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AN AERIAL GUNNERY AERODYNAMIC LEAD PURSUIT MODEL

THE DIVISION OF ENGINEERING RESEARCH
LOUISIANA STATE UNIVERSITY
BATON ROUGE, LOUISIANA 70803

JUNE 1977

FINAL REPORT FOR PERIOD
JUNE 1976-JUNE 1977

AIR FORCE ARMAMENT LABORATORY
AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE
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Aerial Gunnery Aerodynamic Lead Pursuit Model

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A digital simulation of aerial gunnery was developed. A six-degree-of-freedom attacking aircraft controlled by control surface deflections was implemented to perform aerodynamic lead pursuit of an evading target. The attacker is capable of flying within the bounds of its performance envelope. The target is a coordinated flight and aerodynamically constrained model capable of some evasive logic. Three sight systems have been implemented into the simulation. The program was written in FORTRAN IV and has been checked out on the XDS Sigma 5, the IBM 360/65, and the CDC 6600 computers.

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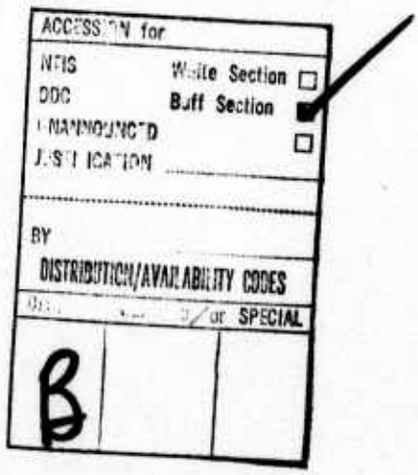
PREFACE

This report was prepared by the Division of Engineering Research, Louisiana State University, Baton Rouge, Louisiana 70803 under Contract F08635-76-C-0273, with the Air Force Armament Laboratory, Armament Development and Test Center, Eglin Air Force Base, Florida 32542. This effort began in June 1976 and was completed in June 1977. Mr. Gerald Solomon (DLYD) monitored the program for the Armament Laboratory.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER:

J. R. MURRAY
Chief, Analysis Division



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SECTION I

INTRODUCTION

OBJECTIVES

The design intent of the effort described by this report was the construction of a digital software simulation of an attacker-target encounter in aerial gunnery combat. The simulation was restricted in scope to the target tracking phase of the encounter with no particular attention being focused on tactical aspects. The primary effort was expended in obtaining an optimally controlled attacking aircraft capable of flying within the boundaries of its performance envelope, the emphasis being placed upon obtaining realistic aerodynamic lead pursuit in the tracking phase of the encounter. Complimentary to this effort were the simulation of the target and the sight systems and the overall problem of fitting the simulation into GAMES (Reference 1).

LITERATURE SURVEY

Consistent with the proposed work outline, a literature survey of available simulations was made to determine the basic capabilities of those simulations (References 2 and 3). Based upon the requirement that the attacker be able to fly realistic uncoordinated flight in the tracking phase, the IMAGE simulation was the only viable candidate for the attacker airframe simulation. The development of a totally new simulation was considered but was deemed infeasible within the time constraints allowed for the project. Thus, the decision to extract from the IMAGE simulation the airframe dynamics and aerodynamics was made and implemented.

OVERVIEW

The overall effort was divided into four basic tasks: (1) Attacker airframe and pilot, (2) target simulation, (3) sight systems, and (4) implementation of tasks 1, 2, and 3 into GAMES.

Attacker Simulation

Section II of this report is devoted to the description of the attacker simulation. The attacker is a full six-degree-of-freedom airframe model with a zero time lag pilot and control system. All data defining the attacker is read in from the input file and defines a three control surface airframe. The aerodynamics data is stored in table form, and a table lookup scheme is used to extract information.

Target Simulation

The target simulation is described in detail in Section III of this report. The target is a psuedo six-degree-of-freedom model in that coordinated flight is assumed and attitude is computed in a dependent fashion from the lineal velocity and acceleration. Acceleration is computed as a demand quantity or as an input quantity based upon the type of maneuver specified.

Target maneuvers are defined by preprogramming a battery of sequentially activated maneuvers. Up to 10 steps or maneuvers may be programmed to define the target motion profile with the sequencing being influenced by what the attacker and target do. Tabular data is also required to define the performance envelope of the target.

Sight Systems

The sight systems have been implemented in subroutine format, and first and second order perfect sights as well as mechanization of one other sight have been structured. Section IV of this report gives the details of the sight system implementation.

GAMES

The final product of the effort is documented in Section V of this report. The attacker-pilot, target, and sight systems are imbedded into the GAMES program as a subunit that updates the state vector for both attacker and target on demand from the executive part of the simulation. GAMES itself has been minimally modified to accept this alternative to its present approach to defining the engagement.

SECTION II

ATTACKER

PURPOSE

The attacker simulation is a six-degree-of-freedom digital model of an airframe and a controller. The controller simulates a pilot whose aim is to maneuver the attacking airframe into firing position. Firing position is achieved by nulling the tracking errors between the line of sight to the target and the pipper position in the heads up display (HUD) computed by the sight system.

SUBPROGRAM PILOT

Subprogram PILOT is an optimum controller for the airframe simulated in the subroutine TURKEY. The task of PILOT is to maneuver, by setting the control surfaces, the airframe into the best position for a successful aerial engagement with the target. All control decisions are made utilizing current information about the attacker and the target, i.e., PILOT does not have access to information concerning the future conditions of either the airframe or the target.

PILOT utilizes the fact that the most rapid means of minimizing the integral of the error is to use maximal rectilinear and angular accelerations and decelerations for the airframe. PILOT communicates to TURKEY by means of a control vector composed of aileron setting, stabilator setting, thrust or throttle control setting, and rudder setting. Therefore, the individual components will, in general, be set at their limits while maneuvering to achieve near aerodynamic lead pursuit. Only in the final stages of the engagement, when the magnitude of the error and its first derivative is small, will the components of the control vector be at some intermediate value.

ERROR COMPUTATION

The error vector is composed of roll error, pitch error, range error, and yaw error. These quantities are computed from the elevation and traverse tracking errors and the range to the target (see Figure 1).

SINGLE CHANNEL CONTROLLER

PILOT uses four single channel controllers, each responsive to a single component of the error vector. Roll error controls the aileron deflections; pitch error controls the stabilator deflections. The thrust is controlled by the range error. Rudder deflections are controlled by the yaw error. In effect, the control vector is the sum of the output of each individual

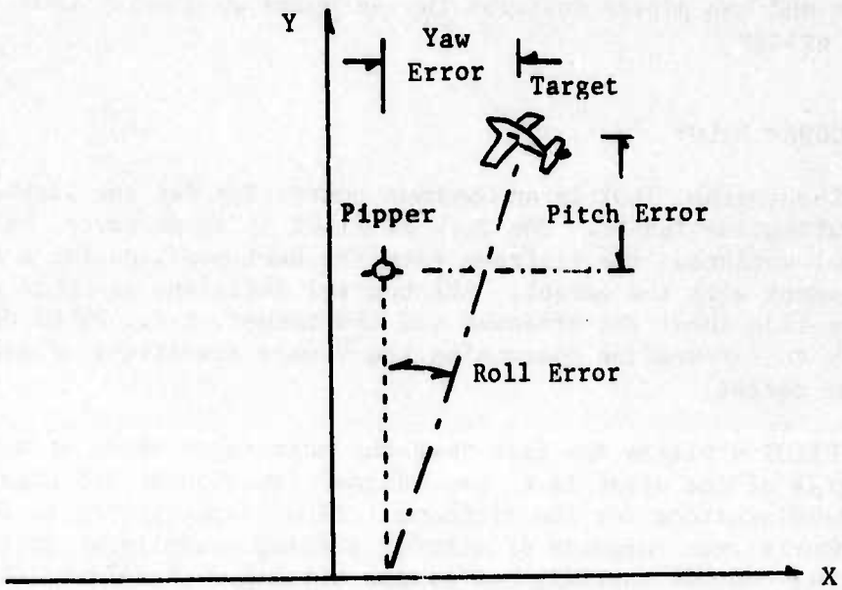

Figure 1. View Through Heads Up Display

controller. Each controller assumes that the other components of the control vector have a negligible effect on the error which it is trying to control.

CONTROLLER LOGIC

In PILOT each controller tries to minimize the integral of the error which it senses. This is accomplished by nulling the error and its first derivative as rapidly as possible. The controller treats the response of the airframe as an unknown transfer function. The controller, sensing the error and the first derivative of the error, is able to sample the range of second derivatives of the error by changing its respective component of the control vector. This enables the controller to choose an appropriate value for the control vector component.

The controller is at liberty to adjust its control parameter and is able to obtain a complete range of values for the second derivative of the error. In general, these will have extreme magnitudes when the control vector is at its limits.

Control Decision If the error at any time t be denoted by x, its first derivative is denoted by $\dot{x}$ and its second derivative is denoted by $\ddot{x}$. The controller has at its command all available values of $\ddot{x}$. The optimal choice will be, in general, between the maximal positive and the maximal negative values of $\ddot{x}$. These values are assumed to be constant over an interval in time. x_1 and $\dot{x}_1$ is the error and its first derivative at the start of the time interval. $\ddot{x}_1$ is judiciously chosen as the second derivative which will improve the situation over the next time interval, t_1. x_2 and $\dot{x}_2$ are the error and its first derivative at the end of the time interval t_1 and at the start of the second time interval t_2. $\ddot{x}_2$ is the second derivative of the error to be used during this second time interval, t_2. The magnitudes of t_1 and t_2 can be obtained from Equations (1) through (4)

$$1/2\ \ddot{x}_1 t_1^2 + \dot{x}_1 t_1 + x_1 = x_2 \qquad (1)$$

$$\ddot{x}_1 t_1 + \dot{x}_1 = \dot{x}_2 \qquad (2)$$

$$1/2\ \ddot{x}_2 t_2^2 + \dot{x}_2 t_2 + x_2 = 0 \qquad (3)$$

$$\ddot{x}_2 t_2 + \dot{x}_2 = 0 \qquad (4)$$

At the end of the second time interval, both the error and its first derivative will be zero if $\ddot{x}_1$ and $\ddot{x}_2$ were constant over the two time intervals.

This method will give reasonable results, but it is more economical,

since the simulation marches in time, to merely ask if the simulation has reached the end of the first interval. This is accomplished by assuming that the first interval is over and by using Equations (3) and (4) to evaluate the projected error at the end of the time interval t_2. t_2 is obtained from Equation (4).

$$t_2 = -\dot{x}_2/\ddot{x}_2 \tag{5}$$

Equation (5) is obtained from Equation (4) by the requirement that at the end of the interval t_2 the derivative of the error should be zero. The projected error is then calculated.

If the projected error is sufficiently small, then the assumption that the end of t_1 has been reached is correct. The component of the control vector is set such that the second derivative is $\ddot{x}_2$.

