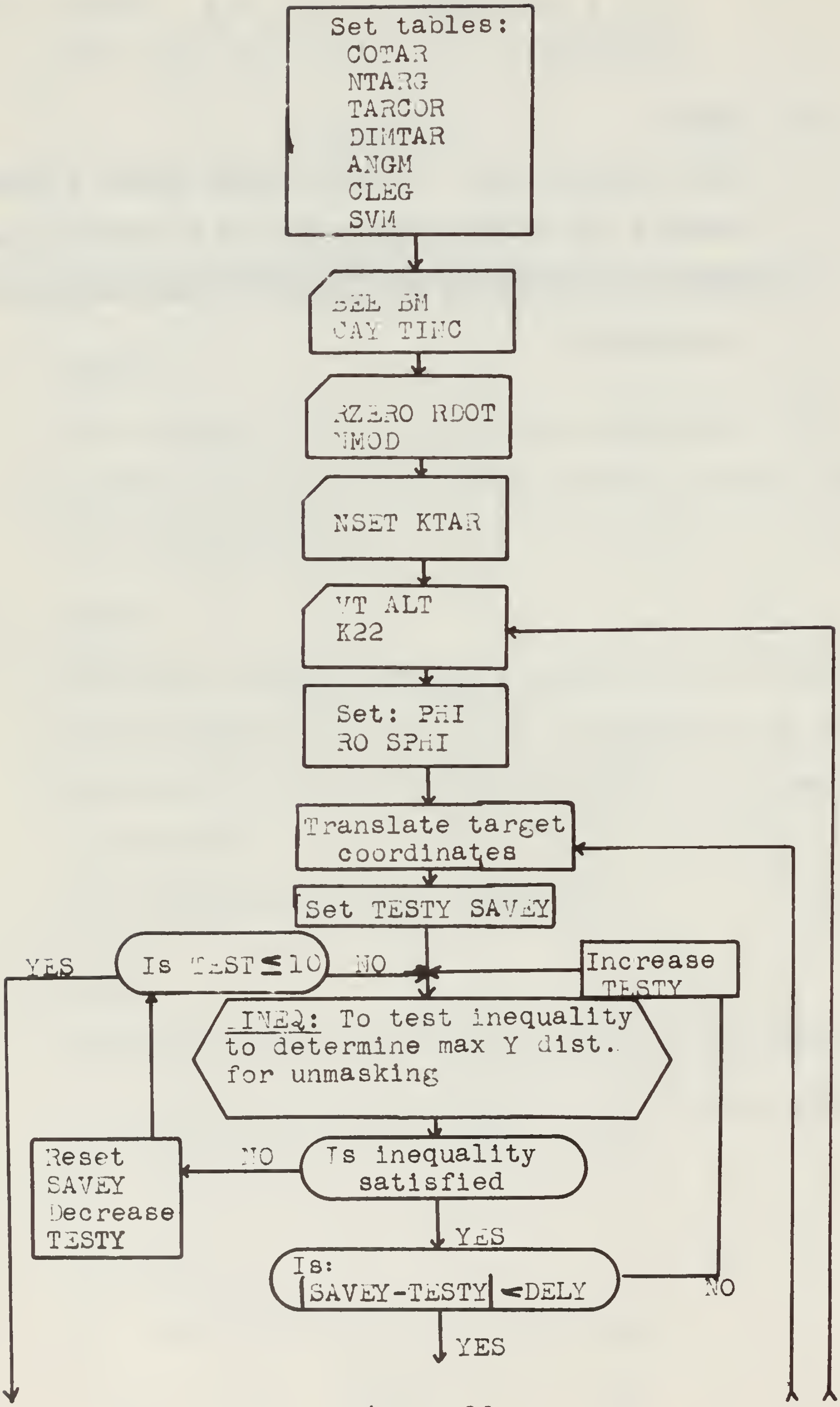


Figure 28

VISTRAC FLOW CHART

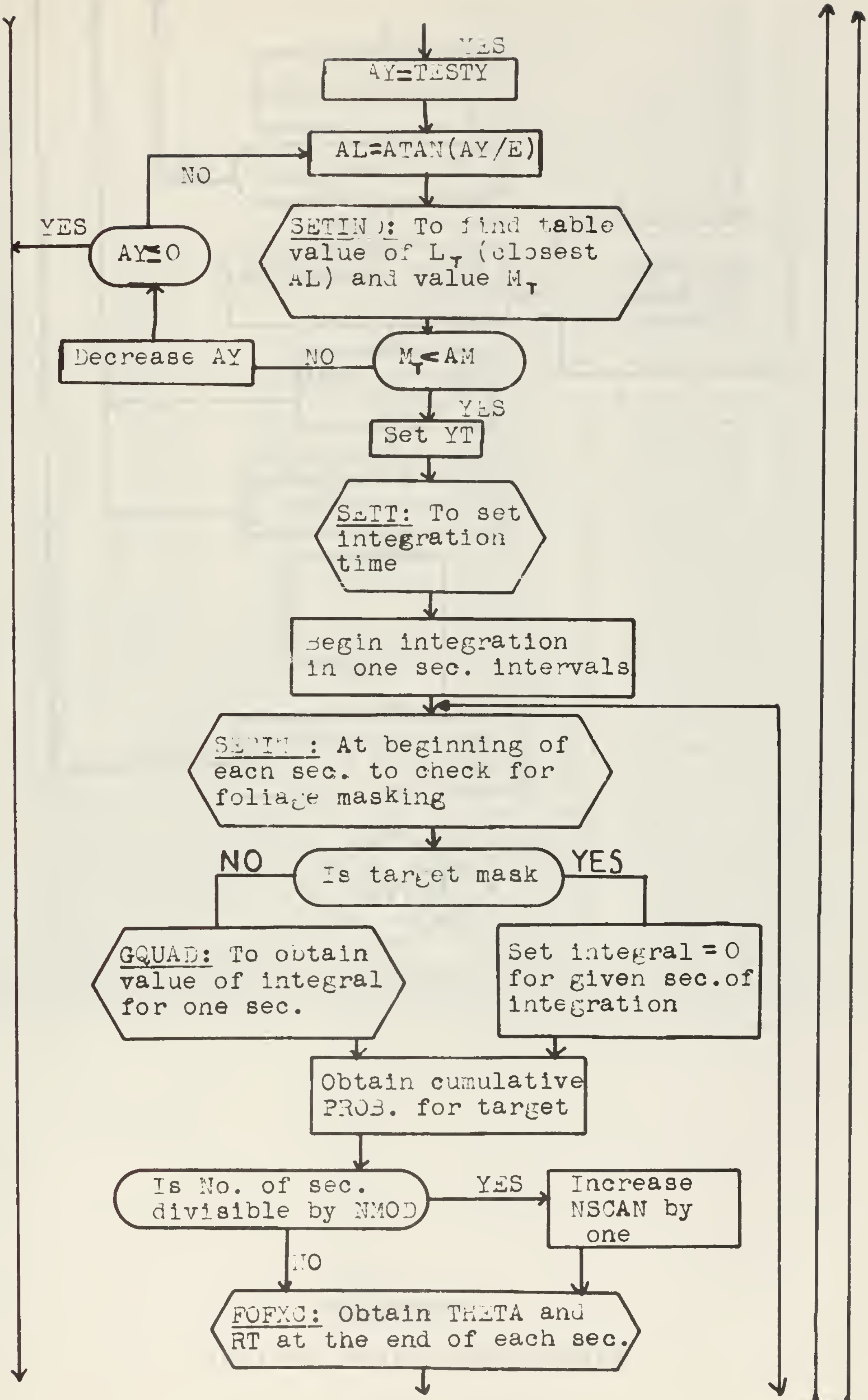


Figure 28

VISTRAC FLOW CHART (Cont'd)