If the magnitude of the projected error is greater than specified limits and if the value is of the same sign as the present value of the error, the end of the interval t_1 has not been reached. In this case the control vector should be set such that the second derivative is equal to $\ddot{x}_1$.

However, if the projected error at t_2 has the opposite sign of its present value, then the airframe is predicted to overshoot the desired state. This means that the roles of $\ddot{x}_1$ and $\ddot{x}_2$ must be interchanged. The component of the control vector again should cause the second derivative of the state vector to equal the new $\ddot{x}_1$.

The algorithm used in choosing the proper extreme second derivatives is shown in the flow chart in the Figure 2. The assumption that $\ddot{x}_1$ and $\ddot{x}_2$ are constant is permissible because they are updated, and the above test is made frequently.

TOTAL CONTROLLER

The assumption that other components of the control vector do not noticeably affect the error sensed by any individual controller is permissible because the errors and their respective derivatives are updated, and adjustments to the control vector are made frequently.

If the magnitude of the component of the error vector and the magnitude of the derivative of that error which a controller is sensing are sufficiently small, that component of the control vector is attenuated.

If the total error, pitch error plus the yaw error, is large, the rudder is not operational. However, if the error is sufficiently small, the rudder is used and the aileron deflections are set to zero.

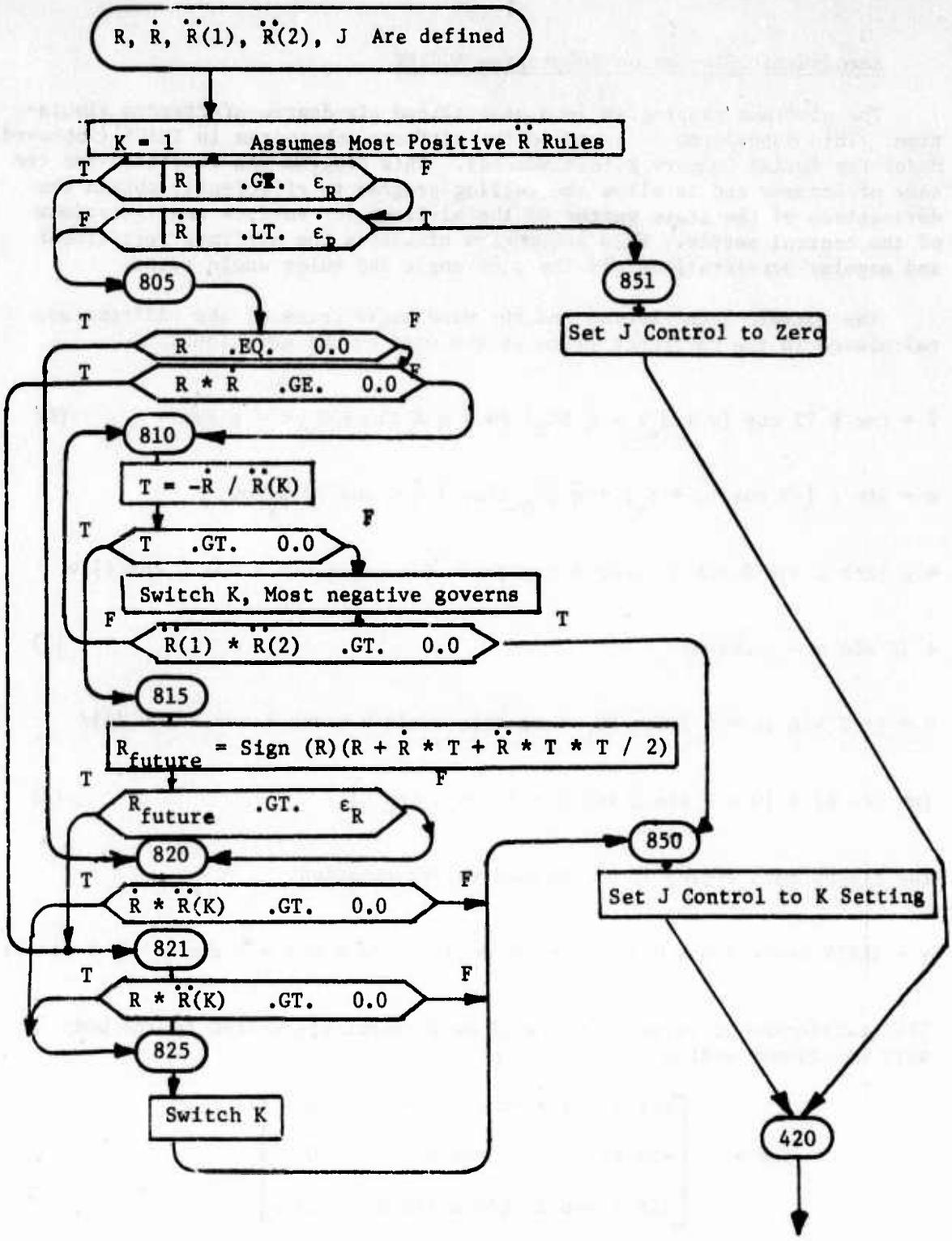

Figure 2. Flow Chart of Controller Logic

Aerodynamic Simulation Subprogram TURKEY

The airframe subprogram is a generalized six-degree-of-freedom simulation. This subprogram is based on the airframe subprogram in IMAGE (Improved Model for Aerial Gunnery Effectiveness). This program was rewritten for the sake of economy and to allow the calling program to efficiently obtain the derivatives of the state vector of the airframe for various configurations of the control vector. This subprogram simulates the airframe rectilinear and angular accelerations and the wind angle and euler angle rates.

The forward acceleration and the wind angle rates of the airframe are calculated in the reference frame of the wind by the equations:

$$\dot{v} = \cos\beta\,[T\cos(\alpha + \delta_e) - \bar{q}\,SC_D]\,/m + \bar{q}\,S\sin\beta\,C_y/m - g\sin\gamma \qquad (6)$$

$$\dot{\beta} = \sin\beta\,[-T\cos(\alpha + \delta_e) + \bar{q}\,SC_D\,1/mv + \bar{q}\,S\cos\beta]\,C_y/mv$$

$$+ g\,[\cos\alpha\sin\beta\sin\theta + \cos\beta\cos\theta\sin\phi - \sin\alpha\sin\beta\cos\theta\cos\phi]/v$$

$$+ (P\sin\alpha - R\cos\alpha) \qquad (7)$$

$$\dot{\alpha} = [-T\sin(\alpha + \delta_e) - \bar{q}\,SC_L + mg\,(\sin\alpha\sin\theta + \cos\alpha\cos\theta\cos\phi)]/$$

$$(mv\cos\beta) + [Q - R\sin\alpha\tan\beta - P\cos\alpha\tan\beta] \qquad (8)$$

The flight path angle, γ, is defined by the equation:

$$\gamma = \text{ARSIN}\,(-\sin\phi\cos\theta\sin\beta - \cos\beta\sin\alpha\cos\theta\cos\phi + \cos\alpha\cos\beta\sin\theta) \qquad (9)$$

The transformation relating the wind axis coordinate system to the body axis coordinate system is defined as:

$$TWB = \begin{bmatrix} \cos\alpha\cos\beta & -\cos\alpha\sin\beta & \sin\alpha \\ \sin\beta & \cos\beta & 0 \\ \sin\alpha\cos\beta & -\sin\alpha\sin\beta & -\cos\alpha \end{bmatrix}$$

The angular accelerations and euler angle rates are calculated in the body axis coordinated system by the equations:

$$\dot{P} = \frac{I_{yy} - I_{zz}}{I_{xx}} QR + \frac{I_{xz}}{I_{xx}} (\dot{R} + PQ) + \frac{\bar{q}\,SB}{I_{xx}} [\cos \beta \cos \alpha\, C_{\ell} - \sin \alpha\, C_n] \quad (10)$$

$$\dot{Q} = \frac{I_{zz} - I_{xx}}{I_{yy}} RP + \frac{I_{xz}}{I_{yy}} (R^2 - P^2) + \frac{\bar{q}Sc}{I_{yy}} C_m + M_t T/I_{yy} \quad (11)$$

$$\dot{R} = \frac{I_{xx} - I_{yy}}{I_{zz}} PQ + \frac{I_{xz}}{I_{zz}} [\dot{P} - QR] + \frac{\bar{q}Sb}{I_{zz}} [\cos \beta \sin \alpha\, C_{\ell} + \cos \alpha\, C_n] \quad (12)$$

$$\dot{\phi} = P + \dot{\psi} \sin \Theta \quad (13)$$

$$\dot{\Theta} = Q \cos \phi - R \sin \phi \quad (14)$$

$$\dot{\psi} = (R \cos \phi + Q \sin \phi)/ \cos \Theta \quad (15)$$

The transformation relating the body axis coordinate system to the inertial coordinate system is defined as:

$$TBE = \begin{bmatrix} \cos \psi \cos \Theta & \sin \psi \cos \Theta & -\sin \Theta \\ \cos \psi \sin \Theta \sin \phi - \sin \psi \cos \phi & \sin \psi \sin \Theta \sin \phi + \cos \psi \cos \phi & \cos \Theta \sin \phi \\ \cos \psi \sin \Theta \cos \phi + \sin \psi \sin \phi & \sin \psi \sin \Theta \cos \psi - \cos \psi \sin \phi & \cos \Theta \cos \phi \end{bmatrix} \quad (16)$$

The rectilinear velocities and accelerations in the inertial reference frame are obtained by the transformation of the velocity vector and its derivative from the wind axis coordinate system into the inertial reference frame.

$$v_E = [T_{EB}][T_{WB}]v_w \qquad \text{where } v_w = \begin{bmatrix} v \\ o \\ o \end{bmatrix} \quad (17)$$

$$\dot{v}_E = A_E = [\dot{T}_{EB}][T_{WB}]v_w + [T_{EB}][\dot{T}_{WB}]v_w + [T_{EB}][T_{WB}]\dot{v}_w \quad (18)$$

where

$$\frac{d}{dt}[T_{WB}] = \begin{bmatrix} -\sin\alpha\cos\beta\,\dot{\alpha} - \cos\alpha\sin\beta\,\dot{\beta} & -\sin\alpha\sin\beta\,\dot{\alpha} + \cos\alpha\cos\beta\,\dot{\beta} & \cos\alpha\,\dot{\alpha} \\ \cos\beta\,\dot{\beta} & -\sin\beta\,\dot{\beta} & 0 \\ \cos\alpha\cos\beta\,\dot{\alpha} - \sin\alpha\sin\beta\,\dot{\beta} & -\cos\alpha\sin\beta\,\dot{\alpha} - \sin\alpha\cos\beta\,\dot{\beta} & +\sin\alpha\,\dot{\alpha} \end{bmatrix}$$

and

$$\frac{d}{dt}[T_{BE}] = [T_{BE}] \begin{bmatrix} 0 & -R & +Q \\ +R & 0 & -P \\ -Q & +P & 0 \end{bmatrix}$$

The airframe simulation subprogram is constructed so that the recalculation of the derivative of the state vector is done efficiently for various control vectors. The majority of the calculations not involving the control vector are saved in dummy variables. Figure 3 is a flow diagram of the airframe simulation.

Data for the Attacker The data to describe the attacker is read by subprograms PILOT and TURKEY. In the read sequence PILOT reads first, then calls ESCAPE which then reads its data to describe the target. ESCAPE is described in Section III of this report. Subsequent to ESCAPE reading data, the SSIGHT subprogram reads data as defined in Section IV of this report. Finally TURKEY reads data to define the airframe.

Data Read by PILOT PILOT reads a minimal amount of data -- only that necessary to define the integration, control, print out, and initial conditions of the attacker.

CARD	FORMAT	QUANTITIES READ
1	(A10, 2I5, E10.2)	LABEL, NF1, NF9, DTIME
2,3,4	(A10,7E10.2)/10X,7E10.2)	LABEL, (SV(I),I=1,15)

The quantities read from the four cards are:

LABEL	Any identifying label up to 10 characters long.
NF1	Control frequency indicator. Sets the number of integration steps between control cycles.

NF9	Print out indicator. Sets the number of control cycles between printout by PILOT.
DTIME	The integration step size to be used by the Runge-Kutta integration algorithm.
SV(1)	X_1 position of attacker
SV(2)	X_2 position of attacker
SV(3)	X_3 position of attacker
SV(4)	$\dot{X}_1$
SV(5)	$\dot{X}_2$
SV(6)	$\dot{X}_3$
SV(7)	$(\dot{X}_1^2 + \dot{X}_2^2 + \dot{X}_3^2)^{\frac{1}{2}}$
SV(8)	Roll Euler Angle, ϕ
SV(9)	Pitch Euler Angle, θ
SV(10)	Heading Euler Angle, Ψ
SV(11)	Angle of Attack, α
SV(12)	Side Slip Angle, β
SV(13)	Angular Velocity, Roll Axis
SV(14)	Angular Velocity, Pitch Axis
SV(15)	Angular Velocity, Yaw Axis

Data Read by TURKEY All of the aerodynamic performance tables used by TURKEY to simulate the airframe are read on the first call to TURKEY. Four separate reads are involved for the four COMMON arrays: IDUM1, TDUM1, TDUM2, and DUM. IDUM1, TDUM1, TDUM2, and DUM are only read once. The read sequence is IDUM1, TDUM1, TDUM2, and then DUM. IDUM1 is integer, and contains 131 integers that describe the data made up of TDUM1 and TDUM2. TDUM1 and TDUM2 store REAL data and have 550 and 4700 words, respectively. IDUM1, TDUM1, and TDUM2 are punched into cards by the data input program from the modified IMAGE program described by Reference 5.

Array DUM contains the following data:

DUM	DATA
1	Angular orientation of the thrust vector
2	Wing surface area
3	Wing span
4	Mass of airframe, slugs
5	Acceleration of gravity
6	Mean aerodynamic chord length
7	Moment of inertia XX, slug ft^2
8	Moment of inertia YY, slug ft^2
9	Moment of inertia ZZ, slug ft^2
10	Product of inertia XZ, slug ft^2
11	Angle of wing with respect to body
12	Moment arm of thrust vector
13	Rudder upper limit, degrees
14	Rudder lower limit, degrees
15	Stabilator upper limit, degrees
16	Stabilator lower limit, degrees
17	Aeleron upper limit, degrees
18	Aeleron lower limit, degrees
19	Thrust value 1, pounds
20	Thrust value 2, pounds
21	Thrust value 3, pounds
22	Thrust value 4, pounds
23	Maximum angle of attack, degrees
24	Maximum side slip, degrees
25	Maximum normal acceleration, G's.

DUM is read under a FORMAT of (8E10.2). Subsequent to the initial read of DUM, selected parts of DUM are re-read for each initialization of a new case, including the first. The re-read uses the same format, and the quantities re-read are DUM(4), DUM(7), DUM(8), DUM(9), DUM(10), which are the inertia parameters.

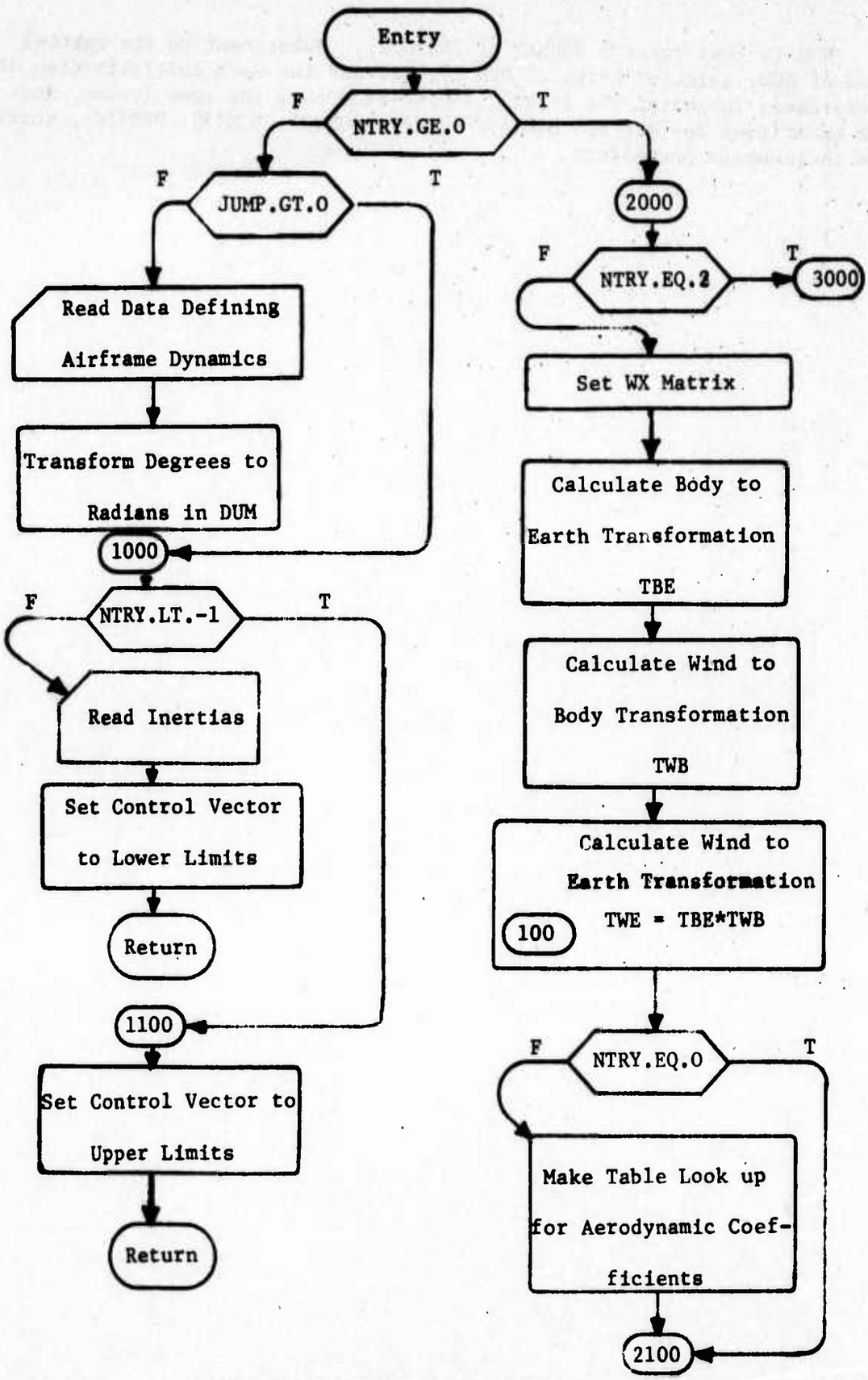

Figure 3. Airframe Simulation

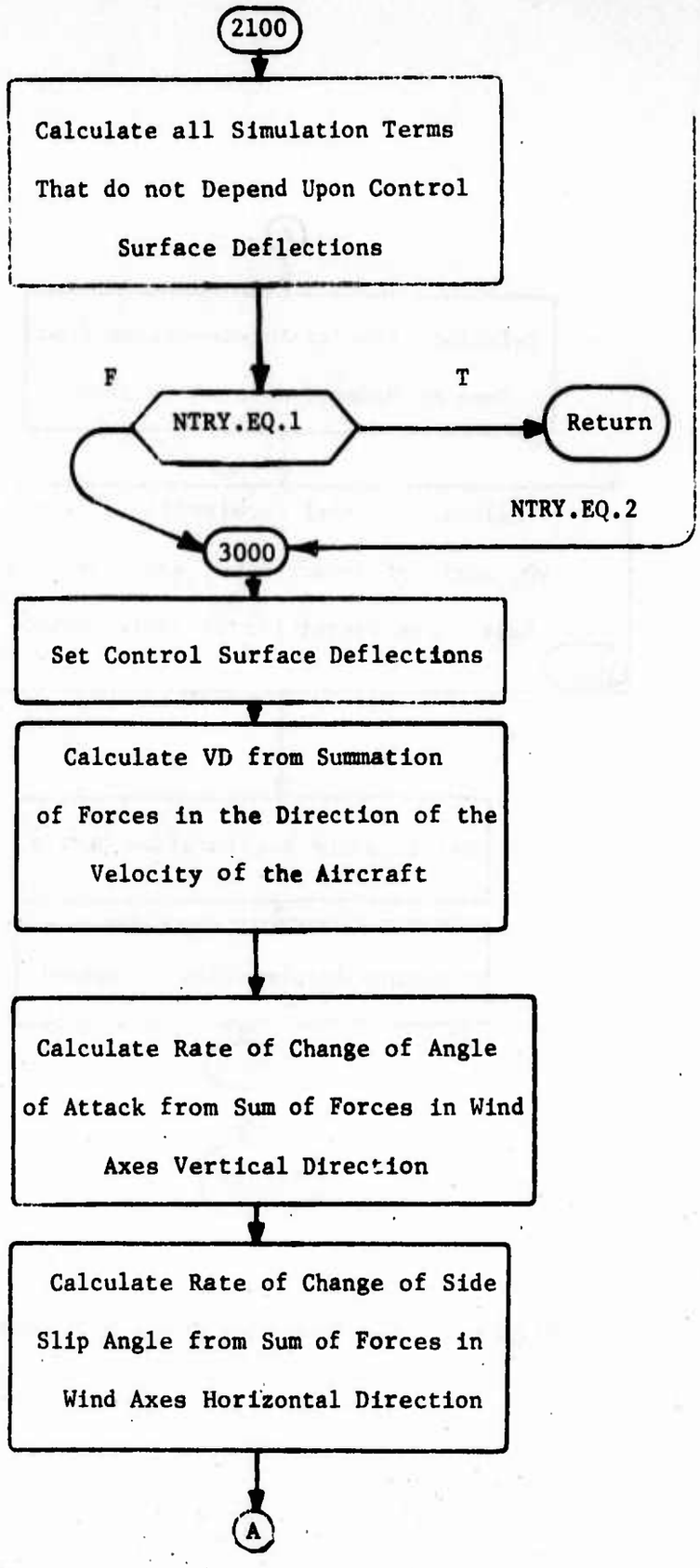

Figure 3. Airframe Simulation (Continued)