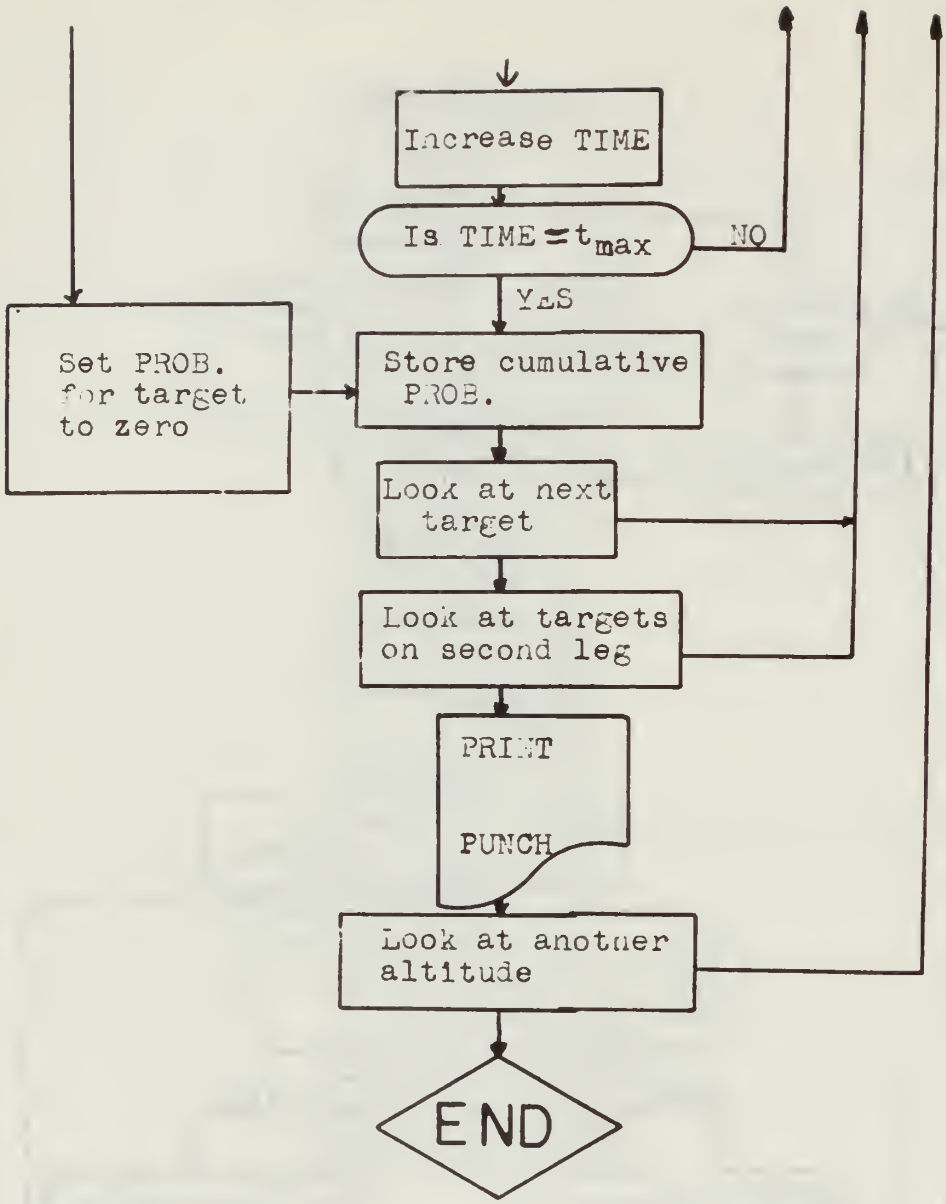


Figure 28

VISTRAC FLOW CHART (Cont'd)

```
C         LINEAR AND CIRCULAR SCAN MODIFICATIONS OF VISUAL
C         ACQUISITION MODEL
          DIMENSION AMAS1(36,5),AMAS2(36,5),AMAS3(36,5),AMAS4(36,5),AMAS5(36
         1,5)
          DIMENSION ANGM(36,25),NTARG(25),TP(30),COTAP(25),
         1DIMTAR(3,25),IANG(36),TARCOR(2,25)
          DIMENSION P(1000),TIME(1000),R(1000),TH(1000)
          DIMENSION SVM(2),CLEG(2,2,2)
C         CLEG = X,Y/INITIAL, FINAL/LEG NO.
C         TARCOR ARRAY OF TARGET COORDINATES - X,Y,TARGET NO.
C         ANGM ARRAY OF MASKING ANGLES - DEGREES,TARGET NO.
C         COTAR ARRAY OF TARGET CONTRASTS
C         DIMTAR-ARRAY OF TARGET DIMENSIONS H,W,TL,TARGET NO.
          COMMON RZERO,RDOT,NMOD
          COMMON ISLOPE,ABE,ZEPS,IEE
          COMMON ALT,TL,H,W,RHOD,PHID,RT,THED
          COMMON TIME,BEE,BM,CAY,CO,VM,YT,E,VT,VE,CF,
         1RO,SRHO,CRHO,SIN2,SPHI,ALT2,F2,NSCAN,HRW
C         DATA FOR MASKING ANGLES FOR PT. TO PT. RECONNAISSANC
C
C         REAL MASKING DATA FOR T1,T4,T5,T13,T14,T15,T18,T19,T ?,T22
C         DATED 3-16-67
C         *ACTUAL MASKING AND ** REPRESENTATIVE MASKING BASED ON *
C         3-24-67
          REAL *8 RAD2D
          REAL *8 DE2RAD
          DATA AMAS1/3.0,3.5,4.0,5.0,6.0,5.5,5.0,6.5,8.0,7.5,7.0,8.0,9.0,6.5
         1,4.0,3.5,3.0,2.0,1.0,0.5,3*0.00,0.5,7*1.00,2.0,3.0,2.5,2.0,2.5,
         25*3.00,6*29.70,16*6.00,2*4.00,4*6.00,3*3.00,4*5.00,14*6.00,11*4.00
         3,7*6.0,4.0,5.0,6.0,4.0,2.0,2.5,3.0,3.5,4.0,4.5,3*5.0,4.5,3*4.0,3.0
         4,2.0,1.5,3*1.0,1.5,2.0,1.5,1.0,1.5,7*2.0,3.0,3*2.0,3.0,3*4.0,3.5,3
         5*3.0,4.0,3*5.0,3.0,1.0,2.5,3*4.0,3.5,3.0,2.5,2.0,3.0,4.0,3.5,3*3.0
         6,2.0,1.0,2.0,3.0,2.5/
          DATA AMAS2/2*39.7,2.5,6*39.7,9*6.0,4*4.0,14*5.7,6*3.0,6*11.0,5*2.3
         1,
         22.9,10*1.4,3*4.0,2*5.7,3*6.0,3.0,2*6.4,3*3.5,25*2.3,3*3.0,13.0,5*3
         3.0,15*6.0,11*4.0,6*6.0,5*1.2,3*0.0,5*3.2,2*0.0,16*2.0,5*2.5/
          DATA AMAS3/3*11.3,45.0,3*2.0,13*3.2,5*2.0,7*0.0,3*4.6,5.7,5*7.4,2*
         12.0,11*3.2,17*0.0,3.4,3*2.0,2.5,3*3.0,3.5,4.0,4.5,5.00,5.5,3*6.0,4
         2.5,3.0,2.5,2.0,1.5,3*1.0,1.5,9*2.0,2.5,3.0,2.5,2.0,2.5,3*3.0,2.5,3
         3*2.0,1.5,5*1.0,1.5,3*2.0,2.5,3*2.0,4.0,3*5.0,6.5,8.0,7.0,6.0,5.5,5
         4.0,4.5,4.0,3.0,3*1.0,2.0,7*3.0,2.0,5*1.0,1.5,2.0,1.5,9*1.0,0.5,5*0
         5.0,0.5/
          DATA AMAS4/5*0.0,2.0,15*3.2,10*2.0,3*2.5,2*0.0,6*7.4,8*6.0,8*4.0,5
         1*7.4,5*3.0,4*11.3,20.0,14.5,9.0,8.0,7.0,8.0,9.0,11.5,14.0,9.5,5.0,
```

```
24.0,3.0,3.5,4.0,5.0,3*6.0,5.0,3*4.0,3.5,3.0,4.[illegible]
33.0,10.5,8.0,11.0,14.0,17.0,4.0,3.0,7*[illegible],3.[illegible]
46.5,9.0,8.5,8.0,9.0,10.0,8.0,6.0,5.5,5.0,6.[illegible],3*7.0,[illegible].5,6.0,6.[illegible],3*7
5.0,5.5,11.0,10.5,10.0,10.5,11.0,9.5,8.0,5.0,[illegible],2.5,3*3.0,4.5,5.0,
65.5,3*5.0,5.5,6.0,4.0,3*2.0,3.5,5.0,4.5,4.0,6.5,3*9.0,8.0,7.0,9.0/
 DATA AMAS5/5*3.0,8*6.0,4*11.0,12*4.0,7*6.0,5*1.0,2.0,3.0,4.0,5.0,4
1.5,3*4.0,3.5,3.0,4.0,5.0,4.5,4.0,2.5,7*1.0,1.5,2.0,2.5,3.0,2.5,2.0
2,2.5,3.0,2.0,4*3.0,10*6.0,4*2.3,9*11.3,9*3.8,5*3.0,13*6.0,12*4.0,6
3*6.0,5*3.0,10*6.0,4*3.0,11*4.0,6*6.0/
 DATA COTAR/35.4,32.6,25.3,13.1,25.6,24.3,11.0,20.0,13.7,80.0,14.6,
115.2,10.4,7.9,25.3,27.0,20.0,29.0,57.7,13.9,62.5,11.0,14.6,24.3,16
2.7/
 DATA RAD2D/57.295779513/
 REAL *8 NTARG
 DATA DUM1/'ABCD'/,NTARG/'     *TC1','    **T02','    **T03','     *T04
1','     *TC5',
28H    **T06,8H    **T07,8H    **T08,8H    **T09,8H    **T10,8H    **T11,
38H    **T12,8H     *T13,8H     *T14,8H     *T15,8H    **T16,8H    **T17,
48H     *T18,8H     *T19,8H     *T20,8H    **T21,8H     *T22,8H    **T23,
58H    **T24,8H    **T25/
 DATA TARCOR/32.7,13.5,34.9,20.0,34.3,22.6,36.1,25.7,35.3,28.3,
138.0,29.8,36.5,34.9,39.0,35.3,39.4,37.9,41.2,41.9,40.5,45.1,42.1,
249.7,43.0,55.4,39.23,58.4,37.9,52.1,35.9,48.2,35.9,45.1,36.8,
342.5,35.3,38.9,33.2,37.9,32.9,34.4,32.2,32.8,33.3,29.7,30.9,24.3,
429.7,19.9/
 DATA DIMTAR/8.0,328.0,328.0,6.0,328.0,247.0,5.0,230.0,230.0,5.0,
1197.0,197.0,7.0,98.0,702.0,7.0,328.0,656.0,9.0,328.0,125.0,5.0,
2150.0,12.0,7.0,115.0,700.0,6.0,378.0,214.0,0.0,350.0,3500.0,7.0,
3492.0,492.0,10.0,400.0,400.0,6.0,200.0,200.0,12.0,213.0,147.0,
46.0,230.0,100.0,11.0,60.0,11.0,6.0,260.0,260.0,8.0,32.0,370.0,
52.0,196.0,100.0,12.0,130.0,100.0,9.0,328.0,125.0,12.0,115.0,540.0,
69.0,328.0,490.0,12.0,550.0,700.0/
 DATA IANG/0,10,20,30,40,50,60,70,80,90,100,110,120,
1130,140,150,160,170,180,-170,-160,-150,-140,-130,-120,
2-110,-100,-90,-80,-70,-60,-50,-40,-30,-20,-10/
 REAL *8 NAMET
 DATA DUM4/'NUTS'/,NAMET/'NOT THIS'/
 DATA SVM/12.0,12.0/
 DATA CLEG/31.7,11.3,43.6,57.5,40.1,62.4,28.5,15.1/
 REAL *8 NTYPE
 REAL *8 ISCAN
 DATA DUM3/'AAAA'/,NTYPE/'PT TO PT'/
 NSUB = 1
 ZEPS = 5.0E-6
 DATA DUM2/'ABCD'/,ISCAN/'CIRCULAR'/
```

```
      DELY=100.0
      DECY=100.0
      FNM=6080.2
      DE2RAD=1.745329252E-2
C
      DO 864 I=1,5
      DO 864 J=1,36
      K=I+5
      L=I+10
      M=I+15
      N=I+20
      ANGM(J,I)=AMAS1(J,I)
      ANGM(J,K)=AMAS2(J,I)
      ANGM(J,L)=AMAS3(J,I)
      ANGM(J,M)=AMAS4(J,I)
      ANGM(J,N)=AMAS5(J,I)
  864 CONTINUE
      READ(5,6) BEE,BM,CAY,TINC
    6 FORMAT(2F6.4,F8.6,F3.1)
      READ(5,1) NSET,KTAR
      TTAR = KTAR
 6006 FORMAT(2F6.2,I3)
      READ(5,6006) RZERO,RDOT,NMOD
      DO 600 MJKL = 1,NSET
    1 FORMAT(4I2)
   11 READ(5,5) VT,ALT ,K22
      IF(ALT.GT.300.0.AND.ALT.LT.1000.0) GO TO 100
      IF(ALT-300.0)101,101,102
  101 PHI=85.0
      GO TO 104
  102 PHI=75.0
      GO TO 104
  100 PHI=85.0-((ALT-300.0)/70.0)
  104 PHID=PHI
      PHI = PHI * DE2RAD
      EYE=COS(PHI)
      RO=ALT/EYE
      SPHI=SIN(PHI)
    5 FORMAT(5X,F6.1,F9.1,I3)
   12 CAYN=-CAY
      ALT2 = ALT * ALT
C     NON - PARALLEL PATHS
      DO 400 LG=1,2
      VM = SVM(LG)
      XI=CLEG(1,1,LG)
```

```
      XJ=CLEG(1,2,LG)
      YJMYI=CLEG(2,1,LG)-CLEG(2,2,LG)
      AYIJ=ABS(YJMYI)
      XJMXI = XJ - XI
      IF(LG.EQ.2) GO TO 161
       GO TO 162
  161 XJMXI=-XJMXI
      YJMYI=-YJMYI
  162 XIMXJ=-XJMXI
      AXIJ=ABS(XJMXI)
      ARG=AXIJ/AYIJ
      RANG=ATAN(ARG)
      ROID=RANG*RAD2D
      TOFQ=ARG
      SIDE3=SQRT(AYIJ**2+AXIJ**2)
      SOFQ=AYIJ/SIDE3
      COFQ=AYIJ/SIDE3
      CQ2=COFQ*COFQ
      SLOPE=YJMYI/XJMXI
      IF(SLOPE.LT.0.0) GO TO 231
      ISLOPE=1
      GO TO 225
  231 ISLOPE=-1
  225 GO TO(401,402),LG
  401 IS=1
      NUTAR=13
      GO TO 403
  402 IS=14
      NOTAR=25
  403 DO 45C II=IS,NOTAR
      NAMET=NTARG(II)
      TL=DIMTAR(3,K22)
      W=DIMTAR(2,K22)
      H=DIMTAR(1,K22)
      CO=COTAR(K22)
      HBW=H*W
      XT=TARCOR(1,II)
      TY=ABS(CLEG(2,1,LG)-TARCOR(2,II))
      XTMXI=XT-XI
      IF(LG.EQ.2) XTMXI=-XTMXI
      XIMXT=-XTMXI
      XTI2=XTMXI**2
      TY2=TY**2
      HYP=SQRT(XTI2+TY2)
      IF(ISLOPE.EQ.1) GO TO 222
```

```
      GO TO 221
C     POSITIVE  SLOPE
  222 TDEN=AYIJ*XTMXI-TY*XJMXI
      IF(ABS(TDEN).LT.ZEPS) GO TO 238
  234 TLOP=(AYIJ*TY+XTMXI*XJMXI)/TDEN
  236 XXX=ABS(TLOP)
      ALOP=ATAN(XXX)
      EP=COS(ALOP)*HYP
      DP=SIN(ALOP)*HYP
      IF(TLOP.LT.0.0) GO TO 229
  228 IEE=1
      GO TO 235
  229 IEE=-1
      EP=-EP
      GO TO 235
C       TARGET ON FLIGHT PATH
  238 EP=0.0
      DP=SQRT(XTI2+TY2)
      IEE=0
      GO TO 235
C     NEGATIVE SLOPE
  221 TDEN=TY*XIMXJ-AYIJ*XIMXT
      IF(ABS(TDEN).LT.ZEPS) GO TO 238
      TLOP=(AYIJ*TY+XIMXJ*XIMXT)/TDEN
      GO TO   236
  235 E=EP*FNM
      TESTY=DP*FNM
  240 ABE=ABS(E)
      E2=E*E
      YINC=TESTY
      CALL TINEQ(TESTY,INEQ,RR)
      IF(INEQ.GT.0) GO TO 440
  411 SAVEY=TESTY
      YINC=YINC/2.0
      TESTY=TESTY-YINC
      IF(TESTY.LE.10.0) GO TO 449
  416 CALL TINEQ(TESTY,INEQ,RR)
      IF(INEQ.GT.0) GO TO 415
      GO TO 411
  415 IF((SAVEY-TESTY).LT.DELY) GO TO 440
  417 YINC=YINC/2.0
      TESTY=TESTY+YINC
      GO TO 416
  440 AY=TESTY
C      FOR NON-PARALLEL FLIGHT PATH
```

```
398 IF(IEE.EQ.C) GO TO 391
    GO TO 433
391 AL=-9C.0
    IND=28
    GO TO 434
433 A1=AY/ABE
    AL=ATAN(A1)
    AL=AL*RAD2D
    CALL SETIND(AL,IANG,IND)
434 AM=ALT/RR
    AM=ARSIN(AM)
    AM=AM*RAD2D
    TM=ANGM(IND,II)
    IF(TM.LT.AM) GO TO 49C
489 AY=AY-DECY
    RR=SQRT(AY*AY+ALT2+E2)
    IF(AY.LE.0.C) GO TO 448
    GO TO 398
490 YT=AY
    TS=0.C
    TE=YT/VT
    IE=TE+1.0
    TE=IE
    CALL SETT (TS,TE,TINC,NT)
    NSCAN=0
    SUM=C.0
    DO 50 I=1,NT
    YL=TIME(I)
    YU=TIME(I+1)
    IERR=0
    T=YL
    DV=YT-T*VT
    IF(DV.LE.0.C) GO TO 845
    RR=SQRT(DV*DV+ALT2+E2)
    IF(IEE.EQ.C) GO TO 833
    GO TO 835
833 AL=-90.0
    IND=28
    GO TO  840
835 A1=DV/ABE
    AL=ATAN(A1)
    AL=AL*RAD2D
    CALL SETIND(AL,IANG,IND)
840 TM=ANGM(IND,II)
    AM=ALT/RR
```

```
      AM=ARSIN(AM)
      AM=AM*RAD2D
      IF(TM.LT.AM) GO TO 850
  845 YY=0.0
      GO TO 846
  850 CALL GQUAD(YL,YU,YY,NSUB,IERR)
  846 SUM=SUM+YY
      PA=CAYN*SUM
      F(I)=1.0-EXP(PA)
      IERR=0
      XXX=MOD(I,NMOD)
      IF(XXX) 49,48,49
   48 NSCAN=NSCAN+1
   49 CALL FOFXC(YU,DUM,IERR)
      TH(I)=THED
      P(I)=RT
   50 CONTINUE
      TP(II)=P(NT)
      NTP1=NT+1
      GO TO 450
  448 TP(II)=0.0
      GO TO 450
  449 TP(II)=0.0
      GO TO 450
  450 CONTINUE
  400 CONTINUE
      FSUM=0.0
      WRITE(6,901) VT,ALT
  901 FORMAT(1H1,2X,'TARGET',2X,'SCORE',2X,'VEL=',F6.0,2X,'ALT =',F6.0,/
     1)
      DO 575 JL=1,KTAR
      WRITE(6,902) NTARG(JL),TP(JL)
  902 FORMAT(1H ,A8,1X,F6.4)
  575 FSUM =FSUM+TP(JL)
      FSUM=FSUM/TTAR
      WRITE(6,876) FSUM
      WRITE(6,6066) RZERO,RDOT,NMOD
      AIRSPD=VT*360.0/608.0
      AK22=K22
 6066 FORMAT(1H0,'RZERO =',F6.2,2X,'RDOT =',F6.2,2X,'NMOD =',I3,/)
  876 FORMAT(1H0,'FINAL SCORE',F8.4)
      PUNCH 6166,FSUM,ALT   ,AIRSPD,AK22,VM,VT
 6166 FORMAT(6F10.4)
      PUNCH 7000,FSUM
 7000 FORMAT(F10.4)
```

```
      PLDA=90.0-PHID
      WRITE(6,53)K22,H,W,TL,PLDA,CO
   53 FORMAT(1HO,'TARGET NUMBER',I3,/,5X,'HEIGHT=',F5.0,3X,'WIDTH=',F3.1
     1,3X,'LENGTH=',F8.0,/,5X,'PILOT LOOK DOWN ANGLE=',F6.2,3X,'CO=',F4.
     21,/)
      WRITE(6,57) VM,BEE,BM,CAY,RO,ALT,VT
   57 FORMAT(1HO,'DATA INPUT WAS',/,5X,'VM=',F3.0,3X,'B=',F7.4,3X,'M=',F
     17.4,3X,'K=',F9.6,/,5X,'RO=',F6.0,3X,'ALT=',F6.0,3X,'VT=',F5.0,/)
  600 CONTINUE
      END


      SUBROUTINE TINEQ(TESTY,INEQ,RR)
      DIMENSION TIME(1000)
      COMMON RZERO,RDOT,NMOD
      COMMON ISLOPE,ABE,ZEPS,IEE
      COMMON ALT,TL,H,W,RHOD,PHID,RT,THED
      COMMON TIME,BEE,BM,CAY,CO,VM,YT,E,VT,VE,OF,
     1RO,SRHO,CRHO,SIN2,SPHI,ALT2,E2,NSCAN,HBW
      REAL *8 PIE
      REAL *8 PIEO2
      PIE=3.14159265
      PIEO2=1.57079633
      RARG=TESTY*TESTY+ALT2+E2
      RR=SQRT(RARG)
      R1=RR/6080.2
      AE=(-3.44*R1)/VM
      T1=CO*EXP(AE)
      IF(E.EQ.0.0) GO TO 75
      AL=TESTY/ABE
      AL=ATAN(AL)
      GO TO 77
   75 AL=PIEO2
   77 XALT=SQRT(RR**2-ALT**2)
      AM=ALT/XALT
      AM=ATAN(AM)
      B1=H*COS(AM)
      B2=TL*COS(AL)
      B3=W*SIN(AL)
      D1=B1*(B2+B3)+TL*W*SIN(AM)
      T2=0.973+(0.195E-6*RARG*PIE)/D1+0.1
      IF(T1.GT.T2) GO TO 5
```

```
      INEQ=-1
      RETURN
    5 INEQ=1
      RETURN
      END



      SUBROUTINE SETIND(BL,IANG,IND)
      COMMON RZERO,RDOT,NMOD
      COMMON ISLOPE,ABE,ZEPS,IFE
      COMMON ALT,TL,H,W,RHOD,PHID,RT,THED
      COMMON TIME,BEE,BM,CAY,CO,VM,YT,E,VT,VF,OF,
     1RO,SRHO,CRHO,SIN2,SPHI,ALT2,E2,NSCAN,HBW
      DIMENSION TIME(1000)
      DIMENSION IANG(1)
      AL=BL
C     NON-PARALLEL FLIGHT LEGS
      IF(IEE-0) 5,6,7
    5 AL=-AL
      GO TO 46
    6 IND=28
      RETURN
    7 AL=-(180-AL)
   46 IF(AL)61,62,63
   62 IND=1
      RETURN
   63 JA=AL/10.0
      JA=JA*10
      FC=JA+5
      JS=1
      JE=19
      IF(AL.LT.FC) GO TO 64
      GO TO 65
   64 LA=JA
      GO TO 66
   65 LA=JA+10
      GO TO 66
   61 FJA=ABS(AL)
      IF(FJA.LE.5.0) GO TO 71
      GO TO 72
   71 IND=1
      RETURN
```

```
 72 IF(FJA.GT.175)GO TO 73
    GO TO 74
 73 IND=19
    RETURN
 74 JS=20
    JE=36
    JA=FJA/10.0
    JA=JA*10
    FC=JA+5
    IF(FJA.GT.FC) GO TO 75
    GO TO 76
 75 LA=-(JA+10)
    GO TO 66
 76 LA=-JA
 66 DO 50 JKL=JS,JE
    IF(IANG(JKL).EQ.LA) GO TO 485
 50 CONTINUE
    WRITE(6,498) AL,JS,JE
    CALL EXIT
485 IND=JKL
    RETURN
498 FORMAT(1H0,'ASIMUTH ANGLE ERROR',5X,'AL =',E15.8,/,5X,'J START IS'
   1,I3,2X,'J END IS',I3)
    END


    SUBROUTINE SETT(TS,TE,TINC,NT)
    DIMENSION TIME(1000)
    COMMON RZERO,RDOT,NMOD
    COMMON ISLOPE,ABE,ZEPS,IFE
    COMMON ALT,TL,H,W,RHOD,PHID,RT,THED
    COMMON TIME,BEE,BM,CAY,CO,VM,YT,E,VT,VE,OF,
   1RO,SRHO,CRHO,SIN2,SPHI,ALT2,E2,NSCAN,HBW
    INC=TINC*100.
    IS=TS*100.0
    IE=TE*100.
    NT=(IE-IS)/INC
    FT=(TE-TS)*100.0
    XX=NT*INC
    DT=FT-XX
    NTIME=0
    TIME(1)=TS
```

```
      DO 10 J=1,NT
      NTIME=NTIME+INC
      TIME(J+1)=NTIME
   10 TIME(J+1)=TIME(J+1)/100.0
      IF(DT.EQ.0.0) RETURN
      NT=NT+1
      TIME(NT+1)=TE
      RETURN
      END



      SUBROUTINE FOFXC(XX,FX,IERR)
C     CIRCULAR SCAN PATTERN
      DIMENSION TIME(1000)
      COMMON RZERO,RDOT,NMOD
      COMMON ISLOPE,ABE,ZEPS,IFE
      COMMON ALT,TL,H,W,RHOD,PHID,RT,THED
      COMMON TIME,BEE,BM,CAY,CO,VM,YT,E,VT,VE,OF,
     1RO,SRHO,CRHO,SIN2,SPHI,ALT2,E2,NSCAN,HBW
      REAL *8 RAD2D
      REAL *8 DE2RAD
      REAL *8 PIE
      REAL *8 PIEO2
      PIEO2=1.57079633
      PIE=3.14159265
      DE2RAD=1.745329252E-2
      RAD2D=57.295779513
      T=XX
      FF=NMOD*NSCAN
      DD=YT-T*VT
      IF(DD.LE.0.0) GO TO 3
      D2=DD*DD
      RT=SQRT(D2+E2+ALT2)
      SGN=(-1)**(NSCAN+2)
      VRHO=SGN*(-RZERO+RDOT*(T-FF))
      VRHO=VRHO*DE2RAD
      SVR=SIN(VRHO)
      CVR=COS(VRHO)
      ANUM=SPHI*(E*SVR+DD*CVR)+(ALT2/RO)
      CHECK=ANUM/RT
      IF(CHECK.GT.1.0) GO TO 10
      GO TO 11
```

```
10 FX=0.0
   WRITE(6,901) CHECK,NSCAN,T
   RETURN
11 THETA=ARCOS(CHECK)
   THED=THETA*RAD2D
901 FORMAT(1HO,'CHECK ERROR IS =',E15.8,5X,'NSCAN=',I4,5X,'T=',E15.8,
  1/)
   IF(E.EQ.0.0) GO TO 20
   GO TO 24
20 AL=PIFO2
   GO TO 25
24 XXX=DD/ABS(E)
   AL=ATAN(XXX)
25 AM=ALT/RT
   AM=ARSIN(AM)
   B1=H*COS(AM)
   B2=TL*COS(AL)
   B3=W*SIN(AL)
   BNUM=B1*(B2+B3)+TL*W*SIN(AM)
   X44=BNUM/PIE
   ALPHA=(6876.0/RT)*SQRT(X44)
   F2=CT(THED,ALPHA)
   IF(F2.EQ.0.0) GO TO 97
   R1=RT/6080.20
   AE=(-3.44*R1)/VM
   F1=CO*EXP(AE)
   T1=F1/F2
   IF(T1.LE.BEE) GO TO 1
 2 FX=(T1-BEE)**BM
   RETURN
 1 FX=0.0
   IERR=1
   RETURN
 3 IERR=1
   RETURN
97 WRITE(6,53)
53 FORMAT(1HO,'ZERO DENOMINATOR - FUNCTION CT')
   CALL EXIT
   END



   FUNCTION CT (AA,ALPHA)
```

```
      IF(ALPHA) 2,1,2
    1 WRITE(6,9)
    9 FORMAT(5X,'ANGEL ALPHA IS ZERO')
      CALL EXIT
    2 BB=ALPHA**2
      IF(AA.GE.0.0.AND.AA.LE..8) GO TO 5
      CT=1.75*SQRT(AA)+(18.57*AA)/BB
      RETURN
    5 CT=1.57+14.86/BB
      RETURN
      END



      SUBROUTINE GQUAD(XL,XU,YY,NSUB,IERR)
      REAL *8 VV
      REAL *8 GG
      DIMENSION VV(16),GG(16)
      DATA VV/-.98940093499,-.94457502307,-.86563120239,-.75540440836,
     1-.61787624440,-.45801677766,-.28160355078,-.95012509838E-01,
     2.95012509838E-01,.28160355078,.45801677766,.61787624440,
     3.75540440836,.86563120239,.94457502307,.98940093499/
      DATA GG/.27152459412E-01,.62253523939E-01,.95158511682E-01,
     1.12462897126,.14959598882,.16915651940,.18260341504,.18945061046,
     2.18945061046,.18260341504,.16915651940,.14959598882,.12462897126,
     3.95158511682E-01,.62253523939E-01,.27152459412E-01/
C     INTEGRATES FROM A TO B
C
C     IF IERR = 1, INTEGRAL IS SET EQUAL TO ZERO
      YY=0.0
      XLGTH=XU-XL
      IF(XLGTH)5,10,5
    5 EN=NSUB
      DO 20 L=1,NSUB
      AREA=0.0
      AL=L
      PPA=(2.*AL-1.0)*XLGTH/EN +2.0*XL
      BMA=XLGTH/EN
      DO 30 M=1,16
      XX=(BPA+VV(M)*BMA)/2.0
    7 CALL FOFXC(XX,FX,IERR)
      IF(IERR.EQ.1) GO TO 50
      AREA=AREA+GG(M)*FX
```