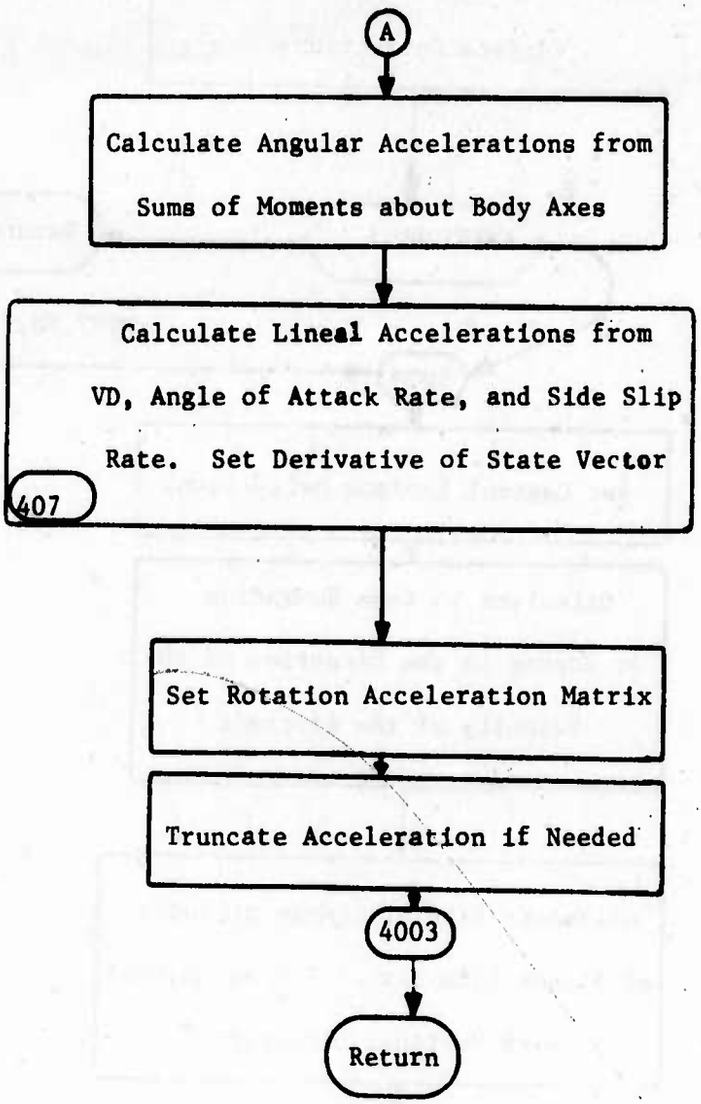

Figure 3. Airframe Simulation (Concluded)

SECTION III

TARGET EVASIVE MANEUVERS

INTRODUCTION

Subroutine ESCAPE was written to simulate the motion and decision of the target aircraft. The target defined by ESCAPE is a six-degree-of-freedom aircraft with realistic aerodynamic characteristics. Basically, the target flies coordinated flight along a flight trajectory that has been predetermined in a generalized fashion by the input data.

Within the target simulation, note is made of the state of both target and attacker, and the target makes evasive decisions based upon those states and bounds established by the input data. A serial decision sequence with no branching is defined such that at each decision point the simulation decides to either continue with the presently defined maneuver or to proceed to the next maneuver in the program stack of maneuvers. If the target completely exhausts the program stack of maneuvers, it simply vanishes by exiting to infinity.

Within the above concept, the analyst is able to program the target to the extent of defining the sequence of maneuvers in the program stack and defining the attacker/target state vector limits that dictate the termination of each step of the target program. There are seven basic maneuvers defined for the analyst to use to program the target. These are described below. Any component of the target or attacker state vector may be used as an upper or lower operating limit for each step of the program. A detailed listing of the index numbers of the state vector components is also given below.

TARGET MANEUVERS

Target maneuvers are designated by their index number, IZG, with integer value 1 through 7. The following gives a detail description of each maneuver:

IZG	Maneuver
1	Fly toward a specified point in space making changes in direction at a specified acceleration. This maneuver can be used to cause the target to fly a straight and level course as well as a circle in some circumstances.

IZG	Maneuver
2	Fly toward a point specified in space as an increment away from the target's position at the beginning of this maneuver. This maneuver becomes maneuver 1 after the new point is defined.
3	Fly toward a moving point a specified increment away from the target using a specified acceleration. This maneuver differs from 1 only in that the point always moves with the attacker. In the limit, this maneuver will result in a target velocity vector in the direction of the incremental position vector.
4	Change the direction of the target velocity vector to a new specified direction in a specified amount of time.
5	Make an incremental change in velocity vector direction where the increment is specified and the time to change is specified.
6	Chase an incremental change in velocity direction. The change is a constant, and the limiting velocity is parallel to the change vector.
7	Fly with a specified roll angle and normal acceleration. A linear function of time may be specified as the roll program for this maneuver.

EQUATIONS OF MOTION

For IZG = 1, 2, 3 the target is attempting a change in position. Over an interval of time, Δt, a change in position, ΔX, would be accomplished with constant kinematic acceleration according to

$$\Delta X = 1/2\ A_K \Delta t^2 \text{ or } A_K = \frac{2\Delta X}{\Delta t^2} \tag{19}$$

where ΔX and A_K are both vectors in the earth system.

The sensible acceleration would then be given by

$$A_S = A_K + G \tag{20}$$

where A_S and G are vectors, and specifically G is the vector representation of the acceleration of gravity.

The target is assumed to have small angle of attack so that the normal acceleration is considered normal to the wind or the target velocity vector. As such, the normal direction, N, is defined by the vector product $(V \times A_S) \times V$ where V is the velocity vector for the target. To achieve an acceleration of A_S then requires a normal acceleration, A_N, given by

$$A_N = A_S \cdot N \tag{21}$$

In the event that the calculated normal acceleration is in excess of the maximum allowed, the normal component of acceleration is truncated and the normal direction maintained.

The tangential component of acceleration is calculated by

$$A_T = A_S \cdot V/|V| \tag{22}$$

where V is the vector velocity of the target and $|V|$ is the scalar speed of the target. If this acceleration is not within the performance limits, it is truncated and the simulation continued.

For IZG = 4, 5, 6, the acceleration is computed for a change in target velocity rather than a change in target position. To this end

$$A_K = \frac{\Delta V}{\Delta t} \tag{23}$$

where ΔV is the vector change in velocity to occur over Δt change in time. The same analysis and constraints for A_N and A_T are used in cases 4, 5, and 6 as were used in cases 1, 2, and 3.

IZG = 7 is essentially a maneuver where the roll angle, and therefore N, is specified as a control. A_N is specified rather than being calculated. A_T is specified by means of throttle setting. Using A_T, A_N, and the roll angle, the kinematic acceleration is established and the motion of the target set.

INTEGRATION OF EQUATIONS OF MOTION

In all maneuver cases a program of acceleration is established for a small interval of time. The equation for velocity then becomes

$$V(t) = V(t_o) + A_K(t_o)(t-t_o) \tag{24}$$

and for the displacement

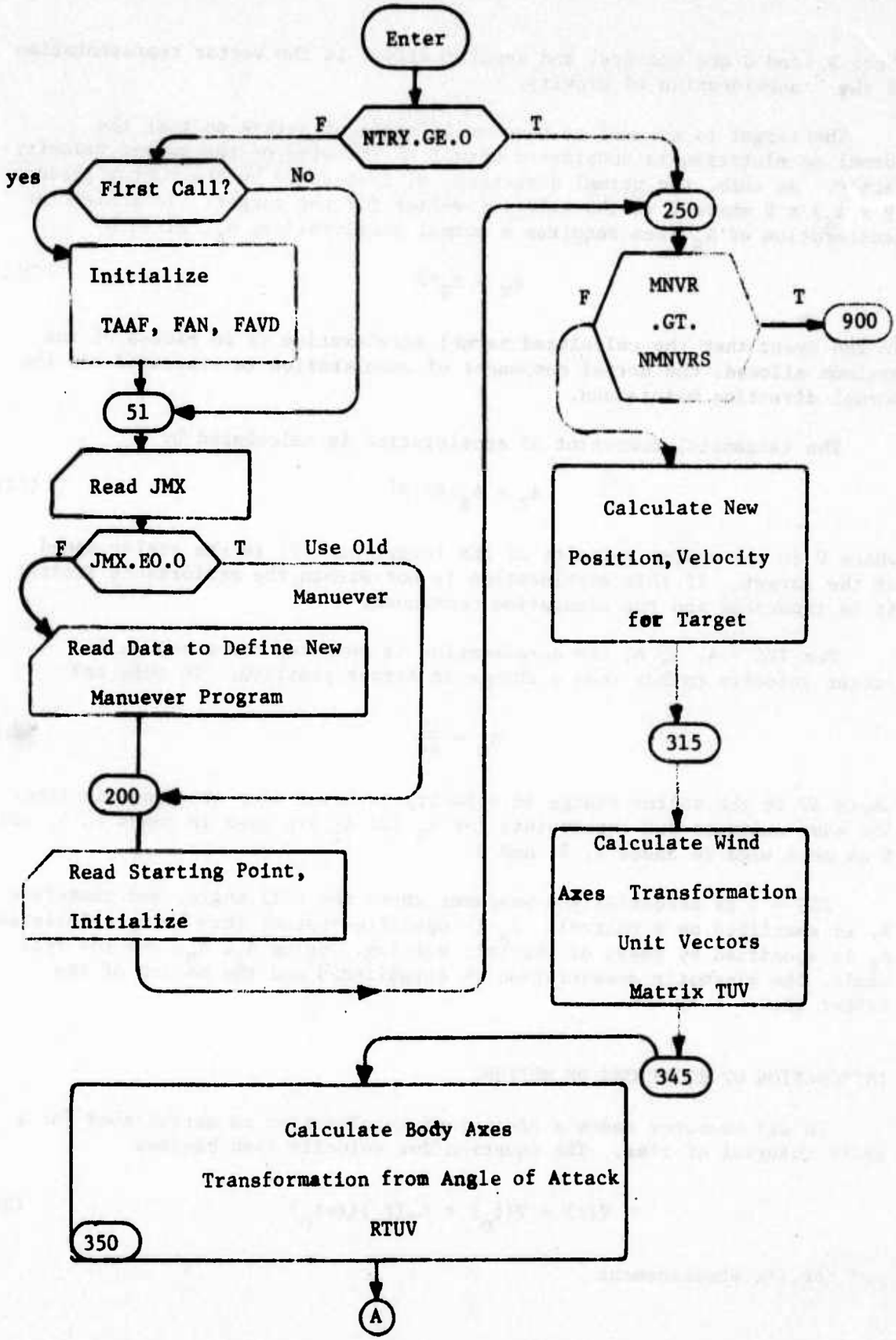

Figure 4. Flow Diagram of ESCAPE

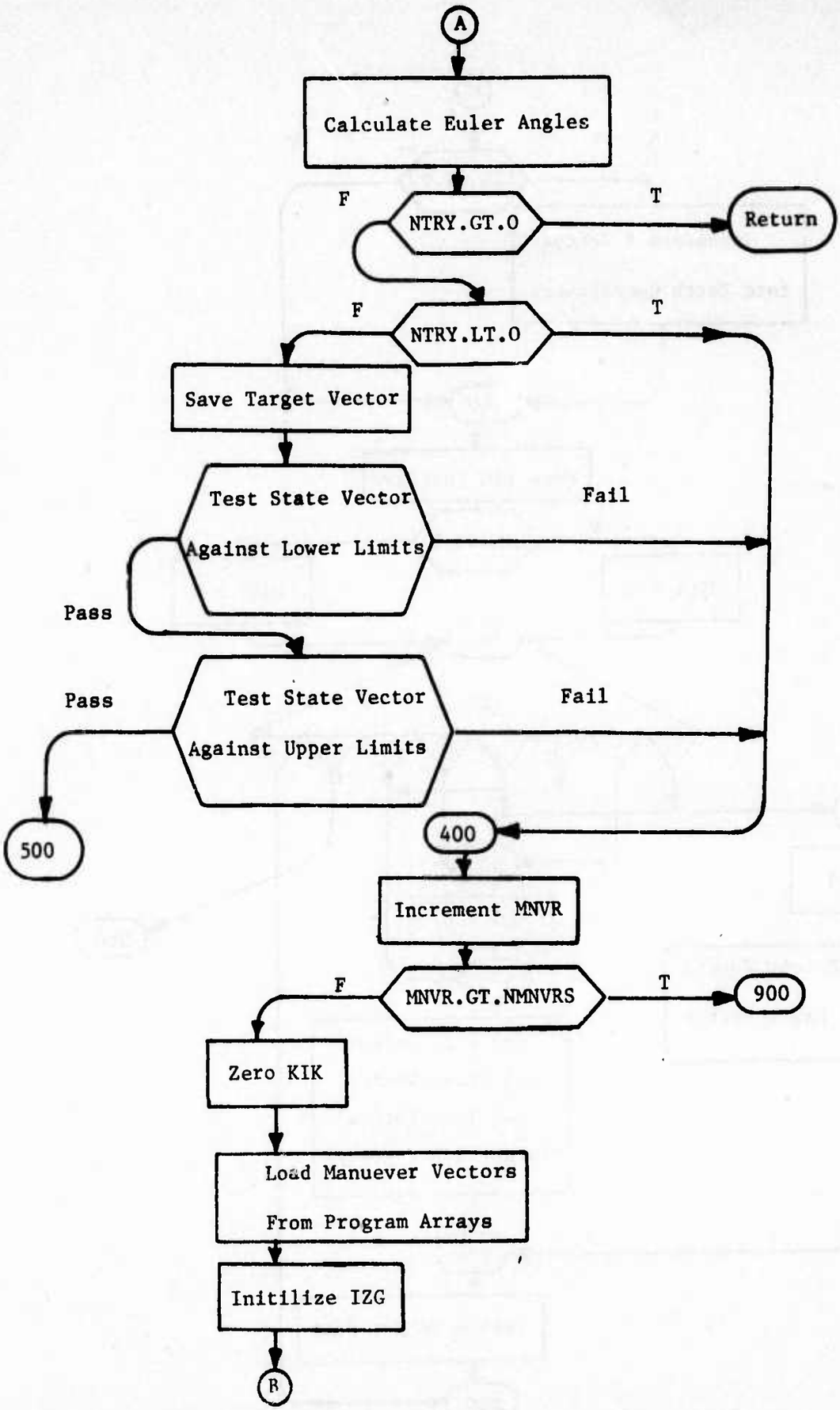

Figure 4. Flow Diagram of ESCAPE (Continued)

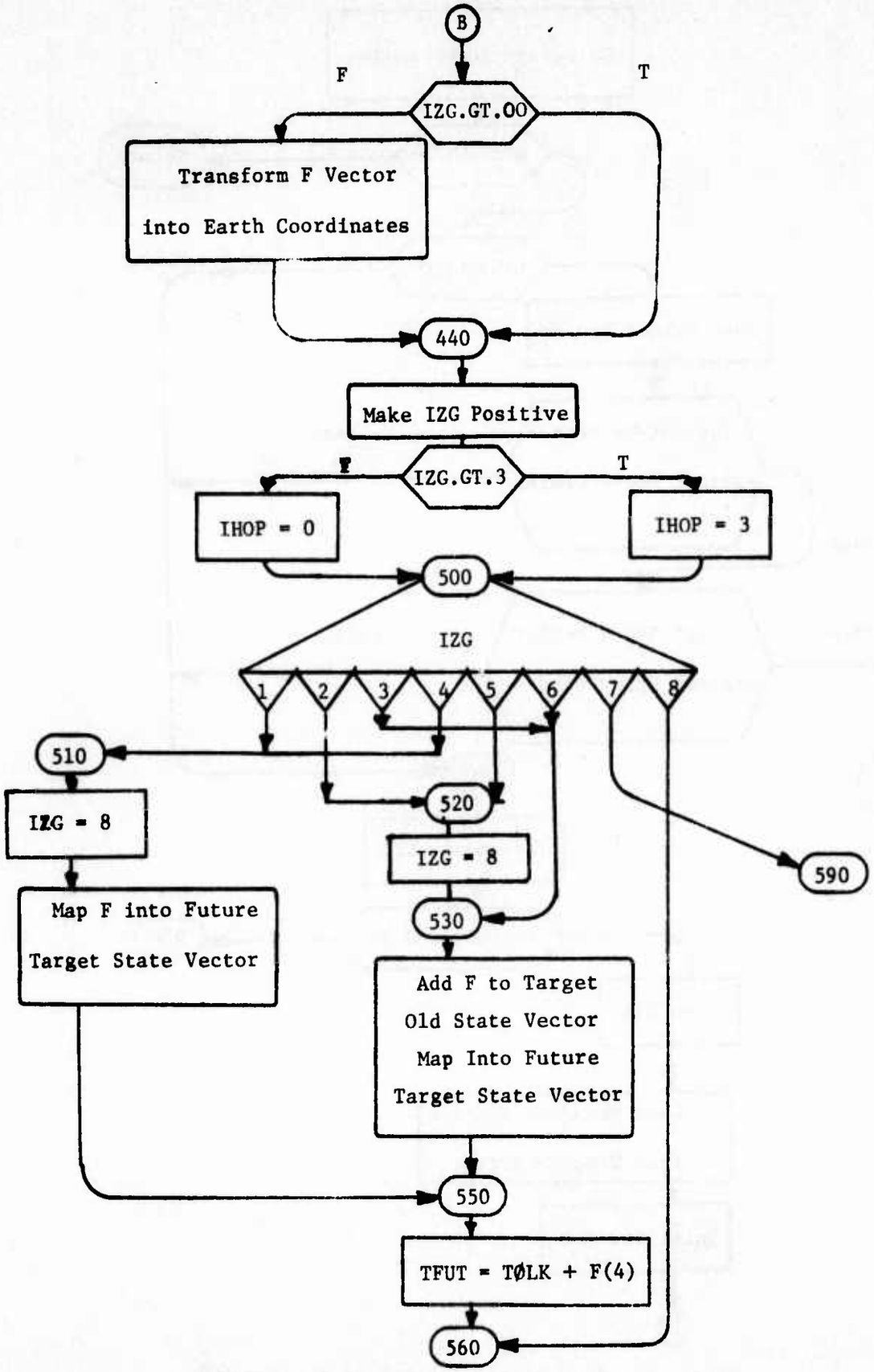

Figure 4. Flow Diagram of ESCAPE (Continued)

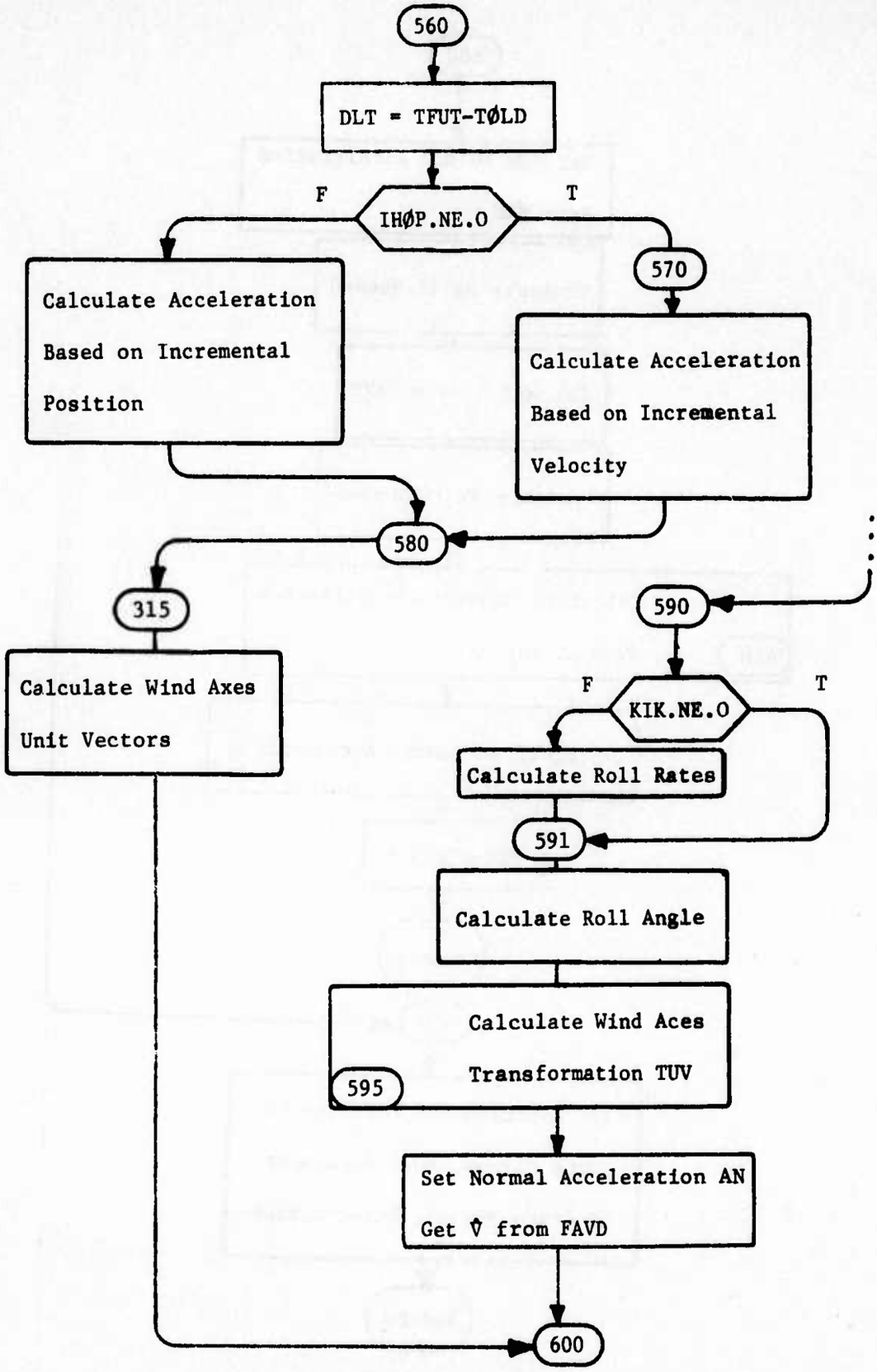

Figure 4. Flow Diagram of ESCAPE (Continued)