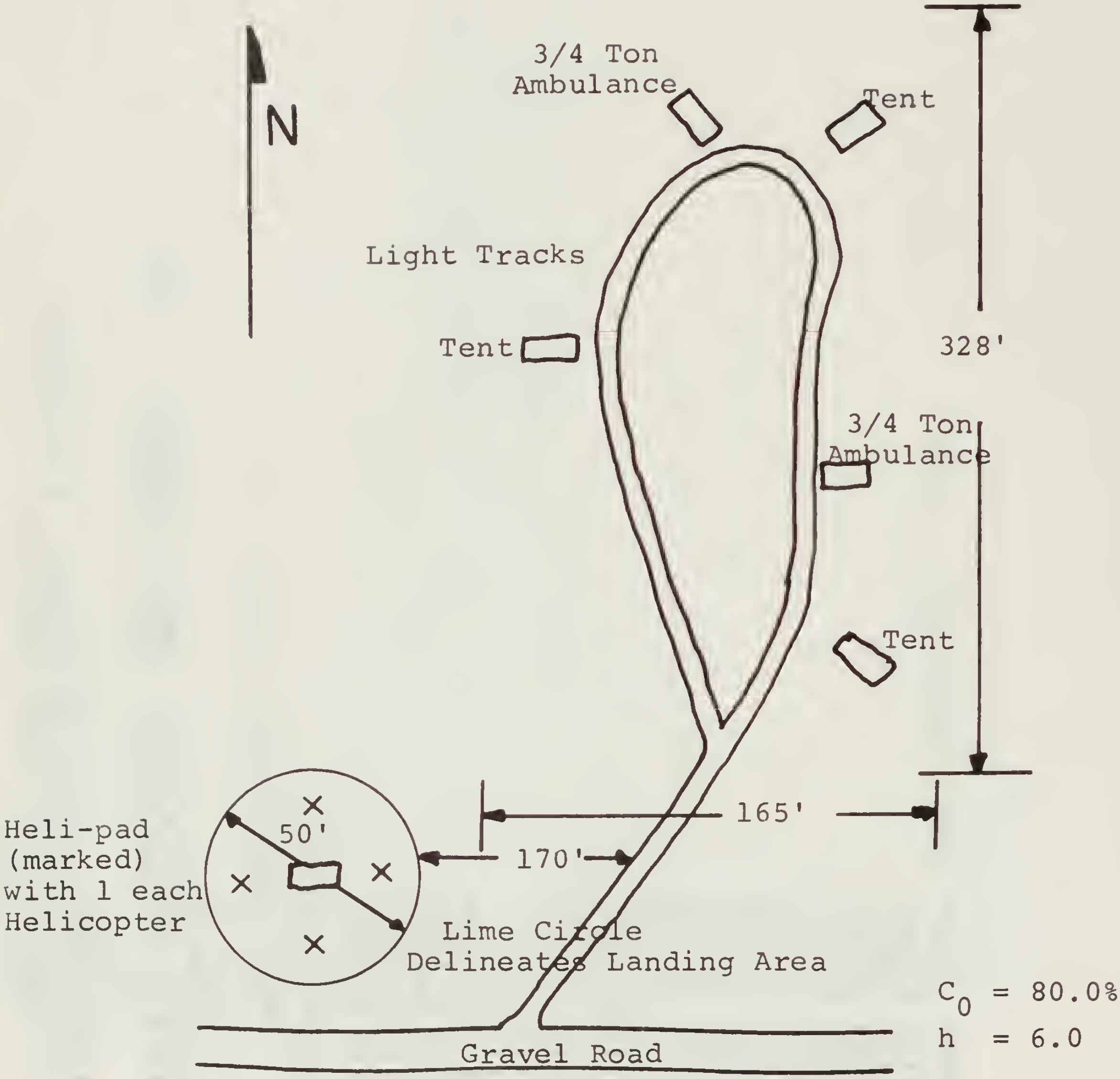
```
   30 CONTINUE
      YY=YY+AREA
   20 CONTINUE
      YY=(XLGTH/(2.0*EN))*YY
   10 RETURN
   50 YY=0.0
      RETURN
      END
```

DATA CARDS

```
0.62  1.9     .0158301.0
 125
 25.5   8.5   6
      608.0     500.0 25
```

```
TARGET  SCORE  VEL=  608.  ALT =  500.
   *T01 0.2863
  **T02 0.0
  **T03 0.2248
   *T04 0.2350
   *T05 0.0657
  **T06 0.0
  **T07 0.0007
  **T08 0.0301
  **T09 0.0160
  **T10 0.0064
  **T11 0.5098
  **T12 0.3392
   *T13 0.5030
   *T14 0.2760
   *T15 0.4402
  **T16 0.1708
  **T17 0.6309
   *T18 0.0
   *T19 0.0
   *T20 0.0644
  **T21 0.1988
   *T22 0.2514
  **T23 0.0025
  **T24 0.2853
  **T25 0.4059

FINAL SCORE  0.1977

RZERO = 25.50  RDOT =  8.50  NMOD =  0

TARGET NUMBER 25
    HEIGHT=  12.    WIDTH=   550.0   LENGTH=    700.
    PILOT LOOK DOWN ANGLE=  7.86   CD=16.7

DATA INPUT WAS
    VM=12.    B= 0.6200   M= 1.9000   K= 0.015830
    RO= 3658.    ALT=  500.    VT= 608.
```

APPENDIX E



DESCRIPTION: 3 each large GP tents; 2 each 3/4 ton ambulances; Heli-pad (marked) with 1 each helicopter; all items marked with red crosses.

Figure 29

TARGET No. 10

FIELD HOSPITAL

(all items marked with red crosses)

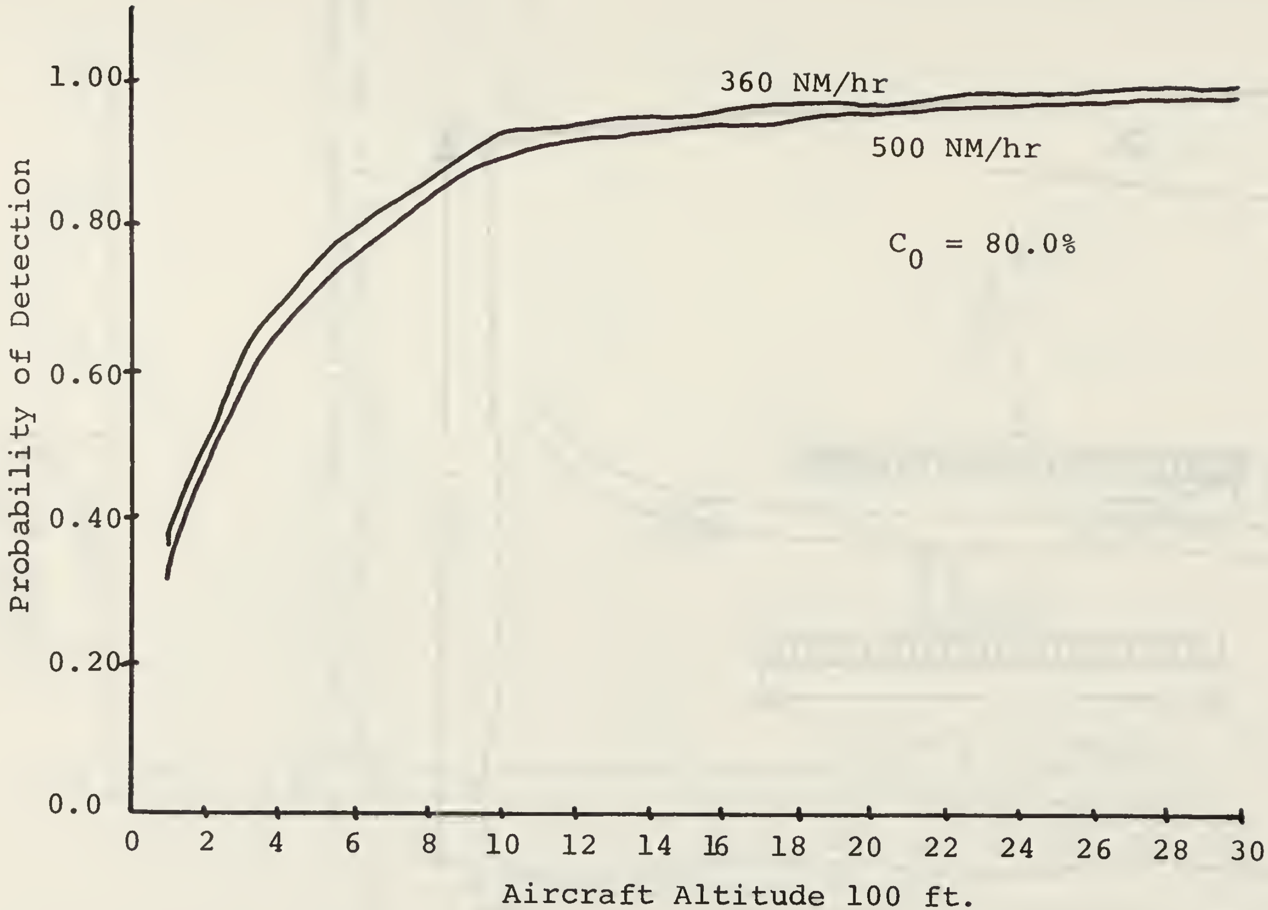
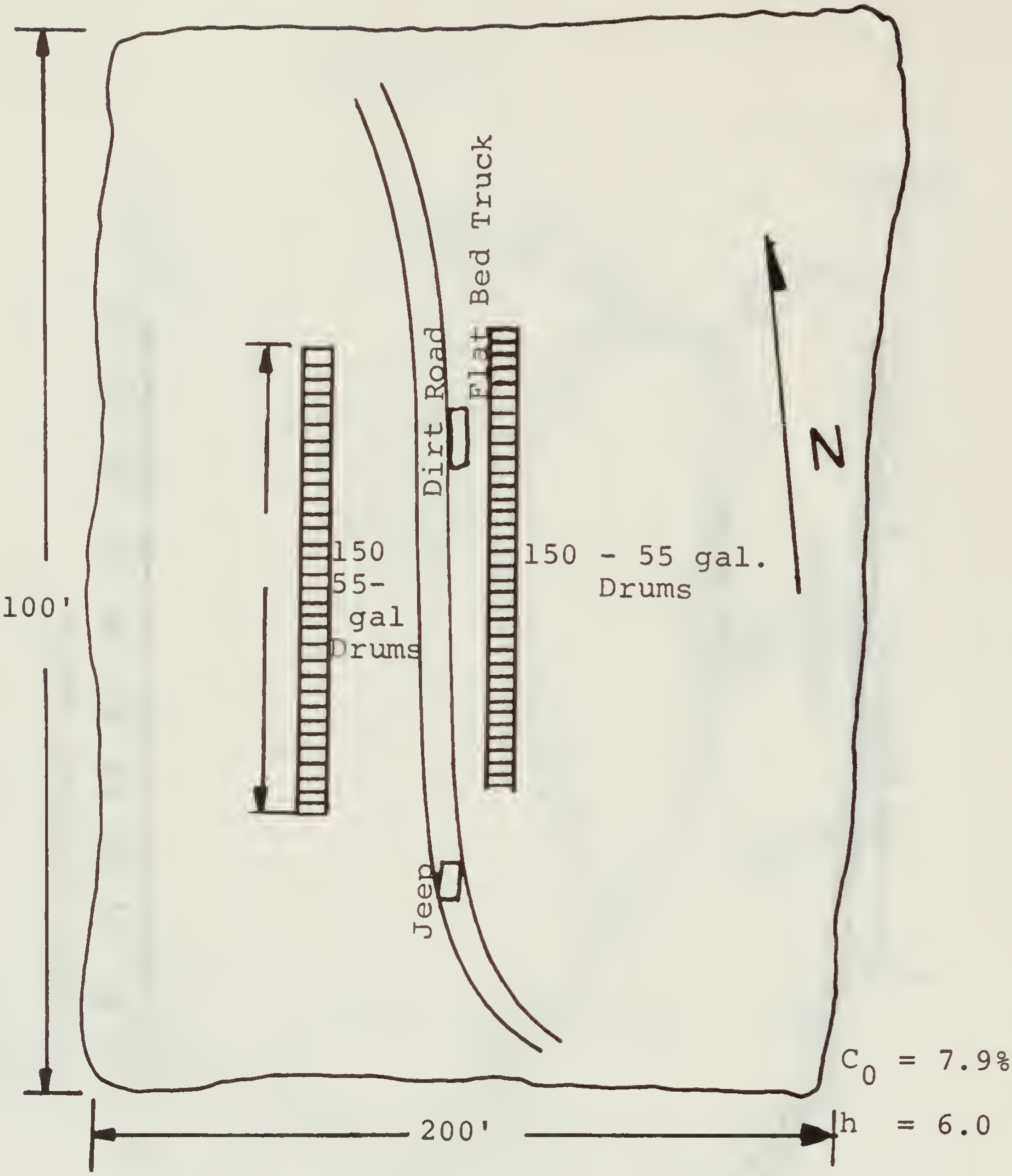


Figure 30

PROBABILITY OF DETECTING TARGET 10 AS A FUNCTION OF ALTITUDE



DESCRIPTION: 300 each 55 gallon drums, stacked in two rows as in Test 4.1; 1 each flatbed truck, 1 each jeep.

Figure 31

TARGET No. 14

POL SITE

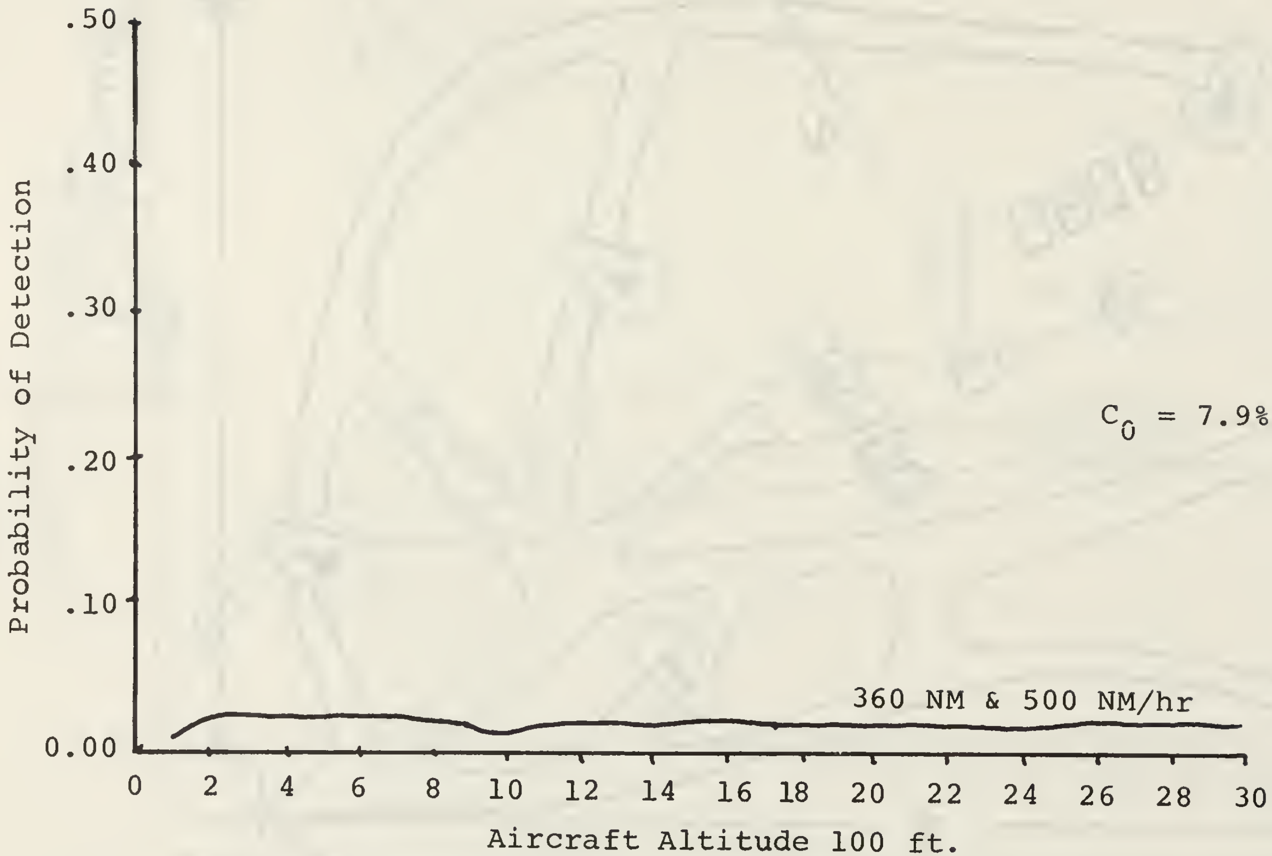
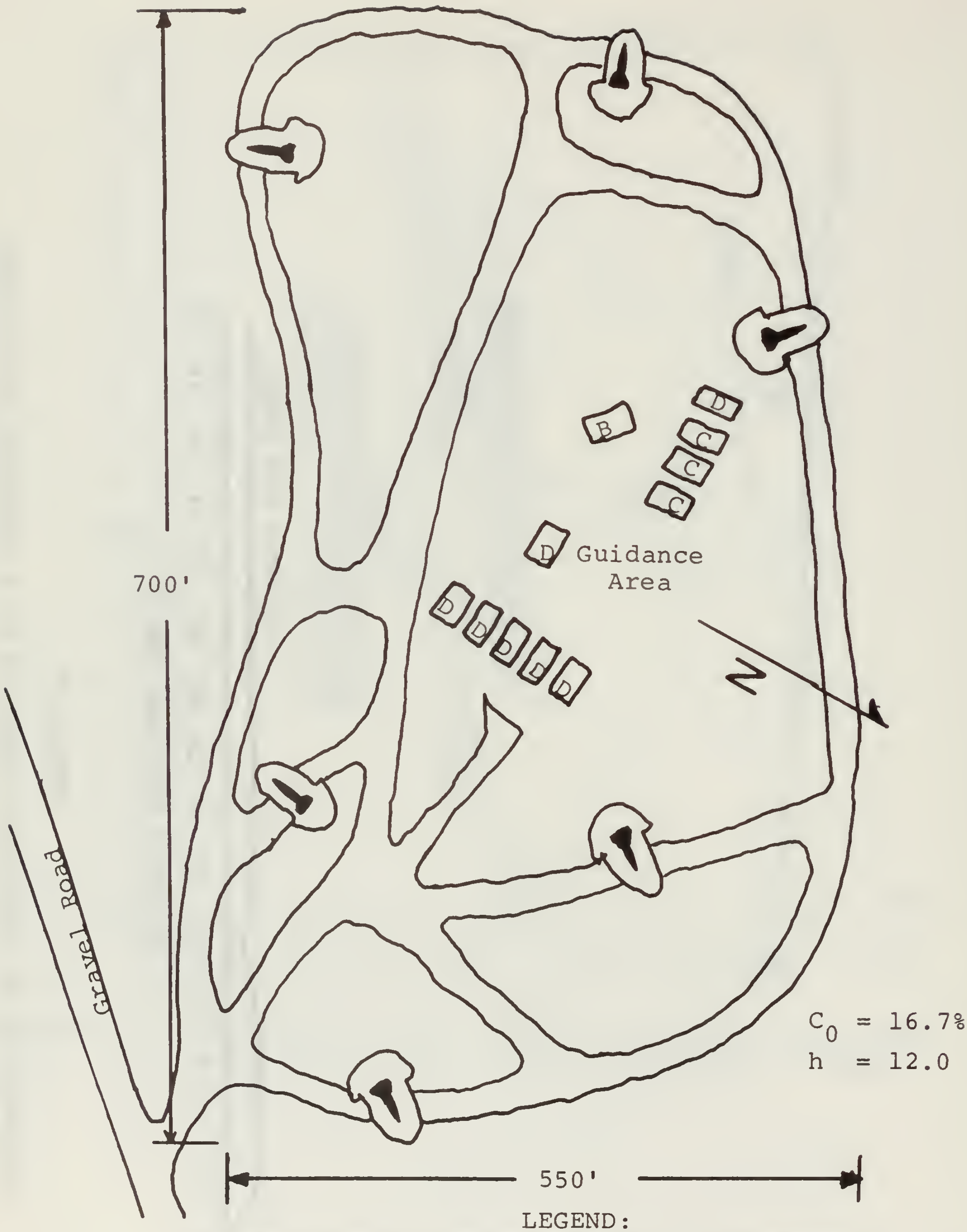


Figure 32

PROBABILITY OF DETECTING TARGET 14 AS A FUNCTION OF ALTITUDE



LEGEND:
B = Missile Control Radar 1
C = Van Type Trailer 3
D = Truck Vans 7

Figure 33

TARGET NO. 25

SAM-2 SITE

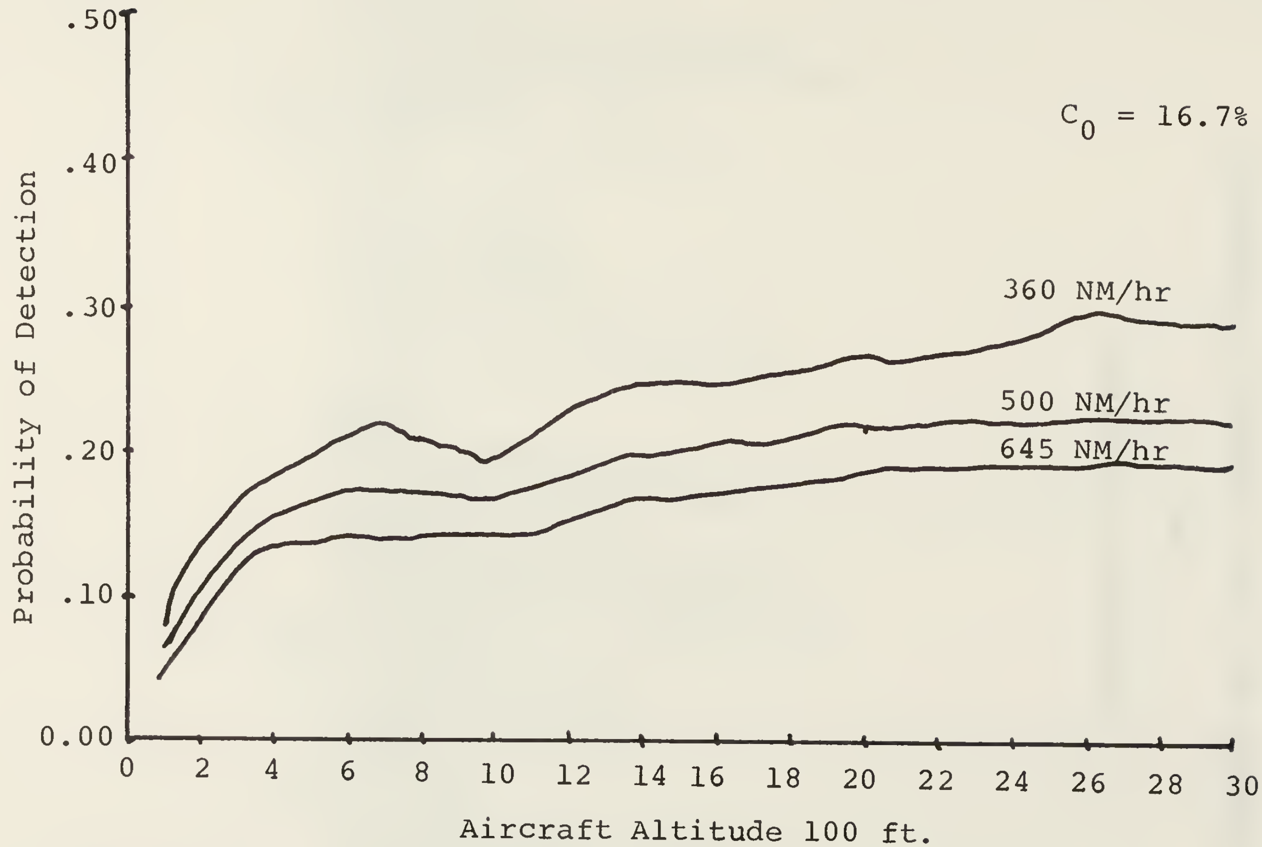


Figure 34

PROBABILITY OF DETECTING TARGET 25 AS A FUNCTION OF ALTITUDE

APPENDIX F

FORTRAN CODE FOR CONSTRAINT EQUATIONS AND DIFFERENCE EQUATIONS

```
C      COMPUTATION OF COST COEFFICIENTS FOR LP
       NTT=NT-2
       TESTO=1500.
       DO 5001 NUTS=2,NTT
       HOLD=TX(NUTS+1)-TX(NUTS)
       IF(HOLD.LT.TESTO) TESTO=HOLD
 5001  CONTINUE
       PRINT 5002, TESTO
 5002  FORMAT(2X,F12.5,////)
       L=0
       K=1
       TTX(1)=TX(2)
       TTY(1)=TY(2)
       COST(1)=C2(2)
       DO 900 J=2,NTT
       I=(TX(J+1)-TX(J))/TESTO
       BI=I
       DELJ=(TX(J+1)-TX(J))/BI
       L=L+I
       N=L-1
       DE=0.
       DO 901 M=K,N
       TTX(M+1)=TTX(M)+DELJ
       TTY(M+1)=(TTX(M+1)-TTX(M))*TS(J+1)+TTY(M)
       DE=DE+1.
       ZM=C2(J+1)-C2(J)
       IF(ZM.GT.0.) GO TO 1076
       COST(M+1)=C2(J)-(DE/BI)*ZM
       GO TO 901
 1076  COST(M+1)=C2(J)+(DE/BI)*ZM
  901  CONTINUE
       TTX(L+1)=TX(J+1)
       TTY(L+1)=TY(J+1)
       K=N+2
       COST(L+1)=C2(J+1)
  900  CONTINUE
       A1=32.2
       DPLUS(1)=TTX(2)-TTX(1)
       DS(1)=TTX(2)
       DMIN(1)=0.
       DO 902 I=2,L
       DPLUS(I)=TTX(I+1)-TTX(I)
       DMIN(I)=TTX(I)-TTX(I-1)
       DS(I)=TTX(I+1)-TTX(I-1)
       CO(I)=DS(I)
```

```
      T(I)=DPLUS(I)*TTY(I-1)-CO(I)*TTY(I)+DMIN(I)*TTY(I+1)
      CU(I)=(GPOS*A1*DPLUS(I)*DMIN(I)*DS(I))/(2.*V**2)-T(I)
      CL(I)=(GNEG*A1*DPLUS(I)*DMIN(I)*DS(I))/(2.*V**2)-T(I)
  902 CONTINUE
      CU(1)=0.
      CL(1)=0.
      PRINT 1005
 1005 FORMAT(17X,'X COORD',17X,'Y COORD',20X,'COST',13X,
     1'U RESTRAINT',13X,'L RESTRAINT',//)
      PRINT 1006,(TTX(I),TTY(I),COST(I),CU(I),CL(I),I=1,L)
 1006 FORMAT(5F24.8)
```

APPENDIX G

FORTRAN CODING FOR LOADING

AND

ITERATING LINEAR PROGRAM

```
      K6=L
 7009 DO 9961 K=1,75
      DO 9961 I=1,100
      A(K,I)=0.C
 9961 CONTINUE
      L=24
      K2=K1
      DO 9964 K=1,L
      K2=K2+1
      DO 9964 I=1,NAP
      BI=I
      ALPHA(K,I)=(BI*100.*COST(K2)+(1.-PD(I)))/(BI*100.)
      TLPHA(K,I)=ALPHA(K,I)*(BI*100.)
 9964 CONTINUE
      PRINT 9918,((TLPHA(K,I),I=1,NAP),K=1,L)
 9918 FORMAT(8F12.6,//)
      NJ=NAP+1
      CSUM=C.
      DO 9963 K=1,L
      TEST=ALPHA(K,NAP)
      TEST1=TLPHA(K,NAP)
      DO 9962 I=1,NAP
      J=NJ-I
      IF(ALPHA(K,J).LT.TEST) TEST=ALPHA(K,J)
      IF(TLPHA(K,J).LT.TEST1) GO TO 6969
      GO TO 9962
 6969 TEST1=TLPHA(K,J)
      BI=J
 9962 CONTINUE
      A(1,K)=TEST1/(BI*100.)
      A(K+49,K)=TEST1/(BI*100.)
      B(K+49)=TEST1
      PRINT 9921,TEST1,BI
 9921 FORMAT(///,10X,F12.6,6X,F12.6)
 9963 CONTINUE
C           HAVE LOADED COST ROW AT THIS POINT
C     NOW LOAD THE REMAINDER OF THE A-MATRIX
     M=0
      K3=K1+2
      MZ1=K3+47
      K9=2
      DO 9373 I=K3,MZ1,2
      N=K9
      NS=N+1
      M=M+1
```

```
      DO 9373 K=N,NS
      A(K,M)=OPLUS(I-1)
      A(K,M+1)=-CO(I)
      A(K,M+2)= OMIN(I+1)
      K9=NS+1
 9373 CONTINUE
      DO 9372 K=2,48,2
      A(K,K+25)=1.
      A(K+1,K+26)=-1.
 9372 CONTINUE
      DO 1991 K=1,24
      A(K+49,K+74)=-1.
 1991 CONTINUE
      N=K1
      DO 9960 I=2,48,2
      N=N+1
      B(I)=CU(N)
      B(I+1)=CL(N)
 9960 CONTINUE
      NZ=0
 9959 CALL PROG
      NZ=NZ+1
      ZJ(NZ)=Y(1)
      IF(NZ.GT.1) GO TO 9957
 9955 DO 9958 K=2,73
      IF(JH(K).GT.24) GO TO 9958
      L1L=JH(K)
      I=(X(K)+50.)/100.
      IF(I.GT.30) I=30
 2138 A(1,L1L)=ALPHA(L1L,I)
 9958 CONTINUE
      GO TO 9959
 9957 IF(DABS(( ZJ(NZ)-ZJ(NZ-1))/ZJ(NZ)).LE.EPSI) GO TO 9956
      GO TO 9955
 9956 PRINT 9954,Y(1)
 9954 FORMAT(1H1,34X,'THE COST OF THE OPTIMAL SOLUTION IS  '
     1,F15.4,///)
C     PRINT 1089,(TS(I),I=2,NTT)
C1089 FORMAT(1H1,10F12.4)
      END
```