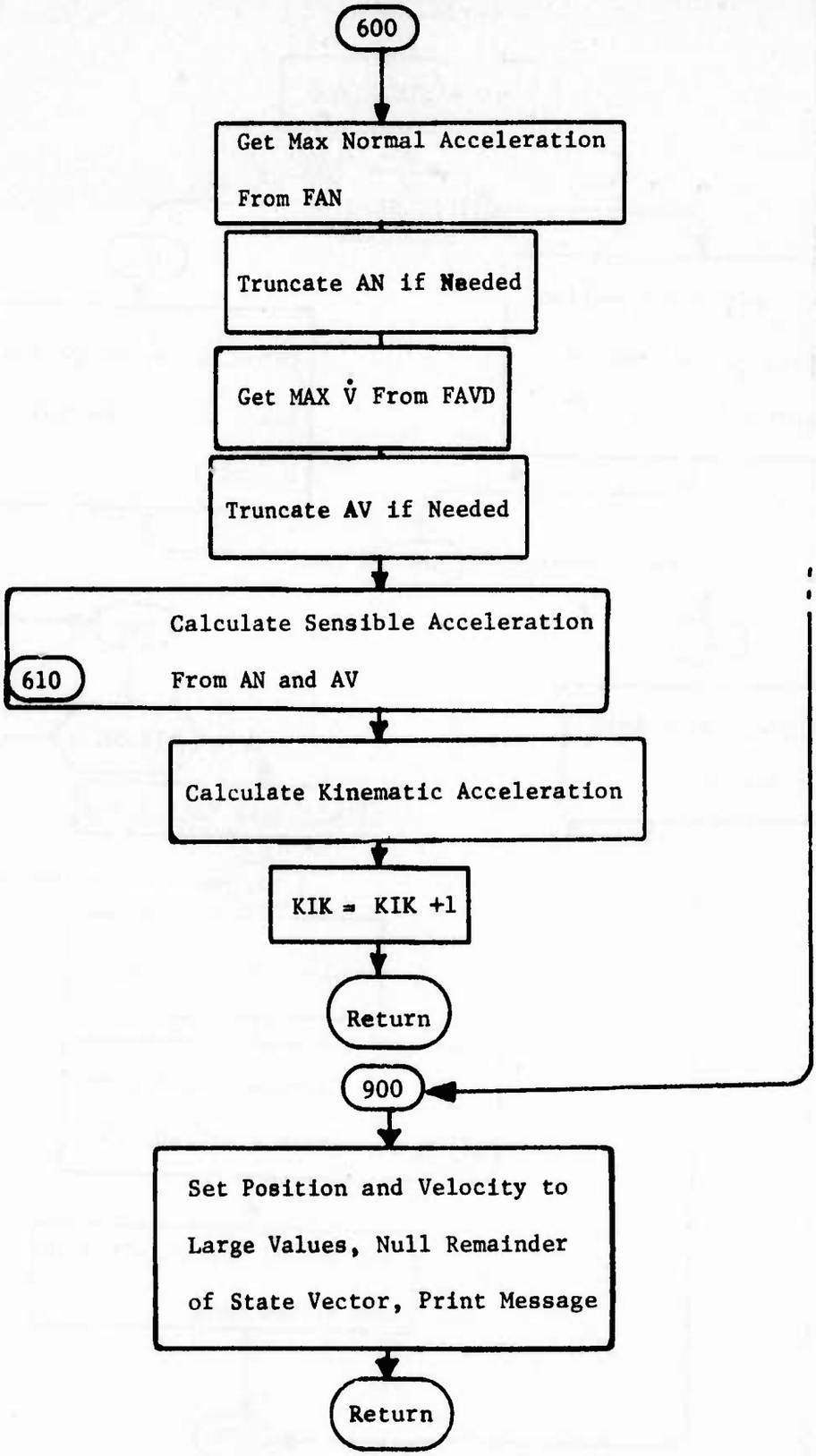

Figure 4. Flow Diagram of ESCAPE (Concluded)

$$X(t) = X(t_o) + A_K(t_o)\frac{(t-t_o)^2}{2} \qquad (25)$$

In use, the maximum value that $t-t_o$ will normally attain is 0.1 second. $A_K(t_o)$ is repeatedly updated as the simulation proceeds and, for instance, when IZG = 1, a feedback loop is established and the acceleration $A_K(t_o)$ and time t_o are continually being updated based on the present position of the target. Figure 4 is a flow diagram of the logic of ESCAPE.

INPUT DATA TO DEFINE A MANEUVER PROGRAM

Card No.	Format	Data
1.	A6, I4	Card title, number of maneuvers in motion program. Maximum number of maneuvers is 10.
2.	A6, I4, 5E10.2	Card title, maneuvers index, maneuver parameters. Maneuver parameters vary with index.
3.	A6, I4, 4(I5,E10.2) /(10x4(I5,E10.2))	Card title, number of lower limits, sequence of (state vector index, lower limit value) pairs. State vector indices are defined below. Maximum number of limits is 10.
4.	A6, I4, 4(I5, E10.2) /(10x4(I5,E10.2))	Card title, number of upper limits, sequence of (state vector index, upper limit value) pairs. State vector indices are defined below. Maximum number of limits is 10.

Cards 2, 3, and 4 are repeated in sequence for each maneuver in the program.

5.	A6, I4, 6E10.2	Card title, starting maneuver index less 1, initial conditions of target, x_1, x_2, x_3, V_1, V_2, V_3. The simulation uses X_3 down.

Card sequence [1, (2, 3, 4), (2, 3, 4), -- -- (2, 3, 4)] may be repeated for additional runs of the target. The minimum number of cards in a data sequence is 5.

MANEUVER PARAMETERS

There are five maneuver parameters read from each No. 2 card, and

the role played by each parameter depends upon the maneuver being defined. In all cases parameter 5 is the throttle setting. Negative values for IZG indicate that the parameters are defined in the target wind coordinate system.

IZG = 1, or -1	Parameter 1, 2, and 3 designate a point in space x_1, x_2, and x_3 toward which the target will fly. Parameter 4 is the time allowed for the maneuver.
IZG = 2, or -2	Parameters 1, 2, and 3 locate a point in space an increment Δx_1, Δx_2, Δx_3 away from the initialization of this maneuver. The target will try to fly to this point in the amount of time given by parameter 4.
IZG = 3, or -3	Parameters 1, 2, and 3 locate a moving point that in the limit leads the target parallel to Δx_1, Δx_2, Δx_3 specified by the parameters. Again parameter 4 is the time allotted to perform the maneuver. In effect, a constant acceleration is specified.
IZG = 4, or -4	Parameters 1, 2, and 3 define a velocity vector that the target will attempt to achieve in parameter 4 number of seconds.
IZG = 5, or -5	Parameters 1, 2, and 3 define an incremental velocity vector that will be added to the present velocity over parameter 4 seconds.
IZG = 6, or -6	Parameters 1, 2, and 3 define an incremental velocity that is used with parameter 4 to define a constant acceleration. This case is essentially the same as IZG = 3 except velocity rather than displacement is used to define acceleration.
IZG = 7	Parameter 1 is the initial roll angle in degrees. Parameter 2 is the roll rate in degrees if parameter 4 is zero. If parameter 4 is not zero, the roll rate is computed as (parameter 2 minus parameter 1)/parameter 4. Parameter 3 is the specified normal acceleration in g's. Tangential acceleration is controlled by parameter 5 as a throttle setting. Parameter 5 has values between 0. and 1.0.

STATE VECTOR INDICES

As described in the data and programming subsection, the target motion program steps up to the next maneuver in the sequence whenever a lower or upper limit is violated. A maximum of 10 upper and 10 lower limits is allowed per maneuver. At least one upper and one lower limit must be specified. The state vector quantity desired as a maneuver trigger is specified by state vector component index. The following list of indices must be used when formulating the limit control cards:

State Vector Quantity	Index
Simulation time	1
Attacker x_1 position	2
Attacker x_2 position	3
Attacker x_3 position	4
Target x_1 position	32
Target x_2 position	33
Target x_3 position	34
Range, attacker to target	31
Attacker velocity V_1	5
Attacker velocity V_2	6
Attacker velocity V_3	7
Attacker speed	8
Target velocity V_1	35
Target velocity V_2	36
Target velocity V_3	37
Target speed	38
Closing rate, attacker to target	56
Attacker roll angle ϕ	9
Attacker pitch angle θ	10
Attacker heading angle Ψ	11

Target roll angle ϕ	46
Target pitch angle θ	45
Target heading angle Ψ	44
Angle off, attacker to target	57
Target normal acceleration (lift)	42
Target tangential acceleration (drag), (thrust)	43

ADDITIONAL DATA

In addition to the target motion program control data described above, the target simulation requires tables of performance data. Specifically, four tables of data are required so that the aerodynamic performance of the target may be realistically constrained.

Maximum Normal Acceleration A two-dimensional table of maximum normal acceleration in feet/second^2 versus mach number and altitude is required. This table gives the maximum available normal acceleration as a function of the target's mach number and altitutde. It is used to make sure that the target does not outperform its capabilities. This table is described by the ordinate data arranged to vary with mach number most rapidly (down the columns) and the two abscissa arrays, mach number and altitude in feet. Formats for all are (10x7E10.2), with read order of mach vector, altitude vector, and then table.

Maximum Thrust To simulate the speed characteristics of the target properly, a table of maximum available thrust versus mach number and altitude is needed. Thrust in feet/second^2 is used with throttle position to control the tangential $\dot{V}$, acceleration of the target. This table is also two-dimensional with mach number as the column variable and altitude as the row variable. The formats are also (10x,7E10.2), with reading in the order mach vector, altitude vector, then table.