APPENDIX H

FORTRAN CODING FOR REVISED SIMPLEX ALGORITHM

```
      SUBROUTINE PROG
      IMPLICIT REAL*8(A-H,O-Z),INTEGER*4(I-N)
      COMMON A(75,100),B(75),X(75),P(75),Y(75),F(75,75),Z(10
     10),DDT(100),ZJ(100),PINV(75,75),XI(75),TOL(10),ERR(10
     2),RUN(8),ZZ(3),TERR(8),KB(100),JH(75),INFIX(10),KOUT(1
     30),IOFIX(16)
      DATA N1N/1/
      EQUIVALENCE (INFIX(2),NCOL),(INFIX(4),MROW)
      D1=0.0
      E1=0.0
C
C     PERMANENT DATA
C        INFIX (3)=MAX NO. OF ROWS (CF. DIMENSION STATEMENT)
C        INFIX(7)=MAX INTERATION COUNT
C
      B(1)=C.
      INFIX(1)=4
      INFIX(3)=75
      INFIX(5)=2
      INFIX(6)=1
      INFIX(7)=150
      INFIX(8)=0
      TOL(1)=1.E-7
       TOL(2) = 1.E-5
      TOL(3) = -1.E-6
      TOL(4) = 1.E-7
       PRM = 0.
C
C     INPUT-- NOTE.. MROW=NO. OF ROWS PLUS ONE, BECAUSE
C      COST COEFFICIENTS ARE ENTERED AS ROW ONE.
C
      N1N=N1N+1
      IF(N1N.GT.2) GO TO 8
      READ                    3,MROW,NCOL,RUN
    3 FORMAT (2I5,7A8,A6)
 8081 IF (NCOL) 500, 500, 8
    8 CONTINUE
      PRINT                   29, RUN
   29 FORMAT (1H1,28X,7A8,A6)
C     PRINT                   100, (A(1,J),J=1,NCOL)
C 100 FORMAT (///10X,17HCOST COEFFICIENTS//(10X,8F13.6))
C     DO 105 I=2,MROW
C     K=I-1
C     PRINT                   102,K,(A(I,J),J=1,NCOL)
C 102 FORMAT (//3X,4HROW I2,1X,8E13.6/(10X,8F13.6))
```

```
C 105 PRINT                    28,K,B(I)
C  28 FORMAT (5H    B(,I2,1H),2X,E13.6)
C
      CALL SIMPLX
C
      PRINT                    29,RUN
      PRINT                    30,Y(1)
   30 FORMAT (///34X38HMINIMUM COST OF OBJECTIVE FUNCTION IS
     1E13.6,////,45X,30HBASIS VECTORS AND COEFFICIENTS///37X
     2,6HVECTOR,10X,30HCOEFFICIENT (X-ZERO COMPONENT)//)
C
C     BACK TO NORMAL
C
   40 PRINT                    43,(JH(I),X(I),I=2,MROW)
   43 FORMAT (37X,2HP(I2,1H),19X,E13.6)
C
      PRINT                    7733
 7733 FORMAT(1H1,47X,23HNEGATIVE OF Z(J) - C(J)///48X,1HJ,10
     1X,12H-(Z(J)-C(J))//)
C
C      DDT(I)=NEGATIVE OF Z(J)-C(J),JH(I) GIVES NUMBERS OF
C      BASIS VECTORS
C
      DO 60 I=1, NCOL
      DO 50 J=2,MROW
      IF (I-JH(J))50,45,50
   50 CONTINUE
      PRINT                    7734,I,DDT(I)
 7734 FORMAT (48X,I2,9X,E13.6)
      GO TO 60
   45 PRINT                    7735,I,DDT(I)
 7735 FORMAT (48X,I2,9X,E13.6,15H (BASIS VECTOR))
   60 CONTINUE
C
      K=MROW*MROW
C     DO 1001 I=1,MROW
C     L=0
C     DO 1001 J=I,K,MROW
C     L=L+1
C1001 PINV(I,L)=E(J,1)
C     PRINT 2000
C2000 FORMAT (1H1,52X,14HINVERSE MATRIX// )
C     DO 1010 I=2,MROW
C1010 PRINT                    2001,(PINV(I,J),J=2,MROW)
C2001 FORMAT (1HO/(6E18.6))
```

```
C
C      X(J) = P INVERSE * P(J)
C
C      PRINT 2002
C2002  FORMAT (1H1,9X,4HXI,S///)
C      DO 1003 L=1,NCOL
C      DO 1002 I=2,MROW
C      XI(I)=0.
C      DO 1002 J=2,MROW
C1002  XI(I)=XI(I)+PINV(I,J)*A(J,L)
C1003  PRINT                    2001,(XI(I),I=2,MROW)
C
       CALL ERR8R(KOUT(1))
       GO TO 1919
  500  CALL ERR8R (7)
       GO TO 1919
 1919  CONTINUE
       RETURN
       END



       SUBROUTINE ERR8R(KK)
       IF (KK-4) 2,70,62
   62  IF (KK-7) 63,72,2
   70  PRINT 71
   71  FORMAT (21HONO FEASIBLE SOLUTION)
       GO TO 2
   63  IF (KK-5) 2,64,67
   64  PRINT 65
   65  FORMAT (28HONO PIVOT, INFINITE SOLUTION)
       GO TO 2
   67  PRINT 68
   68  FORMAT(2X,'ITERATION LIMIT EXCEEDED')
       GO TO 2
   72  PRINT 73
   73  FORMAT(23HOILLEGAL INPUT QUANTITY)
    2  RETURN
       END
```

```
      SUBROUTINE SIMPLX
      IMPLICIT REAL*8(A-H,O-Z),INTEGER*4(I-N)
      COMMON A(7500),B(75),X(75),P(75),Y(75),E(5625),Z(100),DDT(100),
     5ZJ(100),
     1PINV(5625),XI(75),TOL(10),ERR(10),RUN(8),ZZ(3),TERR(8),KB(100),
     2JH(75),INFIX(10),KOUT(10),IOFIX(16)
      EQUIVALENCE  (INFLAG,IOFIX(1) ), (NZ, IOFIX(2) ) ,
     1             (ME,IOFIX(3) ), (MZ,IOFIX(4)), (MF,IOFIX(5)),
     2  (MC, IOFIX(6) ),  ( NCUT, IOFIX(7) ) , ( NVER, IOFIX(8) ),
     3 ( KZ,IOFIX(9) ), (ITER, IOFIX(10) ), (INVC , IOFIX(11) ) ,
     4 (NUMVR, IOFIX(12) ), ( NUMPV, IOFIX(13) ) ,
     5  (INFS, IOFIX(14)  ) , ( JT,  IOFIX(15) ) ,( LA  , IOFIX(16) ),
     6 (ZZ(1),TPIV), (ZZ(2),TZERO),(ZZ(3),TCOST)
      DO 1340  I= 1, 8
       TERR(I) = 0.0
      IOFIX(I+8)  =  0
 1340  IOFIX(I)  =  INFIX(I)
      N = NZ
      M = MZ
      K = KZ
      LA   =   0
      DO 1308  I = 1 , 3
 1308 ZZ(I)  =  TOL(I)
      TCOST=-DABS(TCOST)
      PMIX = PRM
      M2 = M*M
      INFS = 1
C
C     CHECK TO INSURE INPUT LIMITS NOT EXCEEDED
C
      IF (N)  1304, 1304, 1371
 1371  IF (M - MF ) 1304, 1304, 1372
 1372  IF (MF - MC)  1304, 1304, 1373
 1373  IF ( MC ) 1304 , 1304,  1374
 1374  IF (ME - M ) 1304, 1375, 1375
 1375 IF(  MOD (INFLAG, 4 )  - 1 )  1400,  1320,  100
C
C     DETERMINE WHICH VECTORS OF ORIGINAL TABLEAU ARE UNIT VECTORS
C     JH INDEXES WHICH VECTORS ARE IN BASIS
C
 1400   DO 1401 I = 1, M
 1401 JH(I) = 0
       KT  =  0
        DO 1402  J = 1, N
```

```
      KB(J) = 0
      MM  =  KT + MF
      LL  =  KT + M
      KQ  = 0
      DO  1403 L = MM , LL
      IF (A(L)) 1404, 1403, 1404
 1404 KQ = KQ+1
      LQ = L
 1403   CONTINUE
            IF (KQ - 1) 1402, 1405, 1402
 1405 IA = LQ- KT
         IF ( JH(IA) ) 1402, 1406, 1402
 1406 IF (A(LQ)*B(IA)) 1402, 1407, 1407
 1407 JH(IA) = J
      KB(J)  = IA
 1402 KT = KT + ME
 1320 CONTINUE
 1100 ASSIGN  1102  TO KPIV
      ASSIGN  1114  TO KJMY
      IF (LA)  1121, 1121, 1122
 1121 INVC = 0
 1122 NUMVR   =  NUMVR  +1
C
C     ESTABLISH IDENTITY MATRIX E
C
       DO 1101  I = 1, M2
 1101 E(I)=0.
      MM=1
       DO 1113  I = 1, M
      E(MM) =1.0
      X(I) = B(I)
 1113 MM = MM + M + 1
C
C     FLAG UNIT VECTORS
C
        DO 1110  I = MF, M
      IF (JH(I)) 1111, 1110, 1111
 1111 JH(I) = 12345
 1110 CONTINUE
      INFS = 1
C
C     ESTABLISH P INVERSE AND INITIAL BASIS
C
        DO 1102  JT= 1, N
      IF ( KB(JT))  600 , 1102 , 600
```

```
1114 TY = C.
        DO 1104  I = MF, M
     IF (JH(I)  - 12345 )  1104, 1105, 1104
1105 IF (DABS ( Y(I) ) -  TY )  1104, 1104, 1106
1106 IR    = I
     TY = DABS  ( Y(I) )
1104   CONTINUE
     IF  (TY - TPIV )     1107, 1108, 1108
1107 KB(JT)= 0
     GO TO 1102
1108 JH(IR) = JT
     KB(JT) = IR
     GO TO 900
1102     CONTINUE
       DO 1109  I = 1, M
     IF ( JH(I) - 12345  )  1109, 1112, 1109
1112 JH(I) = 0
1109   CONTINUE
 100 ASSIGN   705  TO  NDEL
     ASSIGN  100C  TO  KJMY
     ASSIGN   221  TO  KPIV
1200   JIN   =  C
     NEG = 0
     DO 1201 I = MF, M
     IF (DABS  ( X(I) )  - TZERO)  1202, 1203, 1203
1202 X(I) = 0.0
     GO TO 1201
1203 IF ( X(I) )  1208, 1201, 1205
1205 IF ( JH(I) )  1201, 1206, 1201
1208 NEG = 1
1206   JIN = 1
1201   CONTINUE
     IF (INFS - JIN ) 1320,  500,  200
 200 INFS = 0
 201 PMIX  =  0.0
C
C    P(J) = ELEMENTS OF FIRST ROW OF P INVERSE
C
 500 MM  = MC
 502 DO 503 J = 1, M
     P(J) = E(MM )
 503 MM  =MM  + M
     IF ( INFS )  501, 599, 501
 501 DO 504  J = 1, M
 504 P(J) = P(J)* PMIX
```

```
      DO 505  I = MF, M
      MM  =I
      IF  ( X(I) )  506, 507, 507
  506 DO 508  J = 1, M
      P(J) =  P(J) + E(MM )
  508 MM  = MM  + M
      GO TO 505
  507 IF (JH(I))  505, 509, 505
  509 DO 510  J = 1, M
      P(J) = P(J) - E(MM )
  510 MM  =  MM  +M
  505   CONTINUE
  599 CONTINUE
C
C     DETERMINE Z(J)-C(J)   MAXIMIZE WHEN POSITIVE TO FIND WHICH
C     VECTOR TO INTRODUCE  WHEN NEGATIVE SIGNALS THAT COST IS MINIMIZED
C
  700 JT = 0
      BB = TCOST
  701 DO  702  JM = 1, N
      DDT(JM)=0.
  703 IF ( KB(JM) )  702, 300, 702
  705 IF  ( DT - BB )  708, 702, 702
  708 BB = DT
      JT = JM
  702    CONTINUE
        IF  (JT)    203, 203, 600
  203 K = 3 + INFS
      KZ = K
      GO TO 257
C
C     Y= P INVERSE * P(J)
C
  600 DO 610  I= 1,M
  610 Y(I) =0.
      LP  =  JT*ME - ME
      LL = 0
      DO 605   I= 1,M
      LP = LP + 1
      IF  (A(LP))   601, 602, 601
  601 DO 606  J  =  1,M
      LL = LL + 1
  606 Y(J) = Y(J) + A(LP) * E(LL)
      GO TO 605
  602 LL = LL + M
```

```
 605 CONTINUE
 699 GO TO KJMY , ( 1000 , 1114 ,  1392  )
1000 IR = 0
     AA = 0.0
     IA  =  0
     DO 1050  I = MF,  M
     IF ( X(I) )  1050, 1041, 1050
1041 YI  = DABS  ( Y(I) )
     IF  (  YI  -  TPIV   )   1050, 1050, 1042
1042 IF  ( JH(I) )  1043, 1044, 1043
1043 IF  (IA)   1050, 1048, 1050
1048  IF  ( Y(I) )  1050, 1050, 1045
1044 IF   (IA)   1045, 1046, 1045
1045 IF   (  YI    -  AA   )   1050, 1050, 1047
1046    IA = 1
1047 AA  =  YI
     IR  =  I
C
C    DETERMINE PIVOT ELEMENT XY=A(IR,JT) BY MINIMUM THETA TECHNIQUE
C
1050 CONTINUE
     IF (IR)1099,1001,1099
1001 AA = 1.0E+20
     DO 1010 IT = MF , M
     IF  ( Y(IT)  -  TPIV )  1010, 1010, 1002
1002 IF  ( X(IT) ) 1010, 1010, 1003
1003 XY = X(IT) / Y(IT)
     IF ( XY - AA )  1004, 1005, 1010
1005 IF ( JH(IT))  1010, 1004, 1010
1004 AA = XY
     IR = IT
1010 CONTINUE
     IF (NEG)   1016, 1099, 1016
1016 BB = - TPIV
     DO 1030 I  = MF , M
     IF (X(I))   1012, 1030, 1030
1012  IF  ( Y(I)    -  BB  )   1022, 1030, 1030
1022 IF  (  Y(I) * AA  -  X(I)   )   1024, 1024, 1030
1024 BB  =  Y(I)
     IR  =  I
1030 CONTINUE
1099 CONTINUE
 206   IF( IR )   207, 207, 210
 207 K = 5
     KZ = K
```

```
257 IF (PMIX)    201, 400, 201
210 IF (ITER -NCUT )     900,  160,  160
C
C     P INVERSE BY POWER INVERSE METHOD
C
900 NUMPV  =  NUMPV  +  1
    YI = -Y(IR)
    Y(IR) = -1.
    LL = 0
903 DO 904  L =  IR, M2, M
    IF  ( E(L) )  905, 914, 905
914 LL = LL + M
    GO TO 904
905 XY =  E(L) / YI
    E(L) =0.
    DO 906  I  = 1, M
    LL= LL +1
906 E(LL) = E(LL) +XY* Y(I)
904 CONTINUE
     XY = X(IR) / YI
    X(IR) = 0.
    DO 908  I  = 1, M
908 X(I) = X(I) +XY* Y(I)
    Y(IR) = -YI
999  GO TO KPIV , ( 221, 1102 )
C
C     LABEL WHICH VECTORS IN BASIS
C
221  IA    = JH(IR)
    IF ( IA ) 213, 213, 214
214 KB( IA ) = 0
213 KB(JT)   = IR
    JH(IR)   = JT
    LA  =  0
    ITER    = ITER   +1
    INVC    = INVC   +1
    IF (INVC - NVER  ) 1200, 1320,1200
160 K = 6
    KZ = K
400  ASSIGN 410 TO NDEL
    DO 401 I = 1, M
401 Y(I) =-B(I)
    DO 402 I = 1, M
    JA = JH(I)
    IF (JA) 403, 402, 403
```

```
  403 IA =ME* (JA-1)
      DO 405 IT = 1, M
      IA = IA + 1
      IF(A(IA) )  415, 405, 415
  415 Y(IT) =Y(IT) +X(I) * A(IA)
  405 CONTINUE
  402 CONTINUE
      DO 481  I = 1, M
      YI   = Y(I)
      IF ( JH(I) )  472, 471, 472
  471  YI = YI + X(I)
  472 TERR(LA+1) = TERR(LA+1) + DABS(YI)
      IF  ( DABS (TERR(LA+2))- DABS (   YI   )   )   482, 481, 481
  482 TERR(LA+2) = YI
  481   CONTINUE
      DO 411  I = 1, M
      I36=I
      JM = JH(I36)
      IF (  JM     )  300 , 411 , 300
  410 TERR(LA+3)  =   TERR(LA +3)  +  DABS(DT)
      IF  (DABS(TERR(LA+4))    -    DABS(DT)  )  413, 411, 411
  413  TERR(LA+4)  =  DT
  411 CONTINUE
      IF (LA)   193, 191,  193
  191 LA   =  4
      IF (INFLAG  -  4  )  1320,  193,  193
  193 IF  (K-5)    1392,  194,  1392
  194 ASSIGN 1392 TO KJMY
      GO TO 600
 1304 K   =  7
      KZ = K
 1392   DO  1309  I=  1, 8
 1309 ERR(I)           =   TERR(I)
       DO 1329  I = 1, 7
 1329 KOUT(I)  =  IOFIX(I+8)
      RETURN
C
C     DDT = '(Z(J)'C(J))
C
  300 DT = 0.
       LL  = (JM - 1) * ME
  301 DO  303   MM  = 1, M
      LL   =  LL  + 1
      IF ( A( LL ))304, 303, 304
  304 DT = DT + P( MM ) * A ( LL )
```

```
303 CONTINUE
    DOT(JM)=DT
399   GO TO NDEL , ( 410 , 705 )
    END
```

APPENDIX I

DATA

Radar Probability of Detection, Least Squares Linear Fit to Radar Probability of Detection Curve and Time in Seconds Which The Aircraft is Exposed Because a Linear Fit is Used.

Terrain Point 3	X Coordinate 21800 PHI	Y Coordinate 6410 YYY	EXPOSED TIME
	0.0752951	0.0894802	-7.5116070
	0.0752951	0.0920347	-8.8642815
	0.0806841	0.0945891	-7.3632514
	0.1003172	0.0971435	1.6806020
	0.1024214	0.0996980	1.4421795
	0.1046953	0.1022524	1.2936351
	0.1072998	0.1048068	1.3201058
	0.1096390	0.1073613	1.2061686
	0.1116852	0.1099157	0.9370140
	0.1185452	0.1124701	3.2170154
	0.1195247	0.1150245	2.3829920
	0.1232376	0.1175790	2.9964993
	0.1273961	0.1201334	3.8459005
	0.1300468	0.1226878	3.8968925
	0.1332816	0.1252423	4.2571646
	0.1358948	0.1277967	4.2882800
	0.1374469	0.1303511	3.7574882
	0.1380953	0.1329056	2.7481972
	0.1387174	0.1354600	1.7249437
	0.1393147	0.1380144	0.6885780
	0.1399269	0.1405688	-0.3399555
	0.1408025	0.1431233	-1.2289501
	0.1422951	0.1456777	-1.7912246
	0.1489076	0.1482321	0.3576832
	0.1500733	0.1507866	-0.3776964
	0.1511370	0.1533410	-1.1670789
	0.1521136	0.1558954	-2.0026362
	0.1530149	0.1584498	-2.8780351
	0.1538507	0.1610043	-3.7880939
	0.1546292	0.1635587	-4.7285292

Optimal Cost and Terrain Clearance (in feet) Without Imposition of Acceleration Constraints at Each of 24 Terrain Points Being Examined. Example is for: Terrain One, Points 1-24, Navigation Target 10, Aircraft Speed 360 Knots.

$\alpha_k(c_k)c_k$	C_k
.134505	1100
.137710	1100
.140916	1100
.143956	1000
.146870	1000
.149784	1000
.152698	1000
.155612	1000
.158526	1000
.097236	1800
.099899	1800
.102562	1800
.105224	1800
.106176	1800
.107127	1800
.108078	1800
.109030	1800
.109981	1800
.110932	1800
.111884	1800
.112835	1800
.113787	1800
.114738	1800
.115626	1200

The Radar Cost and G^+ and G^- Constraints

At Each Terrain Point

X COORD	Y COORD	COST	U RESTRAINT	L RESTRAINT
0.0	6000.00	0.00001437		
703.22	6013.22	0.00001473	15146.17	- 30292.35
1406.45	6026.45	0.00001509	15146.17	- 30292.35
2109.67	6039.67	0.00001545	15146.17	- 30292.35
2812.90	6052.90	0.00001581	15146.17	- 30292.35
3516.12	6066.12	0.00001617	15146.17	- 30292.35
4219.35	6079.35	0.00001653	15146.17	- 30292.35
4922.58	6092.58	0.00001689	15146.17	- 30292.35
5625.80	6105.80	0.00001725	15146.17	- 30292.35
6329.03	6119.03	0.00001761	15146.17	- 30292.35
7032.25	6132.25	0.00001797	15146.17	- 30292.35
7735.48	6145.48	0.00001833	15146.17	- 30292.35
8438.70	6158.70	0.00001869	15146.17	- 30292.35
9141.93	6171.93	0.00001905	15146.17	- 30292.35
9845.16	6185.16	0.00001941	15146.17	- 30292.35
10548.38	6198.38	0.00001978	15146.17	- 30292.35
11251.61	6211.61	0.00002014	15146.17	- 30292.35
11954.83	6224.83	0.00002050	15146.17	- 30292.35
12658.06	6238.06	0.00002086	15146.17	- 30292.35
13361.29	6251.29	0.00002122	15146.17	- 30292.35
14064.51	6264.51	0.00002158	15146.17	- 30292.35
14767.74	6277.74	0.00002194	15146.17	- 30292.35
15470.96	6290.96	0.00002230	15146.17	- 30292.35
16174.19	6304.19	0.00002266	15146.17	- 30292.35
16877.41	6317.41	0.00002302	15146.17	- 30292.35
17580.64	6330.64	0.00002338	15146.17	- 30292.35
18283.87	6343.87	0.00002374	15146.17	- 30292.35
18987.09	6357.09	0.00002410	15146.17	- 30292.35
19690.32	6370.32	0.00002446	15146.17	- 30292.35
20393.54	6383.54	0.00002482	15146.17	- 30292.35
21096.77	6396.77	0.00002518	15146.17	- 30292.35
21800.00	6410.00	0.00002554	71798.95	- 127047.25
22600.00	6553.33	0.00002647	22299.16	- 44598.33
23400.00	6696.66	0.00002740	22299.16	- 44598.33
24200.00	6840.00	0.00002276	108147.04	- 45372.57

Navigation Target Number		Terrain Number 1 Points 1-24	Terrain Number 1 Points 101-124	Terrain Number 1 Points 283-306	Terrain Number Two Points 1-24	Terrain Number Two Points 25-48	Terrain Number Two Points 73-96	Terrain Number Two Points 101-124	Terrain Number Two Points 251-274	$\sum$ Rows	Row Means
10	360	3.05	5.14	5.73	1.35	1.94	5.86	3.70	4.54	67.5	4.21
	500	3.52	5.92	6.48	1.62	2.33	6.59	4.3	5.35		
14	360	24.0	25.0	27.3	23.5	24.6	25.4	24.5	24.4	397.5	24.84
	500	24.4	26.0	25.0	23.7	23.9	25.9	25.2	24.7		
25	360	20.3	21.3	21.3	17.9	18.8	21.7	20.8	20.4	331.8	20.73
	500	20.7	21.7	21.9	19.5	20.1	22.4	21.3	21.7		
$\sum$ Columns		95.97	105.1	107.7	87.57	91.67	107.9	99.8	101.09	796.8	
Column Means		15.99	17.51	17.95	14.59	15.27	17.98	16.63	16.84		

Minimum Costs as Computed by Linear Program for 48 Computer Runs

TABLE 6

COST DATA TABLE

Tables 7 through 54

DATA SUMMARY SHEETS FOR COMPUTER RUNS

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimum Altitude No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
1	0	6066	1100	7166	1100	7166
2	745	6072	1100	7172	1186	7258
3	1490	6078	1100	7178	1272	7350
4	2235	6085	1000	7085	1310	7395
5	2980	6091	1000	7091	1372	7463
6	3726	6097	1000	7097	1458	7555
7	4471	6104	1000	7104	1562	7666
8	5216	6110	1000	7110	1689	7799
9	5961	6116	1000	7116	1766	7882
10	6706	6123	1800	7923	1810	7933
11	7496	6001	1800	7801	1800	7801
12	8287	5879	1800	7679	1871	7750
13	9078	5757	1800	7557	1882	7639
14	9792	5733	1800	7533	1923	7656
15	10508	5709	1800	7509	1894	7603
16	11223	5686	1800	7486	1887	7573
17	11937	5662	1800	7462	1902	7564
18	12653	5638	1800	7438	1873	7511
19	13368	5615	1800	7415	1866	7471
20	14081	5591	1800	7391	1822	7413
21	14797	5567	1800	7367	1800	7367
22	15512	5544	1800	7344	1800	7344
23	16227	5520	1800	7320	1823	7343
24	16942	5496	1200	6696	1868	7374

Terrain	1
Aircraft Velocity	360
Navigation Tgt. No.	10
Optimal Cost	3.06

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimum Altitude No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
1	0	6066	1300	7366	1300	7366
2	745	6072	1200	7272	1371	7443
3	1490	6078	1200	7278	1443	7521
4	2235	6085	1200	7285	1526	7611
5	2980	6091	1200	7291	1585	7676
6	3726	6097	1200	7297	1656	7753
7	4471	6104	1200	7304	1728	7832
8	5216	6110	1200	7310	1811	7921
9	5961	6116	1200	7316	1869	7985
10	6706	6123	1900	8023	1900	8023
11	7496	6001	1900	7901	1905	7906
12	8287	5879	1900	7779	2016	7895
13	9078	5757	1900	7657	2096	7853
14	9792	5733	1900	7633	2144	7877
15	10508	5709	1900	7609	2070	7779
16	11223	5686	1900	7586	2007	7693
17	11937	5662	1900	7562	1955	7617
18	12653	5638	1900	7538	1915	7553
19	13368	5615	1800	7415	1852	7467
20	14081	5591	1800	7391	1800	7391
21	14797	5567	1700	7267	1758	7325
22	15512	5544	1700	7244	1728	7272
23	16227	5520	1700	7220	1708	7228
24	16942	5496	1700	7196	1700	7196

Terrain	1
Aircraft Velocity	500
Navigation Tgt. No.	10
Optimal Cost	3.52

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimum Altitude No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
1	0	6066	200	6266	200	6266
2	745	6072	200	6272	200	6272
3	1490	6078	200	6278	200	6278
4	2235	6085	200	6285	200	6285
5	2980	6091	200	6291	200	6291
6	3726	6097	200	6297	200	6297
7	4471	6104	200	6304	200	6304
8	5216	6110	200	6310	200	6310
9	5961	6116	200	6316	200	6316
10	6706	6123	200	6323	225	6348
11	7496	6001	200	6201	200	6201
12	8287	5879	200	6079	254	6133
13	9078	5757	200	5957	248	6005
14	9792	5733	200	5933	272	6005
15	10508	5709	200	5909	226	5935
16	11223	5686	200	5886	202	5888
17	11937	5662	200	5862	200	5862
18	12653	5638	200	5838	200	5838
19	13368	5615	200	5815	200	5815
20	14081	5591	200	5791	200	5791
21	14797	5567	200	5767	200	5767
22	15512	5544	200	5744	200	5744
23	16227	5520	200	5720	200	5720
24	16942	5496	200	5696	200	5696