Drag Drag coefficient as a function of normal acceleration, mach number, and altitude is required in a three-dimensional format. The table defines a volume with each vertical slice defining a two-dimensional table. In the two-dimensional table the data varies down the columns with normal acceleration and from column to column with mach number. Each two-dimensional table is associated with an altitude. The read details are a format

of (10x7E10.2) and read sequence is normal acceleration vector, mach vector, altitude vector, and then table.

Angle of Attack The target simulation does not need the angle of attack for aerodynamic purposes. However, the actual attitude of the target with respect to the wind axes may affect the evaluation of a gun system. For this reason the target angle of attack is used to complete the attitudinal picture. For this purpose, angle of attack is considered a function of normal acceleration, mach number, and altitude. A three-dimensional table is used with column-wise organization with respect to varying normal acceleration, row-wise organization with respect to increasing mach number, and slice-wise organization with respect to increasing altitude.

ANCILLARY PROGRAMS

The target simulation uses three ancillary programs to do the data reading and table look up for the normal acceleration, thrust, drag and angle of attack. These programs are described briefly in the following paragraphs.

Function FAN handles the data manipulation used to describe the maximum normal acceleration available as a function of mach number and altitude. Upon the first call to FAN, data describing a table of normal acceleration versus mach number and altitude is read and stored. In the read sequence, the reference values for the mach number are read first and stored in array AM in ascending order according to magnitude. Next the reference values for the altitude in feet are read and stored in the array AH according to ascending index and magnitude. Finally the tabular values for normal acceleration in feet per second are read and stored in FMH. FMH is assumed to be structured as a two-dimensional array with the column entries indexed to the mach number array and the row entries indexed to the altitude array. Each data card has the first ten columns reserved for a label which is read and pointed via LABEL. The presently implemented program has three data entries in AM and AH and nine entries in FMH. Variables NM and NH indicate that the data is 3 X 3.

On calls subsequent to the initial call, a value for the normal acceleration, FAN, is calculated by the two variable table look-up program LOOK2 using VM and H as input values for mach number and altitude.

Function FAVD controls the data and calculations needed to obtain the maximum available tangential, or V, acceleration. On the first call to FAVD data is read and stored that defines two tables: One for maximum available thrust as a function of mach number and altitude, and one for drag-to-lift ratio as a function of normal acceleration, mach number and altitude.

The read sequence first reads the reference values of normal acceleration in ft /S^2 and stores them in the array AAN. Next reference values for the mach number are read and stored in array AM. The third read fills the array AH with the reference values of the altitude in feet. In the fourth read the tabular values of the maximum available thrust are read into array TRST in a two-dimensional array format. Row-wise organization is indexed according to the reference values stored in AM, the mach number, and column-wise organization is indexed according to the values stored in AH, altitude.

The fifth read ingests and stores the table of drag ratios into array DRG. These are nondimensional ratios of the drag to lift at the various normal acceleration (lift), mach number, and altitude reference points stored in AAN, AM, and AH, respectively. The array DRG varies most rapidly with normal acceleration (row-wise organization), next most rapidly with mach number (column-wise organization) and least rapidly with altitude (slice-wise variation). DRG is structured as a three-dimensional array with first subscript associated with altitude. Again the first 10 columns of the data cards are reserved for LABEL to be used strictly as a label.

On subsequent calls to FAVID, AN, VM and H are used by LOOK3 to look up and interpolate a value for DRAG, and VM and H are used by LOOK2 to look up and interpolate a value for THRST. The $\dot{V}$ acceleration for the target is calculated as

$$FAVD = THRST * TP - DRAG * AN$$

where $0. \leq TP \leq 1.$ and TP is the throttle position variable.

NA, NM, and NH show that the implemented program expects a 3 X 3 TRST and a 3 X 3 X 3 DRG.

Function TAAF is used to read and control the data for the definition of the target angle of attack. The angle of attack is considered as a function of three variables: normal acceleration, mach number, and altitude.

Upon the first call to TAAF the following read and store sequence is activated: first reference values for target normal acceleration in ft /S^2 are read and stored in array TAN; second reference values for mach number are read and stored in array TM; third reference values for altitude in feet are read and stored in array TH; and finally the three-dimensional table of angle of attack in degrees is read and stored in TAA. The assumed organization of TAA is that of a three-subscripted array with the first index linked to the values in TAN, the second index linked to the values in TM, and the third index linked to the reference values in TH. Each data card has the first 10 columns reserved for a label which is read and printed from LABEL. The expected data organization for the implemented program is 3 X 3 X 3 as indicated by NA, NM and NH.

On subsequent calls LOOK3 uses normal acceleration, AN, mach number, VM, and altitude, H, to look up and interpolate a value for angle of attack TAAF.

SECTION IV

SIGHT SYSTEM

SIGHT MODES

Three basic sight modes were adapted for implementation in the lead pursuit model: (1) A perfect first order prediction using the basic methodology present in GAMES (Reference 1); (2) a second order modification of the linear prediction model; and (3) an existing sight simulation. Modes (1) and (2) are perfect systems in that they assume position, velocity, and accelerations of the target are all known and available. Mode (3) is the disturbed-reticle sight supplied by AFATL personnel (AFAL-TR-75-52).

SIGHT ALGORITHM 1

In the first algorithm, the perfect first order prediction, the time of flight, and range are determined using the iterative procedure described in GAMES (Reference 1). The relative position, relative velocity, and acceleration vectors in the inertial system are calculated from

$$P_{rel} = P_{targ} - P_{att}$$
$$V_{rel} = V_{targ} - V_{att} \qquad (26)$$

The initializing range is taken as the present range from attacker to target.

The projectile average velocity is calculated as was done in GAMES using the appropriate projectile drag coefficients from subroutine DRAG (in GAMES). From these, a time of flight is calculated and used to calculate a new range. This procedure is repeated until the change in range is sufficiently small. The final range and time of flight values are used with attacker position and velocity vectors and gun information (muzzle velocity and position) to calculate the future position of the projectile one time of flight in the future. The proper pipper position is then calculated by backing up from the projectile future position an amount and in a direction determined from the target velocity and position.

SIGHT ALGORITHM 2

The second order approximation is accomplished by the addition of acceleration terms during calculation of both target and attacker positions after one time of flight. Otherwise, the algorithm is exactly the same as algorithm 1. In fact, the second order algorithm is imbedded in the linear prediction model and controlled by a flag.

The entire first and second order algorithm was extracted from GAMES, modified and installed in a separate subroutine called SSIGHT. Information describing the gun is transmitted through common block GUN while encounter data is transmitted through common block STATE.

SIGHT ALGORITHM 3

Subroutine SIGHT contains the disturbed-reticle sight algorithm. This routine was taken from technical report AFAL-TR-75-52 (Reference 4) and modified to accept encounter information externally through common STATE. The algorithm presented in Reference 4 assumed a particular encounter geometry and contained a loop which carried out the encounter. The modified routine uses the attacker information available in STATE, and makes one pass using the lead angles calculated from the previous pass through the algorithm and stored. The routine does not utilize the target information available in STATE. Thus, the algorithm assumes no target information is available and positions the pipper to indicate the position in the HUD of the impact point of a projectile fired one time of flight prior.

DATA REQUIREMENTS

The general data requirements are that, in the event that sight parameters are not fixed, they will be read in upon the first call to the sight program. This means that the subprogram writer will have to include logic in the sight program to recognize the first call. Further, some sight systems may require some standard initialization whenever a new case is begun. This report contains three implementations that can serve as examples for the programmer.

The first order sight requires a minimum amount of data. The gun muzzle velocity and the gun angle are the only data needed for the first order sight.

The second order sight is imbedded within the same program as the first order sight and consequently its data is taken care of by that program.

The disturbed reticle sight program SGHT is an example of a mechanization of a sight system. It is included as the third option for this attacker-target simulation. For this program, the program listing provides the best display of the needed information. For a different sight, this program would be rewritten and subroutine SGHT might read different data entirely, although there would be obvious similarities.

DATA FOR THE SIGHT PROGRAMS

Upon the first call to SSIGHT in the initialization phase of each new engagement, data defining the sight system is read and stored. There is one

READ command using the FORMAT (A6,I4,7E10.2). The following quantities are read from one card in the card in the card input file:

LABEL	a six character identifier.
IORD	order of sight system.
	IORD = 1 = first order perfect.
	IORD = 2 = second order perfect.
	IORD = 3 = sight implemented in subprogram SGHT.
VELMUZ	muzzle velocity, feet per second
GUNALP	gun angle, degrees.
GHR	gun harmonization range, feet.
DA	location of gun in azimuth direction from HUD, feet.
DE	location of gun in elevation direction from HUD, feet.
HALP	HUD angular displacement from airframe longitudinal axis, degrees.
SIG	Sight system damping factor.

SECTION V

IMPLEMENTATION INTO GAMES

GAMES

The Joint Technical Coordinating Group (JTCG) guns study program GAMES is essentially a design program for aerial gunnery systems whereby the effects of gun system parameters can be studied. The effective procedure of using the program is to set the gun system parameters and then evaluate their effectiveness by running a spectrum of engagements. The relevance of this concept to the present effort is that provision had to be made for a sequence of initial conditions and engagement descriptors to be read in by the simulation.

STRUCTURE OF GAMES

The structure of the GAMES program was not violated by the present effort. In fact, the program resulting from the inclusion of aerodynamic lead pursuit into GAMES still has all of the features and capabilities of the original version. This was accomplished by taking advantage of the fact that GAMES was written to be able to receive flight path data for both target and attacker from an outside source. The present attacker and target modelling program simply becomes another outside source of data. In this manner, GAMES itself was only modified to the extent of a third read option, a call to PILOT, and a few branches to take advantage of the fact that the new simulation produces more data than before.

PILOT

Subroutine PILOT has been explained in some detail in Section II of this report, especially with respect to the control algorithm aspects. PILOT as a subprogram also has executive duties. It must make appropriate initiation reads when a new case is started as well as initiation calls to TURKEY ESCAPE and SSIGHT. It also must envoke ESCAPE and SSIGHT after an integration of the equation of motion has been made and a reference state reached.

As indicated above, reinitialization is needed each time GAMES goes on to its next case. This is accomplished by calling PILOT with time set to zero. Upon this call PILOT calls the other programs in the attacker-target simulation with the initialization flag set, as well as reading its own initialization data.

For regular calls, time greater than zero, the PILOT program is first called and after integration of the simulation by PILOT, a call to ESCAPE is with the reference point flag set.

Subroutine PILOT is a slave to the main program of GAMES and does not have the capability of terminating the simulation. A listing of the main program of GAMES is included in the appendix along with PILOT and the other programs used in the simulation.