Terrain	1
Aircraft Velocity	360
Navigation Tgt. No.	14
Optimal Cost	23.96

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimum Altitude No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
1	0	6066	200	6266	200	6266
2	745	6072	200	6272	200	6272
3	1490	6078	200	6278	200	6278
4	2235	6085	200	6285	200	6285
5	2980	6091	100	6191	194	6285
6	3726	6097	100	6197	201	6298
7	4471	6104	100	6204	219	6323
8	5216	6110	100	6210	249	6359
9	5961	6116	100	6216	292	6408
10	6706	6123	300	6423	309	6432
11	7496	6001	300	6301	300	6301
12	8287	5879	300	6179	397	6276
13	9078	5757	300	6057	462	6219
14	9792	5733	300	6033	496	6229
15	10508	5709	300	6009	435	6144
16	11223	5686	300	5986	385	6071
17	11937	5662	300	5962	347	6009
18	12653	5638	300	5938	320	5958
19	13368	5615	300	5915	304	5919
20	14081	5591	300	5891	300	5891
21	14797	5567	300	5867	300	5867
22	15512	5544	300	5844	300	5844
23	16227	5520	300	5820	300	5820
24	16942	5496	300	5796	300	5796

Terrain	1
Aircraft Velocity	500
Navigation Tgt. No.	14
Optimal Cost	24.44

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimum Altitude No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
1	0	6066	700	6766	700	6766
2	745	6072	700	6772	1058	7130
3	1490	6078	700	6778	1415	7493
4	2235	6085	700	6785	1735	7820
5	2980	6091	700	6791	2007	8098
6	3726	6097	600	6697	2230	8327
7	4471	6104	600	6794	2394	8498
8	5216	6110	600	6710	2513	8623
9	5961	6116	600	6716	2582	8698
10	6706	6123	2600	8723	2600	8723
11	7496	6001	700	6701	2568	8569
12	8287	5879	700	6579	2615	8494
13	9078	5757	700	6457	2601	8358
14	9792	5733	700	6433	2528	8261
15	10508	5709	700	6409	2306	8015
16	11223	5686	700	6386	2042	7728
17	11937	5662	700	6362	1798	7460
18	12653	5638	700	6338	1577	7215
19	13368	5615	700	6315	1377	6992
20	14081	5591	700	6291	1200	6791
21	14797	5567	700	6267	1044	6611
22	15512	5544	700	6244	910	6454
23	16227	5520	700	6220	794	6314
24	16942	5496	700	6196	700	6196

Terrain 1

Aircraft Velocity 360

Navigation Tgt. No. 25

Optimal Cost 20.34

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimum Altitude No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
1	0	6066	500	6566	500	6566
2	745	6072	500	6572	500	6572
3	1490	6078	500	6578	500	6578
4	2235	6085	500	6585	500	6585
5	2980	6091	500	6591	513	6604
6	3726	6097	500	6597	539	6636
7	4471	6104	500	6604	574	6678
8	5216	6110	500	6610	622	6732
9	5961	6116	500	6616	674	6790
10	6706	6123	700	6823	700	6823
11	7496	6001	700	6701	700	6701
12	8287	5879	700	6579	806	6685
13	9078	5757	700	6457	880	6637
14	9792	5733	700	6433	923	6656
15	10508	5709	700	6409	858	6567
16	11223	5686	700	6386	804	6490
17	11937	5662	700	6362	761	6423
18	12653	5638	700	6338	729	6367
19	13368	5615	700	6315	709	6324
20	14081	5591	700	6291	700	6291
21	14797	5567	700	6267	700	6267
22	15512	5544	700	6244	700	6244
23	16227	5520	700	6220	700	6220
24	16942	5496	700	6196	700	6196

Terrain	1
Aircraft Velocity	500
Navigation Tgt. No.	25
Optimal Cost	20.72

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
101	75,163	5912	1000	6912	1066	6978
102	75,872	5796	1000	6796	1022	6818
103	76,581	5681	1000	6681	1000	6681
104	77,291	5566	1000	6566	1000	6566
105	78,000	5450	1000	6450	1013	6463
106	78,753	5473	1000	6473	1047	6520
107	79,506	5495	1000	6495	1101	6596
108	80,259	5518	1000	6518	1042	6560
109	81,012	5540	1000	6540	1011	6551
110	81,764	5562	1000	6562	1000	6562
111	82,517	5585	1000	6585	1000	6585
112	83,270	5608	1000	6608	1027	6635
113	84,023	5630	1000	6630	1018	6648
114	84,893	5567	1000	6567	1035	6602
115	85,762	5504	1000	6504	1000	6504
116	86,464	5533	1000	6533	1005	6538
117	87,166	5562	1000	6562	1050	6612
118	87,868	5591	1000	6591	1026	6617
119	88,570	5620	1000	6620	1013	6633
120	89,272	5649	1000	6649	1017	6666
121	89,974	5677	1000	6677	1000	6677
122	90,676	5706	1000	6706	1000	6706
123	91,378	5735	1000	6735	1022	6757
124	92,080	5764	1000	6764	1000	6764

Terrain	1
Aircraft Velocity	360
Navigation Tgt. No.	10
Optimal Cost	5.14

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
101	75,163	5912	1200	7112	1209	7121
102	75,872	5796	1200	6996	1200	6996
103	76,581	5681	1100	6781	1203	6884
104	77,291	5566	1100	6666	1217	6783
105	78,000	5450	1100	6550	1241	6791
106	78,753	5473	1000	6473	1276	6649
107	79,506	5495	1000	6495	1321	6816
108	80,259	5518	1000	6518	1241	6759
109	81,012	5540	1000	6540	1183	6723
110	81,764	5562	1000	6562	1125	6687
111	82,517	5585	1000	6585	1081	6666
112	83,270	5608	1000	6608	1051	6659
113	84,023	5630	1000	6630	1034	6664
114	84,893	5567	1000	6567	1031	6598
115	85,762	5504	1000	6504	1000	6504
116	86,464	5533	1000	6533	1031	6564
117	87,166	5562	1000	6562	1083	6645
118	87,868	5591	1000	6591	1052	6643
119	88,570	5620	1000	6620	1019	6639
120	89,272	5649	1000	6649	1005	6654
121	89,974	5677	1000	6677	1000	6677
122	90,676	5706	1000	6706	1000	6706
123	91,378	5735	1000	6735	1011	6746
124	92,080	5764	1000	6764	1000	6764

Terrain	1
Aircraft Velocity	500
Navigation Tgt. No.	10
Optimal Cost	5.92

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
101	75,163	5912	200	6112	200	6112
102	75,872	5796	200	5996	200	5996
103	76,581	5681	100	5781	162	5843
104	77,291	5566	100	5666	234	5800
105	78,000	5450	100	5550	151	5601
106	78,753	5473	100	5573	177	5650
107	79,506	5495	100	5595	224	5719
108	80,259	5518	100	5618	156	5674
109	81,012	5540	100	5640	119	5659
110	81,764	5562	100	5662	100	5662
111	82,517	5585	100	5685	100	5685
112	83,270	5608	100	5708	100	5708
113	84,023	5630	100	5730	100	5730
114	84,893	5567	100	5667	127	5694
115	85,762	5504	100	5604	100	5604
116	86,464	5533	100	5633	103	5636
117	87,166	5562	100	5662	145	5707
118	87,868	5591	100	5691	118	5709
119	88,570	5620	100	5720	100	5720
120	89,272	5649	100	5749	100	5749
121	89,974	5677	100	5777	100	5777
122	90,676	5706	100	5806	100	5806
123	91,378	5735	100	5835	100	5835
124	92,080	5764	100	5864	100	5864

Terrain	1
Aircraft Velocity	360
Navigation Tgt. No.	14
Optimal Cost	24.97

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
101	75,163	5912	100	6012	172	6084
102	75,872	5796	100	5896	107	5903
103	76,581	5681	100	5781	124	5805
104	77,291	5566	100	5666	153	5719
105	78,000	5450	100	5550	192	5642
106	78,753	5473	100	5573	241	5714
107	79,506	5495	100	5595	300	5795
108	80,259	5518	100	5618	235	5753
109	81,012	5540	100	5640	189	5729
110	81,764	5562	100	5662	146	5708
111	82,517	5585	100	5685	117	5702
112	83,270	5608	100	5708	102	5710
113	84,023	5630	100	5730	100	5730
114	84,893	5567	100	5667	112	5679
115	85,762	5504	100	5604	100	5604
116	86,464	5533	100	5633	150	5683
117	87,166	5562	100	5662	198	5760
118	87,868	5591	100	5691	163	5754
119	88,570	5620	100	5720	126	5746
120	89,272	5649	100	5749	108	5757
121	89,974	5677	100	5777	100	5777
122	90,676	5706	100	5806	100	5806
123	91,378	5735	100	5835	100	5835
124	92,080	5764	100	5864	100	5864

Terrain	1
Aircraft Velocity	500
Navigation Tgt. No.	14
Optimal Cost	25.96

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
101	75,163	5912	600	6512	600	6512
102	75,872	5796	600	6396	600	6396
103	76,581	5681	600	6281	600	6281
104	77,291	5566	600	6166	600	6166
105	78,000	5450	600	6050	600	6050
106	78,753	5473	300	5773	585	6058
107	79,506	5495	300	5795	591	6086
108	80,259	5518	300	5818	483	6001
109	81,012	5540	300	5840	410	5950
110	81,764	5562	300	5862	347	5909
111	82,517	5585	300	5885	310	5895
112	83,270	5608	300	5908	300	5908
113	84,023	5630	300	5930	300	5930
114	84,893	5567	300	5867	327	5894
115	85,762	5504	300	5804	300	5804
116	86,464	5533	300	5833	303	5836
117	87,166	5562	300	5862	345	5907
118	87,868	5591	300	5891	318	5909
119	88,570	5620	300	5920	300	5920
120	89,272	5649	300	5949	300	5949
121	89,974	5677	300	5977	300	5977
122	90,676	5706	300	6006	300	6006
123	91,378	5735	300	6035	300	6035
124	92,080	5764	300	6064	300	6064

Terrain	1
Aircraft Velocity	360
Navigation Tgt. No.	25
Optimal Cost	21.25

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
101	75,163	5912	500	6412	500	6412
102	75,872	5796	400	6196	498	6294
103	76,581	5681	400	6081	507	6188
104	77,291	5566	400	5966	528	6094
105	78,000	5450	400	5850	558	6008
106	78,753	5473	400	5873	598	6071
107	79,506	5495	400	5895	650	6145
108	80,259	5518	400	5918	576	6094
109	81,012	5540	400	5940	524	6064
110	81,764	5562	400	5962	472	6034
111	82,517	5585	400	5985	434	6019
112	83,270	5608	400	6008	410	6018
113	84,023	5630	400	6030	400	6030
114	84,893	5567	400	5967	403	5970
115	85,762	5504	400	5904	400	5904
116	86,464	5533	400	5933	458	5991
117	87,166	5562	400	5962	505	6067
118	87,868	5591	400	5991	468	6059
119	88,570	5620	400	6020	428	6048
120	89,272	5649	400	6049	409	6058
121	89,974	5677	400	6077	400	6077
122	90,676	5706	400	6106	400	6106
123	91,378	5735	400	6135	400	6135
124	92,080	5764	400	6164	400	6164

Terrain	1
Aircraft Velocity	500
Navigation Tgt. No.	25
Optimal Cost	21,71

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
283	216,300	7633	1000	8633	1000	8633
284	217,013	7736	1000	8736	1316	9052
285	217,726	7839	1000	8839	1213	9052
286	218,439	7942	1000	8942	1133	9075
287	219,152	8045	1000	9045	1074	9119
288	219,882	8024	1000	9024	1038	9062
289	220,611	8003	1000	9003	1024	9027
290	221,341	7982	1000	8982	1032	9014
291	222,070	7961	1000	8961	1000	8961
292	222,800	7940	1000	8940	1045	8985
293	223,600	8050	1000	9050	1044	9094
294	224,400	8160	1000	9160	1040	9200
295	225,151	8211	1000	9211	1060	9271
296	225,902	8261	1000	9261	1103	9364
297	226,653	8312	1000	9312	1038	9350
298	227,350	8223	1000	9223	1004	9227
299	228,047	8134	1000	9134	1003	9137
300	228,745	8046	1000	9046	1027	9073
301	229,442	7957	1000	8957	1000	8957
302	230,139	7868	1000	8868	1070	8938
303	230,851	7831	1000	8831	1098	8929
304	231,563	7795	1000	8795	1085	8880
305	232,275	7758	1000	8758	1034	8792
306	232,987	7721	1000	8721	1000	8721

Terrain	1
Aircraft Velocity	360
Navigation Tgt. No.	10
Optimal Cost	5.73

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
283	216,300	7633	1000	8633	1000	8633
284	217,013	7736	1000	8736	1356	9092
285	217,726	7839	1000	8839	1275	9114
286	218,439	7942	1000	8942	1205	9147
287	219,152	8045	1000	9045	1147	9192
288	219,882	8024	1000	9024	1101	9125
289	220,611	8003	1000	9003	1067	9070
290	221,341	7982	1000	8982	1044	9026
291	222,070	7961	1000	8961	1000	8961
292	222,800	7940	1000	8940	1054	8994
293	223,600	8050	1000	9050	1090	9140
294	224,400	8160	1000	9160	1138	9298
295	225,151	8211	1000	9211	1199	9410
296	225,902	8261	1000	9261	1272	9533
297	226,653	8312	1100	9412	1223	9535
298	227,350	8223	1000	9223	1190	9413
299	228,047	8134	1000	9134	1187	9321
300	228,745	8046	1100	9146	1157	9203
301	229,442	7957	1100	9057	1100	9057
302	230,139	7868	1100	8968	1162	9030
303	230,851	7831	1100	8931	1203	9034
304	231,563	7795	1100	8895	1222	9017
305	232,275	7758	1000	8758	1220	8978
306	232,987	7721	1000	8721	1228	8949

Terrain	1
Aircraft Velocity	500
Navigation Tgt. No.	10
Optimal Cost	6.48

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
283	216,300	7633	100	7733	100	7733
284	217,013	7736	100	7836	416	8152
285	217,726	7839	100	7939	313	8152
286	218,439	7942	100	8042	233	8175
287	219,152	8045	100	8145	174	8219
288	219,882	8024	100	8124	138	8162
289	220,611	8003	100	8103	124	8127
290	221,341	7982	100	8082	132	8114
291	222,070	7961	100	8061	100	8061
292	222,800	7940	100	8040	145	8085
293	223,600	8050	100	8150	141	8191
294	224,400	8160	100	8260	139	8299
295	225,151	8211	100	8311	158	8369
296	225,902	8261	100	8361	201	8462
297	226,653	8312	100	8412	135	8447
298	227,350	8223	100	8323	100	8323
299	228,047	8134	100	8234	152	8287
300	228,745	8046	100	8146	152	8198
301	229,442	7957	100	8057	100	8057
302	230,139	7868	100	7968	145	8013
303	230,851	7831	100	7931	149	7980
304	231,563	7795	100	7895	115	7910
305	232,275	7758	100	7858	100	7858
306	232,987	7721	100	7821	100	7821

Terrain	1
Aircraft Velocity	360
Navigation Tgt. No.	14
Optimal Cost	27.27

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
283	216,300	7633	100	7733	100	7733
284	217,013	7736	100	7836	454	8190
285	217,726	7839	100	7939	372	8211
286	218,439	7942	100	8042	301	8243
287	219,152	8045	100	8145	241	8286
288	219,882	8024	100	8124	194	8218
289	220,611	8003	100	8103	158	8161
290	221,341	7982	100	8082	133	8115
291	222,070	7961	100	8061	100	8061
292	222,800	7940	100	8040	165	8105
293	223,600	8050	100	8150	209	8259
294	224,400	8160	100	8260	266	8426
295	225,151	8211	100	8311	336	8547
296	225,902	8261	100	8361	418	8679
297	226,653	8312	100	8412	377	8689
298	227,350	8223	100	8323	306	8529
299	228,047	8134	100	8234	264	8398
300	228,745	8046	100	8146	196	8242
301	229,442	7957	100	8057	100	8057
302	230,139	7868	100	7968	124	7992
303	230,851	7831	100	7931	126	7957
304	231,563	7795	100	7895	108	7903
305	232,275	7758	100	7858	100	7858
306	232,987	7721	100	7821	100	7821

Terrain	1
Aircraft Velocity	500
Navigation Tgt. No.	14
Optimal Cost	24.96

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
283	216,300	7633	300	7933	300	7933
284	217,013	7736	300	8036	615	8351
285	217,726	7839	300	8139	512	8351
286	218,439	7942	300	8242	430	8372
287	219,152	8045	300	8345	370	8415
288	219,882	8024	300	8324	334	8358
289	220,611	8003	300	8303	319	8322
290	221,341	7982	300	8282	326	8308
291	222,070	7961	300	8261	300	8261
292	222,800	7940	300	8240	351	8291
293	223,600	8050	300	8350	357	8407
294	224,400	8160	300	8460	387	8547
295	225,151	8211	300	8511	442	8653
296	225,902	8261	300	8561	520	8781
297	226,653	8312	300	8612	490	8802
298	227,350	8223	300	8523	491	8714
299	228,047	8134	300	8434	579	8713
300	228,745	8046	600	8646	615	8661
301	229,442	7957	600	8557	600	8557
302	230,139	7868	600	8468	682	8550
303	230,851	7831	600	8431	722	8553
304	231,563	7795	600	8395	720	8515
305	232,275	7758	300	8058	680	8438
306	232,987	7721	300	8021	602	8323

Terrain	1
Aircraft Velocity	360
Navigation Tgt. No.	25
Optimal Cost	21.26

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
283	216,300	7633	300	7933	300	7933
284	217,013	7736	300	8036	669	8405
285	217,726	7839	300	8139	600	8439
286	218,439	7942	300	8242	543	8485
287	219,152	8045	300	8345	498	8543
288	219,882	8024	300	8324	464	8488
289	220,611	8003	300	8303	442	8445
290	221,341	7982	400	8382	431	8413
291	222,070	7961	400	8361	400	8361
292	222,800	7940	400	8340	466	8406
293	223,600	8050	300	8350	512	8562
294	224,400	8160	300	8460	550	8710
295	225,151	8211	300	8511	601	8812
296	225,902	8261	300	8561	664	8925
297	226,653	8312	400	8712	605	8917
298	227,350	8223	400	8623	551	8774
299	228,047	8134	400	8534	528	8662
300	228,745	8046	400	8446	477	8523
301	229,442	7957	400	8357	400	8357
302	230,139	7868	400	8268	442	8310
303	230,851	7831	400	8231	463	8294
304	231,563	7795	400	8195	462	8241
305	232,275	7758	400	8158	440	8198
306	232,987	7721	400	8121	400	8121

Terrain	1
Aircraft Velocity	500
Navigation Tgt. No.	25
Optimal Cost	21.89

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
1	0	6000	2600	8600	3078	9078
2	703	6013	2600	8613	2979	8992
3	1406	6026	2600	8626	2880	8906
4	2110	6040	2600	8640	2781	8821
5	2813	6053	2600	8653	2703	8756
6	3516	6066	2600	8666	2647	8713
7	4219	6079	2600	8679	2613	8692
8	4923	6093	2600	8693	2600	8693
9	5626	6106	2600	8706	2609	8715
10	6329	6119	2600	8719	2639	8758
11	7032	6132	2600	8732	2626	8758
12	7735	6145	2600	8745	2635	8780
13	8438	6159	2600	8759	2600	8759
14	9142	6172	2200	8372	2575	8747
15	9845	6185	2200	8385	2572	8757
16	10548	6198	2200	8398	2525	8723
17	11252	6212	2200	8412	2500	8712
18	11955	6225	2200	8425	2497	8722
19	12658	6238	2200	8438	2456	8694
20	13361	6251	2200	8451	2435	8686
21	14064	6265	2200	8465	2374	8639
22	14768	6278	2200	8478	2333	8611
23	15471	6291	2200	8491	2259	8550
24	16174	6304	2200	8504	2200	8504

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	10
Optimal Cost	1.35

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
1	0	6000	3000	9000	3024	9024
2	703	6013	2800	8813	2973	8986
3	1406	6026	2800	8826	2921	8947
4	2110	6040	2800	8840	2870	8910
5	2813	6053	2800	8853	2829	8882
6	3516	6066	2800	8866	2800	8866
7	4219	6079	2600	8679	2782	8861
8	4923	6093	2600	8693	2742	8835
9	5626	6106	2600	8706	2713	8819
10	6329	6119	2600	8719	2694	8813
11	7032	6132	2600	8732	2654	8786
12	7735	6145	2600	8745	2625	8770
13	8438	6159	2600	8759	2607	8766
14	9142	6172	2600	8772	2600	8772
15	9845	6185	2600	8785	2604	8789
16	10548	6198	2600	8798	2603	8801
17	11252	6212	2600	8812	2613	8825
18	11955	6225	2600	8825	2632	8857
19	12658	6238	2600	8838	2631	8869
20	13361	6251	2600	8851	2641	8892
21	14064	6265	2600	8865	2629	8894
22	14768	6278	2600	8878	2628	8906
23	15471	6291	2600	8891	2610	8901
24	16174	6304	2600	8904	2600	8904

Terrain 2

Aircraft Velocity 500

Navigation Tgt. No. 10

Optimal Cost 1.62

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
1	0	6000	200	6200	200	6200
2	703	6013	200	6213	200	6213
3	1406	6026	200	6226	200	6226
4	2110	6040	200	6240	200	6240
5	2813	6053	200	6253	200	6253
6	3516	6066	200	6266	200	6266
7	4219	6079	200	6279	200	6279
8	4923	6093	200	6293	200	6293
9	5626	6106	200	6306	200	6306
10	6329	6119	200	6319	200	6319
11	7032	6132	200	6332	200	6332
12	7735	6145	200	6345	200	6345
13	8438	6159	200	6359	200	6359
14	9142	6172	200	6372	200	6372
15	9845	6185	200	6385	200	6385
16	10548	6198	200	6398	200	6398
17	11252	6212	200	6412	200	6412
18	11955	6225	200	6425	200	6425
19	12658	6238	200	6438	200	6438
20	13361	6251	200	6451	200	6451
21	14064	6265	200	6465	200	6465
22	14768	6278	200	6478	200	6478
23	15471	6291	200	6491	200	6491
24	16174	6304	200	6504	200	6504

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	14
Optimal Cost	23.5

Terrain Point	Distance From Pt. 1	Terrain Altitude (1)	Optimal Clearance No G Constraint (2)	Column 1 + 2	Terrain Clearance Linear Program Solution (3)	Column 1 + 3
1	0	6000	500	6500	500	6500
2	703	6013	500	6513	500	6513
3	1406	6026	500	6526	500	6526
4	2110	6040	500	6540	500	6540
5	2813	6053	500	6553	500	6553
6	3516	6066	500	6566	500	6566
7	4219	6079	500	6579	500	6579
8	4923	6093	500	6593	500	6593
9	5626	6106	500	6606	500	6606
10	6329	6119	500	6619	500	6619
11	7032	6132	500	6632	500	6632
12	7735	6145	500	6645	500	6645
13	8438	6159	500	6659	508	6667
14	9142	6172	500	6672	528	6700
15	9845	6185	500	6685	525	6710
16	10548	6198	500	6698	500	6698
17	11252	6212	300	6512	452	6664
18	11955	6225	300	6525	402	6627
19	12658	6238	300	6538	362	6600
20	13361	6251	300	6551	331	6582
21	14064	6265	300	6565	311	6576
22	14768	6278	300	6578	301	6579
23	15471	6291	300	6591	300	6591
24	16174	6304	300	6604	300	6604

Terrain	2
Aircraft Velocity	500
Navigation Tgt. No.	14
Optimal Cost	23.71

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
1	0	6000	2600	8600	2600	8600
2	703	6013	2600	8613	2600	8613
3	1406	6026	2600	8626	2600	8626
4	2110	6040	2600	8640	2600	8640
5	2813	6053	2600	8653	2600	8653
6	3516	6066	2600	8666	2622	8688
7	4219	6079	2600	8679	2636	8715
8	4923	6093	2600	8693	2607	8700
9	5626	6106	2600	8706	2600	8706
10	6329	6119	2600	8719	2614	8733
11	7032	6132	2600	8732	2607	8739
12	7735	6145	2600	8745	2622	8767
13	8438	6159	2600	8759	2600	8759
14	9142	6172	2600	8772	2600	8772
15	9845	6185	2600	8785	2622	8807
16	10548	6198	2600	8798	2600	8798
17	11252	6212	2600	8812	2600	8812
18	11955	6225	2600	8825	2619	8844
19	12658	6238	2600	8838	2600	8838
20	13361	6251	2600	8851	2603	8854
21	14064	6265	2600	8865	2600	8865
22	14768	6278	2600	8878	2617	8895
23	15471	6291	2600	8891	2600	8891
24	16174	6304	2600	8904	2600	8904

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	25
Optimal Cost	17.92

Terrain Point	Distance From Pt. 1	Terrain Altitude (1)	Optimal Clearance No G Constraint (2)	Column 1 + 2	Terrain Clearance Linear Program Solution (3)	Column 1 + 3
1	0	6000	1900	7900	1900	7900
2	703	6013	1900	7913	1900	7913
3	1406	6026	1900	7926	1900	7926
4	2110	6040	1900	7940	1900	7940
5	2813	6053	1900	7953	1900	7953
6	3516	6066	1900	7966	1911	7977
7	4219	6079	1900	7979	1919	7998
8	4923	6093	1900	7993	1904	7997
9	5626	6106	1900	8006	1900	8006
10	6329	6119	1900	8019	1907	8026
11	7032	6132	1900	8032	1904	8036
12	7735	6145	1900	8045	1911	8056
13	8438	6159	1900	8059	1900	8059
14	9142	6172	1900	8072	1900	8072
15	9845	6185	1900	8085	1911	8096
16	10548	6198	1900	8098	1900	8098
17	11252	6212	1900	8112	1900	8112
18	11955	6225	1900	8125	1910	8135
19	12658	6238	1900	8138	1900	8138
20	13361	6251	1900	8151	1901	8152
21	14064	6265	1900	8165	1900	8165
22	14768	6278	1900	8178	1909	8187
23	15471	6291	1900	8191	1900	8191
24	16174	6304	1900	8204	1900	8204

Terrain	2
Aircraft Velocity	500
Navigation Tgt. No.	25
Optimal Cost	19.46

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
25	16,877	6317	1900	8217	1900	8217
26	17,581	6331	1900	8231	1906	8237
27	18,284	6344	1900	8244	1933	8277
28	18,987	6357	1900	8257	1982	8339
29	19,690	6370	1900	8270	1988	8358
30	20,394	6384	1900	8284	2013	8397
31	21,097	6397	1800	8197	1999	8396
32	21,800	6410	1800	8210	2005	8415
33	22,600	6553	1800	8353	2031	8584
34	23,400	6697	1800	8497	1963	8660
35	24,200	6840	1900	8740	1920	8760
36	24,967	6868	1900	8768	1900	8768
37	25,733	6897	1800	8697	1942	8839
38	26,500	6925	1800	8725	1934	8859
39	27,267	6953	1800	8753	1941	8894
40	28,033	6982	1800	8782	1897	8879
41	28,800	7010	1800	8810	1879	8889
42	29,700	6965	1800	8765	1886	8851
43	30,600	6920	1800	8720	1905	8825
44	31,550	7035	1800	8835	1969	9004
45	32,500	7150	1800	8950	1886	9036
46	33,233	7283	1800	9083	1852	9035
47	33,967	7417	1800	9217	1816	9233
48	34,700	7550	1800	9350	1800	9350

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	10
Optimal Cost	19.39

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
25	16,877	6317	2600	8917	2600	8917
26	17,581	6331	2200	8531	2608	8939
27	18,284	6344	2200	8544	2628	8972
28	18,987	6357	2200	8557	2658	9015
29	19,690	6370	2200	8570	2667	9037
30	20,394	6384	2200	8584	2684	9068
31	21,097	6397	2200	8597	2710	9107
32	21,800	6410	2200	8610	2747	9157
33	22,600	6553	2200	8753	2795	9348
34	23,400	6697	1900	8597	2710	9407
35	24,200	6840	2600	9440	2600	9440
36	24,967	6868	2200	9068	2466	9334
37	25,733	6897	2200	9097	2420	9317
38	26,500	6925	1900	8825	2367	9292
39	27,267	6953	1900	8853	2310	9263
40	28,033	6982	1900	8882	2226	9208
41	28,800	7010	1900	8910	2156	9166
42	29,700	6965	1900	8865	2113	9078
43	30,600	6920	1900	8820	2151	9071
44	31,550	7035	1900	8935	2218	9253
45	32,500	7150	1900	9050	2116	9266
46	33,233	7283	1900	9183	2039	9322
47	33,967	7417	1900	9317	1964	9381
48	34,700	7550	1900	9450	1900	9450

Terrain	2
Aircraft Velocity	500
Navigation Tgt. No.	10
Optimal Cost	2.33

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
25	16,877	6317	200	6517	200	6517
26	17,581	6331	200	6531	200	6531
27	18,284	6344	200	6544	200	6544
28	18,987	6357	200	6557	200	6557
29	19,690	6370	200	6570	200	6570
30	20,394	6384	200	6584	200	6584
31	21,097	6397	200	6597	212	6609
32	21,800	6410	200	6610	245	6655
33	22,600	6553	200	6753	297	6850
34	23,400	6697	200	6897	255	6952
35	24,200	6840	200	7040	238	7078
36	24,967	6868	200	7068	200	7068
37	25,733	6897	200	7097	224	7121
38	26,500	6925	200	7125	203	7128
39	27,267	6953	200	7153	200	7153
40	28,033	6982	200	7182	200	7182
41	28,800	7010	200	7210	200	7210
42	29,700	6965	200	7165	200	7165
43	30,600	6920	200	7120	233	7153
44	31,550	7035	200	7235	314	7349
45	32,500	7150	200	7350	248	7398
46	33,233	7283	200	7483	231	7514
47	33,967	7417	200	7617	205	7622
48	34,700	7550	200	7750	200	7750

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	14
Optimal Cost	24.63

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
25	16,877	6317	300	6617	300	6617
26	17,581	6331	300	6631	300	6631
27	18,284	6344	300	6644	300	6644
28	18,987	6357	300	6657	300	6657
29	19,690	6370	300	6670	313	6683
30	20,394	6384	300	6684	333	6717
31	21,097	6397	300	6697	364	6761
32	21,800	6410	300	6710	404	6814
33	22,600	6553	300	6853	455	7008
34	23,400	6697	300	6997	400	7097
35	24,200	6840	300	7140	358	7198
36	24,967	6868	300	7168	300	7168
37	25,733	6897	300	7197	331	7228
38	26,500	6925	300	7225	334	7259
39	27,267	6953	300	7253	310	7263
40	28,033	6982	300	7282	300	7282
41	28,800	7010	300	7310	300	7310
42	29,700	6965	300	7265	300	7265
43	30,600	6920	300	7220	373	7293
44	31,550	7035	300	7335	482	7517
45	32,500	7150	300	7450	422	7572
46	33,233	7283	300	7583	387	7670
47	33,967	7417	300	7717	338	7755
48	34,700	7550	300	7850	300	7850

Terrain	2
Aircraft Velocity	500
Navigation Tgt. No.	14
Optimal Cost	23.91

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
25	16,877	6317	2600	8917	2622	8939
26	17,581	6331	2600	8931	2600	8931
27	18,284	6344	2600	8944	2600	8944
28	18,987	6357	2600	8957	2622	8979
29	19,690	6370	2600	8970	2600	8970
30	20,394	6384	2600	8984	2600	8984
31	21,097	6397	2600	8997	2609	9006
32	21,800	6410	2600	9010	2637	9047
33	22,600	6553	2600	9153	2686	9239
34	23,400	6697	2600	9297	2640	9337
35	24,200	6840	2600	9440	2620	9460
36	24,967	6868	2600	9468	2600	9468
37	25,733	6897	2600	9497	2642	9539
38	26,500	6925	2600	9525	2634	9559
39	27,267	6953	2600	9553	2648	9601
40	28,033	6982	2600	9582	2611	9593
41	28,800	7010	2600	9610	2600	9610
42	29,700	6965	2600	9565	2600	9565
43	30,600	6920	700	7620	2633	9553
44	31,550	7035	700	7735	2714	9749
45	32,500	7150	2600	9750	2648	9798
46	33,233	7283	2600	9883	2631	9914
47	33,967	7417	2600	10017	2605	10022
48	34,700	7550	2600	10150	2600	10150

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	25
Optimal Cost	18.77

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
25	16,877	6317	1900	8217	1911	8228
26	17,581	6331	1900	8231	1900	8231
27	18,284	6344	1900	8244	1900	8244
28	18,987	6357	1900	8257	1900	8257
29	19,690	6370	1900	8270	1908	8278
30	20,394	6384	1900	8284	1925	8309
31	21,097	6397	1900	8297	1952	8349
32	21,800	6410	1900	8310	1989	8399
33	22,600	6553	1900	8453	2036	8589
34	23,400	6697	1900	8597	1978	8675
35	24,200	6840	1900	8740	1933	8773
36	24,967	6868	1900	8768	1900	8768
37	25,733	6897	1900	8797	1956	8853
38	26,500	6925	1900	8825	1977	8902
39	27,267	6953	1900	8853	1978	8931
40	28,033	6982	1900	8882	1953	8935
41	28,800	7010	1900	8910	1900	8910
42	29,700	6965	700	7665	1837	8802
43	30,600	6920	700	7620	1811	8731
44	31,550	7035	700	7735	1736	8771
45	32,500	7150	700	7850	1426	8576
46	33,233	7283	700	7983	1125	8408
47	33,967	7417	700	8117	907	8324
48	34,700	7550	700	8250	700	8250

Terrain	2
Aircraft Velocity	500
Navigation Tgt. No.	25
Optimal Cost	20.09

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
73	55,400	9180	1000	10180	1000	10180
74	56,400	8815	1000	9815	1106	9921
75	57,400	8450	1000	9450	1464	9914
76	58,233	8730	1000	9730	1874	10604
77	59,066	9010	1000	10010	1618	10623
78	59,900	9290	1000	10290	1376	10666
79	60,700	9170	1000	10170	1000	10170
80	61,500	9050	1000	10050	1001	10051
81	62,450	8995	1000	9995	1021	10016
82	63,400	8940	1000	9940	1000	9940
83	64,133	8773	1000	9773	1032	9805
84	64,867	8607	1000	9607	1199	9806
85	65,600	8440	1000	9440	1362	9802
86	66,700	9010	1000	10010	1545	10555
87	67,900	8780	1000	9780	1000	9780
88	68,900	8925	1000	9925	1505	10430
89	69,900	9070	1000	10070	1296	10366
90	70,600	9062	1000	10062	1150	10212
91	71,300	9054	1000	10054	1082	10136
92	72,000	9046	1000	10046	1034	10080
93	72,700	9038	1000	10038	1007	10045
94	73,400	9030	1000	10030	1000	10030
95	74,225	9072	1000	10072	1014	10086
96	75,050	9115	1000	10115	1005	10120

Terrain 2

Aircraft Velocity 360

Navigation Tgt. No. 10

Optimal Cost 5.86

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
73	55,400	9180	1100	10280	1100	10280
74	56,400	8815	1100	9915	1204	10019
75	57,400	8450	1000	9450	1592	10042
76	58,233	8730	1000	9730	2008	10738
77	59,066	9010	1000	10010	1732	10742
78	59,900	9290	1100	10390	1472	10762
79	60,700	9170	1100	10270	1100	10270
80	61,500	9050	1000	10050	1136	10186
81	62,450	8995	1000	9995	1158	10153
82	63,400	8940	1000	9940	1124	10064
83	64,133	8773	1000	9773	1118	9891
84	64,867	8607	1000	9607	1299	9906
85	65,600	8440	1000	9440	1464	9904
86	66,700	9010	1000	10010	1639	10649
87	67,900	8780	1000	9780	1000	9780
88	68,900	8925	1000	9925	1494	10419
89	69,900	9070	1100	10170	1325	10395
90	70,600	9062	1100	10162	1178	10240
91	71,300	9054	1000	10054	1142	10196
92	72,000	9046	1000	10046	1118	10164
93	72,700	9038	1000	10038	1104	10142
94	73,400	9030	1100	10130	1100	10130
95	74,225	9072	1100	10172	1107	10179
96	75,050	9115	1000	10115	1080	10195

Terrain	2
Aircraft Velocity	500
Navigation Tgt. No.	10
Optimal Cost	6.59

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
73	55,400	9180	100	9280	100	9280
74	56,400	8815	100	8915	129	8944
75	57,400	8450	100	8550	132	8582
76	58,233	8730	100	8830	948	9678
77	59,066	9010	100	9110	713	9723
78	59,900	9290	100	9390	476	9766
79	60,700	9170	100	9270	100	9270
80	61,500	9050	100	9150	101	9151
81	62,450	8995	100	9095	121	9116
82	63,400	8940	100	9040	100	9040
83	64,133	8773	100	8873	100	8873
84	64,867	8607	100	8707	305	8912
85	65,600	8440	100	8540	500	8940
86	66,700	9010	100	9110	716	9726
87	67,900	8780	100	8880	534	9314
88	68,900	8925	100	9025	100	9025
89	69,900	9070	100	9170	287	9357
90	70,600	9062	100	9162	101	9163
91	71,300	9054	100	9154	100	9154
92	72,000	9046	100	9146	100	9146
93	72,700	9038	100	9138	100	9138
94	73,400	9030	100	9130	100	9130
95	74,225	9072	100	9172	111	9183
96	75,050	9115	100	9215	100	9215

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	14
Optimal Cost	25.38

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
73	55,400	9180	100	9280	100	9280
74	56,400	8815	100	8915	144	8959
75	57,400	8450	100	8550	525	8975
76	58,233	8730	100	8830	934	9664
77	59,066	9010	100	9110	651	9661
78	59,900	9290	100	9390	427	9717
79	60,700	9170	100	9270	100	9270
80	61,500	9050	100	9150	182	9232
81	62,450	8995	100	9095	238	9233
82	63,400	8940	100	9040	238	9178
83	64,133	8773	100	8873	267	9040
84	64,867	8607	100	8707	481	9088
85	65,600	8440	100	8540	641	9081
86	66,700	9010	100	9110	779	9789
87	67,900	8780	100	8880	100	8880
88	68,900	8925	100	9025	554	9479
89	69,900	9070	100	9170	346	9416
90	70,600	9062	100	9162	151	9213
91	71,300	9054	100	9154	123	9177
92	72,000	9046	100	9146	106	9152
93	72,700	9038	100	9138	100	9138
94	73,400	9030	100	9130	104	9134
95	74,225	9072	100	9172	119	9191
96	75,050	9115	100	9215	100	9215

Terrain	2
Aircraft Velocity	500
Navigation Tgt. No.	14
Optimal Cost	25.89

Terrain Point	Distance From Pt.1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
73	55,400	9180	600	9780	600	9780
74	56,400	8815	300	9115	647	9462
75	57,400	8450	300	8750	1048	9498
76	58,233	8730	300	9030	1502	10232
77	59,066	9010	300	9310	1259	10269
78	59,900	9290	600	9890	1002	10292
79	60,700	9170	600	9770	600	9770
80	61,500	9050	300	9350	575	9625
81	62,450	8995	300	9295	515	9510
82	63,400	8940	300	9240	414	9354
83	64,133	8773	300	9073	367	9140
84	64,867	8607	300	8907	524	9131
85	65,600	8440	300	8740	679	9119
86	66,700	9010	300	9310	854	9864
87	67,900	8780	300	9080	300	9080
88	68,900	8925	300	9225	796	9721
89	69,900	9070	600	9670	600	9670
90	70,600	9062	300	9362	428	9490
91	71,300	9054	300	9354	440	9494
92	72,000	9046	300	9346	473	9519
93	72,700	9038	300	9338	526	9564
94	73,400	9030	600	9630	600	9630
95	74,225	9072	600	9672	633	9705
96	75,050	9115	300	9415	569	9674

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	25
Optimal Cost	21.69

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
73	55,400	9180	400	9580	400	9580
74	56,400	8815	400	9215	462	9277
75	57,400	8450	300	8750	862	9312
76	58,233	8730	300	9030	1289	10019
77	59,066	9010	300	9310	1020	10030
78	59,900	9290	400	9690	765	10055
79	60,700	9170	400	9570	400	9570
80	61,500	9050	400	9450	443	9493
81	62,450	8995	400	9395	463	9458
82	63,400	8940	400	9340	429	9369
83	64,133	8773	400	9173	421	9194
84	64,867	8607	300	8907	602	9209
85	65,600	8440	300	8740	766	9206
86	66,700	9010	400	9410	940	9950
87	67,900	8780	300	9080	300	9080
88	68,900	8925	300	9225	793	9718
89	69,900	9070	400	9470	624	9694
90	70,600	9062	400	9462	434	9496
91	71,300	9054	400	9454	412	9466
92	72,000	9046	400	9446	401	9447
93	72,700	9038	400	9438	400	9438
94	73,400	9030	400	9430	404	9434
95	74,225	9072	400	9472	419	9491
96	75,050	9115	400	9515	400	9515

Terrain	2
Aircraft Velocity	500
Navigation Tgt. No.	25
Optimal Cost	22.38

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
101	79,000	9150	1000	10150	1029	10179
102	79,700	9033	1000	10033	1000	10033
103	80,400	8915	1000	9915	1034	9949
104	81,100	8798	1000	9798	1026	9824
105	81,800	8680	1000	9680	1033	9713
106	82,533	8293	1000	9293	1000	9293
107	83,267	7907	1000	8907	1176	9083
108	84,000	7520	1000	8520	1305	8825
109	84,729	7450	1000	8450	1457	8907
110	85,457	7380	1000	8380	1334	8714
111	86,185	7310	1000	8310	1233	8543
112	86,914	7240	1000	8240	1148	8388
113	87,643	7170	1000	8170	1086	8256
114	88,371	7100	1000	8100	1045	8145
115	89,100	7030	1000	8030	1027	8057
116	89,875	7013	1000	8013	1030	8043
117	90,650	6995	1000	7995	1004	7999
118	91,425	6978	1000	7978	1000	7978
119	92,200	6960	1000	7960	1024	7984
120	93,200	6865	1000	7865	1017	7882
121	94,200	6770	1000	7770	1005	7775
122	94,967	6786	1000	7786	1037	7823
123	95,733	6803	1000	7803	1005	7808
124	96,500	6820	1000	7820	1000	7820

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	10
Optimal Cost	3.7

Terrain Point	Distance From Pt. 1	Terrain Altitude (1)	Optimal Clearance No G Constraint (2)	Column 1 + 2	Terrain Clearance Linear Program Solution (3)	Column 1 + 3
101	79,000	9150	1200	10350	1266	10416
102	79,700	9033	1200	10233	1200	10233
103	80,400	8915	1200	10115	1221	10136
104	81,100	8798	1200	9998	1220	10018
105	81,800	8680	1200	9880	1220	9900
106	82,533	8293	1200	9493	1200	9493
107	83,267	7907	1200	9107	1410	9317
108	84,000	7520	1200	8720	1596	9116
109	84,729	7450	1200	8650	1794	9244
110	85,457	7380	1200	8580	1706	9086
111	86,185	7310	1200	8510	1629	8939
112	86,914	7240	1200	8440	1561	8801
113	87,643	7170	1200	8370	1504	8674
114	88,371	7100	1200	8300	1459	8559
115	89,100	7030	1200	8230	1426	8456
116	89,875	7013	1200	8213	1403	8416
117	90,650	6995	1200	8195	1340	8335
118	91,425	6978	1200	8178	1287	8265
119	92,200	6960	1200	8160	1235	8195
120	93,200	6865	1200	8065	1200	8065
121	94,200	6770	1200	7970	1219	7989
122	94,967	6786	1200	7986	1260	8046
123	95,733	6803	1200	8003	1223	8026
124	96,500	6820	1200	8020	1200	8020

Terrain 2

Aircraft Velocity 500

Navigation Tgt. No. 10

Optimal Cost 4.3

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
101	79,000	9150	200	9350	200	9350
102	79,700	9033	200	9233	200	9233
103	80,400	8915	200	9115	263	9178
104	81,100	8798	200	8998	283	9081
105	81,800	8680	200	8880	262	8942
106	82,533	8293	200	8493	200	8493
107	83,267	7907	200	8107	347	8254
108	84,000	7520	200	7720	479	7999
109	84,729	7450	200	7650	634	8084
110	85,457	7380	200	7580	513	7893
111	86,185	7310	200	7510	414	7724
112	86,914	7240	200	7440	333	7573
113	87,643	7170	200	7370	273	7443
114	88,371	7100	200	7300	235	7335
115	89,100	7030	200	7230	219	7249
116	89,875	7013	200	7213	225	7238
117	90,650	6995	200	7195	201	7196
118	91,425	6978	200	7178	200	7178
119	92,200	6960	200	7160	200	7160
120	93,200	6865	200	7065	200	7065
121	94,200	6770	200	6970	200	6970
122	94,967	6786	200	6986	233	7019
123	95,733	6803	200	7003	204	7007
124	96,500	6820	200	7020	200	7020

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	14
Optimal Cost	24.48

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
101	79,000	9150	100	9250	183	9333
102	79,700	9033	100	9133	100	9133
103	80,400	8915	100	9015	104	9019
104	81,100	8798	100	8898	120	8918
105	81,800	8680	100	8780	120	8800
106	82,533	8293	100	8393	100	8393
107	83,267	7907	100	8007	310	8217
108	84,000	7520	100	7620	496	8016
109	84,729	7450	100	7550	694	8144
110	85,457	7380	100	7480	606	7986
111	86,185	7310	100	7410	529	7839
112	86,914	7240	100	7340	461	7701
113	87,643	7170	100	7270	404	7574
114	88,371	7100	100	7200	359	7459
115	89,100	7030	100	7130	326	7356
116	89,875	7013	100	7113	303	7316
117	90,650	6995	100	7095	240	7235
118	91,425	6978	100	7078	187	7165
119	92,200	6960	100	7060	135	7095
120	93,200	6865	100	6965	100	6965
121	94,200	6770	100	6870	119	6889
122	94,967	6786	100	6886	160	6946
123	95,733	6803	100	6903	123	6926
124	96,500	6820	100	6920	100	6920

Terrain	2
Aircraft Velocity	500
Navigation Tgt. No.	14
Optimal Cost	25.22

		1	2		3	
Terrain Point	Distance From Pt.1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
101	79,000	9150	300	9450	820	9970
102	79,700	9033	600	9633	728	9761
103	80,400	8915	600	9515	600	9515
104	81,100	8798	600	9398	629	9427
105	81,800	8680	600	9280	682	9362
106	82,533	8293	600	8893	758	9051
107	83,267	7907	600	8507	659	8566
108	84,000	7520	600	8120	600	8120
109	84,729	7450	600	8050	640	8090
110	85,457	7380	600	7980	600	7980
111	86,185	7310	600	7910	677	7987
112	86,914	7240	600	7840	771	8011
113	87,643	7170	600	7770	735	7905
114	88,371	7100	600	7700	717	7817
115	89,100	7030	600	7630	726	7756
116	89,875	7013	600	7613	762	7775
117	90,650	6995	600	7595	671	7666
118	91,425	6978	600	7578	610	7588
119	92,200	6960	600	7560	600	7560
120	93,200	6865	600	7465	623	7488
121	94,200	6770	600	7370	600	7370
122	94,967	6786	600	7386	798	7584
123	95,733	6803	600	7403	923	7726
124	96,500	6820	600	7420	975	7795

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	25
Optimal Cost	20.81

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
101	79,000	9150	500	9650	554	9704
102	79,700	9033	500	9533	500	9533
103	80,400	8915	500	9415	533	9448
104	81,100	8798	500	9298	543	9341
105	81,800	8680	500	9180	532	9212
106	82,533	8293	500	8793	500	8793
107	83,267	7907	500	8407	698	8605
108	84,000	7520	500	8020	885	8405
109	84,729	7450	500	7950	1084	8534
110	85,457	7380	500	7880	996	8376
111	86,185	7310	500	7810	921	8231
112	86,914	7240	500	7740	854	8094
113	87,643	7170	500	7670	798	7968
114	88,371	7100	500	7600	754	7854
115	89,100	7030	500	7530	721	7751
116	89,875	7013	500	7513	699	7712
117	90,650	6995	500	7495	636	7631
118	91,425	6978	500	7478	585	7563
119	92,200	6960	500	7460	534	7494
120	93,200	6865	500	7365	500	7365
121	94,200	6770	500	7270	519	7289
122	94,967	6786	500	7286	560	7346
123	95,733	6803	500	7303	523	7326
124	96,500	6820	500	7320	500	7320

Terrain	2
Aircraft Velocity	500
Navigation Tgt. No.	25
Optimal Cost	21.27

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
251	199,067	8142	1000	9142	1220	9362
252	199,800	8200	1000	9200	1128	9328
253	200,600	8040	1000	9040	1000	9040
254	201,400	7880	1000	8880	1029	8909
255	202,200	7720	1000	8720	1082	8802
256	203,100	7730	1000	8730	1160	8890
257	204,000	7740	1000	8740	1059	8799
258	204,900	7695	1000	8695	1000	8695
259	205,800	7650	1000	8650	1040	8690
260	206,500	7465	1000	8465	1000	8465
261	207,200	7280	1000	8280	1079	8359
262	207,950	7262	1000	8262	1174	8436
263	208,700	7245	1000	8245	1140	8385
264	209,450	7227	1000	8227	1124	8351
265	210,200	7210	1000	8210	1135	8345
266	211,000	7340	1000	8340	1172	8512
267	211,800	7470	1000	8470	1083	8553
268	212,633	7587	1000	8587	1024	8611
269	213,467	7703	1000	8703	1016	8719
270	214,300	7820	1000	8820	1041	8861
271	215,150	7683	1000	8683	1000	8683
272	216,000	7545	1000	8545	1180	8725
273	216,850	7407	1000	8407	1286	8693
274	217,700	7270	1000	8270	1430	8700

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	10
Optimal Cost	4.54

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
251	199,067	8142	1000	9142	1408	9550
252	199,800	8200	1200	9400	1311	9511
253	200,600	8040	1200	9240	1200	9240
254	201,400	7880	1100	8980	1269	9149
255	202,200	7720	1100	8820	1350	9070
256	203,100	7730	1100	8830	1444	9174
257	204,000	7740	1100	8840	1341	9081
258	204,900	7695	1100	8795	1259	8954
259	205,800	7650	1200	8850	1200	8850
260	206,500	7465	1100	8565	1154	8619
261	207,200	7280	1100	8380	1283	8563
262	207,950	7262	1100	8362	1420	8682
263	208,700	7245	1100	8345	1417	8662
264	209,450	7227	1100	8327	1427	8654
265	210,200	7210	1200	8410	1451	8661
266	211,000	7340	1100	8440	1489	8829
267	211,800	7470	1200	8670	1387	8857
268	212,633	7587	1200	8787	1301	8888
269	213,467	7703	1100	8803	1250	8953
270	214,300	7820	1200	9020	1217	9037
271	215,150	7683	1200	8883	1200	8883
272	216,000	7545	1200	8745	1438	8983
273	216,850	7407	1200	8607	1639	9046
274	217,700	7270	1200	8470	1858	9138

Terrain	2
Aircraft Velocity	500
Navigation Tgt. No.	10
Optimal Cost	5.35

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
251	199,067	8142	100	8242	462	8604
252	199,800	8200	200	8400	348	8548
253	200,600	8040	200	8240	200	8240
254	201,400	7880	100	7980	209	8089
255	202,200	7720	100	7820	242	7962
256	203,100	7730	100	7830	300	8030
257	204,000	7740	100	7840	179	7919
258	204,900	7695	100	7795	100	7795
259	205,800	7650	100	7750	125	7775
260	206,500	7465	100	7565	100	7565
261	207,200	7280	100	7380	184	7464
262	207,950	7262	100	7362	285	7547
263	208,700	7245	100	7345	255	7500
264	209,450	7227	100	7327	246	7473
265	210,200	7210	200	7410	264	7474
266	211,000	7340	100	7440	307	7647
267	211,800	7470	200	7670	224	7694
268	212,633	7587	100	7687	171	7758
269	213,467	7703	100	7803	169	7872
270	214,300	7820	200	8020	200	8020
271	215,150	7683	200	7883	200	7883
272	216,000	7545	200	7745	421	7966
273	216,850	7407	200	7607	568	7975
274	217,700	7270	200	7470	643	7913

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	14
Optimal Cost	24.39

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
251	199,067	8142	100	8242	331	8473
252	199,800	8200	100	8300	222	8422
253	200,600	8040	100	8140	100	8140
254	201,400	7880	100	7980	158	8038
255	202,200	7720	100	7820	228	7948
256	203,100	7730	100	7830	311	8041
257	204,000	7740	100	7840	191	7931
258	204,900	7695	100	7795	104	7799
259	205,800	7650	100	7750	100	7750
260	206,500	7465	100	7565	100	7565
261	207,200	7280	100	7380	235	7515
262	207,950	7262	100	7362	366	7628
263	208,700	7245	100	7345	359	7604
264	209,450	7227	100	7327	364	7591
265	210,200	7210	100	7310	383	7593
266	211,000	7340	100	7440	415	7755
267	211,800	7470	100	7570	308	7778
268	212,633	7587	100	7687	216	7803
269	213,467	7703	100	7803	161	7864
270	214,300	7820	100	7920	122	7942
271	215,150	7683	100	7783	100	7783
272	216,000	7545	100	7645	333	7878
273	216,850	7407	100	7507	528	7935
274	217,700	7270	100	7370	686	7956

Terrain	2
Aircraft Velocity	500
Navigation Tgt. No.	14
Optimal Cost	24.7

Terrain Point	Distance From Pt. 1	1 Terrain Altitude	2 Optimal Clearance No G Constraint	Column 1 + 2	3 Terrain Clearance Linear Program Solution	Column 1 + 3
251	199,067	8142	600	8742	600	8742
252	199,800	8200	600	8800	600	8800
253	200,600	8040	600	8640	688	8728
254	201,400	7880	600	8480	733	8613
255	202,200	7720	700	8420	737	8457
256	203,100	7730	700	8430	700	8430
257	204,000	7740	600	8340	873	8613
258	204,900	7695	600	8295	1000	8695
259	205,800	7650	600	8250	1150	8800
260	206,500	7465	600	8065	1025	8490
261	207,200	7280	600	7880	922	8202
262	207,950	7262	600	7862	836	8098
263	208,700	7245	600	7845	772	8017
264	209,450	7227	600	7827	730	7957
265	210,200	7210	600	7810	710	7920
266	211,000	7340	600	7940	712	8052
267	211,800	7470	600	8070	684	8154
268	212,633	7587	600	8187	678	8265
269	213,467	7703	700	8403	700	8403
270	214,300	7820	700	8520	703	8523
271	215,150	7683	700	8383	700	8383
272	216,000	7545	700	8245	733	8278
273	216,850	7407	600	8007	704	8111
274	217,700	7270	700	7970	700	7970

Terrain	2
Aircraft Velocity	360
Navigation Tgt. No.	25
Optimal Cost	20.39

		1	2		3	
Terrain Point	Distance From Pt. 1	Terrain Altitude	Optimal Clearance No G Constraint	Column 1 + 2	Terrain Clearance Linear Program Solution	Column 1 + 3
251	199,067	8142	400	8542	631	8773
252	199,800	8200	500	8700	522	8722
253	200,600	8040	400	8440	400	8440
254	201,400	7880	400	8280	458	8338
255	202,200	7720	400	8120	528	8248
256	203,100	7730	400	8130	611	8341
257	204,000	7740	400	8140	497	8237
258	204,900	7695	400	8095	405	8100
259	205,800	7650	400	8050	401	8051
260	206,500	7465	400	7865	400	7865
261	207,200	7280	400	7680	534	7814
262	207,950	7262	400	7662	674	7936
263	208,700	7245	400	7645	676	7921
264	209,450	7227	400	7627	692	7919
265	210,200	7210	400	7610	721	7931
266	211,000	7340	400	7740	764	8104
267	211,800	7470	500	7970	668	8138
268	212,633	7587	400	7987	586	8173
269	213,467	7703	400	8103	540	8243
270	214,300	7820	500	8320	512	8332
271	215,150	7683	500	8183	500	8183
272	216,000	7545	500	8045	743	8288
273	216,850	7407	500	7907	949	8356
274	217,700	7270	500	7770	1117	8387

Terrain	2
Aircraft Velocity	500
Navigation Tgt, No.	25
Optimal Cost	21.7

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13. ABSTRACT

The problem of determining a survivability index for an attack aircraft, penetrating a missile only defense, is formulated as an iterative linear programming model. The costs for the linear program are determined from a simplified radar detection model and a pilot visual navigation model. The costs which are determined are not functionally linear with terrain clearance and the program is solved as an iteration on a linear program, with convergence to an optimal survivability index. The survivability indices (optimal costs) computed are shown to be dependent upon the terrain and type of navigation target selected. This dependence suggests that terrain-navigation target combinations which yield high indices should be avoided when mission planning.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
LINEAR PROGRAM						
RADAR DETECTION MODEL						
TERRAIN DIGITALIZATION						
VISUAL TARGET RECONNAISSANCE AND ACQUISITION						
REVISED SIMPLEX ALGORITHM						