CDC 6600 RUNS

The modified GAMES program was implemented on the Eglin AFB CDC 6600 digital computer system. Test cases using engagements and data supplied by DLYD were run. Sample output from the simulation is included in the appendix to this report.

SECTION VI

OVERVIEW OF INPUT FILE STRUCTURE

INITIAL CALL TO PILOT

Upon the first call to PILOT with zero argument, a sequence of reads is initiated. The structure of the input file must be consistent with this sequence of reads. The basic initial sequence is as follows.

PILOT

Integration and print-out parameters and attacker initial conditions as described in Section II. Requires 4 cards.

ESCAPE

Data as described in detail in Section III. Upon the initialization of ESCAPE as now written a minimum of 25 cards will be read.

SSIGHT

Each time PILOT is called with zero argument SSIGHT will read one card as described in Section IV.

TURKEY

Upon the initial call to PILOT, all of the tabular data described in the IMAGE (Reference 1) program will be read. The card file must contain the following data sequences:

IDUM1	Integer data totaling 7 cards.
TDUM1	Real data totaling 69 cards.
TDUM2	Real data totaling 588 cards.
DUM	Real data totaling 4 cards.

Additions to DUM totaling 1 card

Total Cards on Initial Read

The above described card files give a minimum card set of 699 cards to be read as the initial data.

SUBSEQUENT RE-RUNS

Should reinitialization of the simulation be required, a call to PILOT with zero for argument will cause reinitialization of the programs. A much reduced data file is required as follows:

PILOT	3 cards, initial conditions only.
ESCAPE	2 cards minimum (see Section III).
SSIGHT	1 card
TURKEY	1 card, update on DUM only.

REFERENCES

1. Solomon, G., Caluda, M. J., Gunnery Analysis, Modular Effectiveness Simulation (GAMES) AFATL-TR-75-118, September, 1975.

2. Berger, J. B., M. Meyers, R. R. Wallace, Improved Model for Aerial Gunnery Effectiveness. AFATL-TR-68-112, September, 1968.

3. Whitehouse, G. D., A. J. McPhate, L. Theriot, A Research and Analysis Program of Studies on the Analysis of Weapon Effectiveness, Phase II Results, AFATL-TR-71-110, August, 1971.

4. Manske, Robert A., Air to Air Gunfire Control Equations for Digital Lead Computing Optical Sights, AFAL-TR-75-52, January, 1975.

5. McDonnel-Douglas Corporation, IMAGE User's Manual. Supplement to AFATL-TR-68-112, September, 1968.

APPENDIX A

PROGRAM LISTINGS AND SAMPLE RUN

```
      SUBROUTINE PILOT( TNEW )                                                  PBGN   10
      REAL  LKSLZR                                                              PBGN   20
      COMMON /GUN/ GUNS(5)                                                      PBGN   30
      COMMON /SIGHTS/ALPHUD,SGTSIG                                              PBGN   40
      COMMON /FROGS/ TWB(3,3),TWE(3,3),TWBD(3,3),W(3,3),WD(3,3)                 PBGN   50
      COMMON / KILLER / GOTCHA                                                  PBGN   60
      LOGICAL FLAG1,FLAG2,FLAG3                                                 PBGN   70
      LOGICAL KONOFF(4)                                                         PBGN   80
      INTEGER JB(2) , JY(2)                                                     PBGN   90
      COMMON/PLOP/NO,BV(456),YV(456),RV(456),TV(456)                            PBGN  100
      DIMENSION ZONK(456,4)                                                     PBGN  110
      EQUIVALENCE(ZONK(1,1),BV(1)),(ZONK(1,2),YV(1)),(ZONK(1,3),RV(1))          PBGN  120
     &  , (ZONK(1,4),TV(1))                                                     PBGN  130
      DIMENSION TD(3),XDD(3),YDD(3),DDX(3)                                      PBGN  140
      DIMENSION Y(3),YD(3),        TE(3),D(3)                                   PBGN  150
     P                 ,SVDS(15),ST(15)                                       PBGN  160
      DIMENSION X(3),XD(3),ZERO(4)                                              PBGN  170
      DIMENSION DX(3)                                                           PBGN  180
      DIMENSION EV(3)                                                           PBGN  190
      DIMENSION BOOGIE(7,8)                                                     PBGN  200
     &                 ,TBE(3,3)                                              PBGN  210
        DIMENSION ARRDDS(2)                                                     PBGN  220
      DIMENSION          CVCTR(4),ERVCTR(3),WS(3,3)                           PBGN  230
      DIMENSION EPS1(4),EPS2(4),EPSD1(4),EPSD2(4)                               PBGN  240
      COMMON /PILOTS/ BOOGIE,D,DX                                               PBGN  250
      COMMON /STATE/ TIME,SV(30),TSV(30),SVD(15),XHUD,YHUD,XHUDD,YHUDD          PBGN  260
      EQUIVALENCE ( SV(26),CVCTR(1)),(SYANK,SINY),(CYANK,COSY)                  PBGN  270
      EQUIVALENCE ( RDOT,RANGED )                                               PBGN  280
      EQUIVALENCE( EV(1),ERVCTR(1) ),( R,RANGE )                                PBGN  290
     &                 ,(RANGE,SV(30))                                         PBGN  300
     &                 ,(TBE(1,1),SV(16))                                      PBGN  310
      EQUIVALENCE ( YANKD,YDOT )                                                PBGN  320
     &                 ,(Y(1),TSV(1)),(YD(1),TSV(4)),(YDD(1),TSV(8))          PBGN  330
     &     ,(X(1),SV(1)),(XD(1),SV(4)),(XDD(1),SVD(4))                        PBGN  340
     &                 ,(SV(11),ALPHA),(SVD(11),ALPHAD)                       PBGN  350
      EQUIVALENCE( JB(1),JBP ),( JB(2),JBN ),( JY(1),JYP ),( JY(2),JYN )PBGN  360
      EQUIVALENCE(BOOGIE(7,1),BANK),(BOOGIE(7,2),BANKD),                        PBGN  370
     1(BOOGIE(7,3),YANK),(BOOGIE(7,4),YANKD),(BOOGIE(7,5),RDIPH),               PBGN  380
     2(BOOGIE(7,6),RDOT),(BOOGIE(7,7),SIGMA),(BOOGIE(7,8),SIGMAD)               PBGN  390
      EQUIVALENCE ( ARRDDS(1),ARRDDP ),( ARRDDS(2),ARRDDN )                     PBGN  400
```

```
      KWAK(K) = K - ( K / 2 ) * 2 + 1                                   PBGN  410
      DATA EPSRC/0.05/                                                  PBGN  420
      DATA EPSAR / 0.05 /                                               PBGN  430
      DATA EPSARD / 0.05 /                                              PBGN  440
      DATA JUMP/0/                                                      PBGN  450
      DATA EPS1 / 0.05 , 0.05 , 100.0 , 0.05 /                          PBGN  460
      DATA EPS2 / 0.01 , 0.01 , 200.0 , 0.01 /                          PBGN  470
      DATA EPSD1 / 0.10 , 0.10 , 50.0 , 0.10 /                          PBGN  480
      DATA EPSD2 / 0.05 , 0.05 , 100.0 , 0.05 /                         PBGN  490
      DATA PIE2 /1.5708 /                                               PBGN  500
      DATA WGHT1,WGHT2 / 0.8992 , 0.1008 /                              PBGN  510
      DATA DUCK1,DUCK2,DUCK3/0.3980,0.2506,0.3107/                      PBGN  520
      DATA LKSLZP / 0.5312 /                                            PBGN  530
       DATA PIE / 3.14159 /                                             PBGN  540
      IF( TNEW.GT.0.0 ) GOTO 4000                                       PBGN  550
      IF( JUMP.GT.00 ) GOTO 4100                                        PBGN  560
      JUMP = 01                                                         PBGN  570
      READ 3,LABEL,NF1,NF9,DTIME                                        PBGN  580
      PRINT7,LABEL,NF1,NF9,DTIME                                        PBGN  590
      DTIMEP = DTIME * 1.010                                            PBGN  600
      DTIMEM = DTIME * 0.010                                            PBGN  610
      FLAG2 = .FALSE.                                                   PBGN  620
      IF( NF9.GT.00 ) GOTO 4103                                         PBGN  630
      FLAG2 = .TRUE.                                                    PBGN  640
      NF9 = -NF9                                                        PBGN  650
4103   CONTINUE                                                         PBGN  660
4100 READ4,LABEL,(SV(I),I=1,15)                                         PBGN  670
      SV(7) = SQRT( SV(4)**2+SV(5)**2+SV(6)**2 )                        PBGN  680
      PRINT 8,LABEL,(SV(I),I=1,15)                                      PBGN  690
      DO 4101 I=1,4                                                     PBGN  700
      ZERO(I) = 0.0                                                     PBGN  710
4101 CVCTR(I) = 0.0                                                     PBGN  720
      TIME = 0.0                                                        PBGN  730
      CALL ESCAPE(-1)                                                   PBGN  740
      RANGE = 0.0                                                       PBGN  750
      DO   4102   J=1,3                                                 PBGN  760
4102   RANGE = RANGE + ( Y(J)-X(J) )**2                                 PBGN  770
      RANGE = SQRT( RANGE )                                             PBGN  780
      CALL SSIGHT(-1)                                                   PBGN  790
      CALL TURKEY(-1)                                                   PBGN  800
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      DO                3001        J=1,4                                  PBGN 810
 3001 BOOGIE(1,J*2-1) = CVCTR(J)                                           PBGN 820
      CALL TURKEY(-2)                                                      PBGN 830
      DO                3002        J=1,4                                  PBGN 840
      BOOGIE(1,J*2) = CVCTR(J)                                             PBGN 850
 3002 CVCTR(J)=0.0                                                         PBGN 860
      RETURN                                                               PBGN 870
C     CVCTR( 1 ) = DA                                                      PBGN 880
C     CVCTR(2) = DDS                                                       PBGN 890
C     CVCTR(3) = CDHM                                                      PBGN 900
C     CVCTR(4) = DR                                                        PBGN 910
 4000 KK = NF1-01                                                          PBGN 920
      KKK = NF9-01                                                         PBGN 930
      AICH = DTIME                                                         PBGN 940
      AICH2 = 0.5*AICH                                                     PBGN 950
 400  IF( TIME.LE.TNEW-DTIMEP ) GOTO 4200                                  PBGN 960
      IF( TIME.GE.TNEW-DTIMEM ) GOTO 4700                                  PBGN 970
      AICH = TNEW-TIME                                                     PBGN 980
      AICH2 = 0.5*AICH                                                     PBGN 990
 4200 KK = KK +01                                                          PBGN1000
      IF( KK.NE.NF1 ) GOTO 4300                                            PBGN1010
      KK = 00                                                              PBGN1020
      DO                4201        J=1,4                                  PBGN1030
      IF( J.EQ.04 ) GOTO 4201                                              PBGN1040
      ZERO(J) = WGHT1*ZERO(J) + WGHT2*CVCTR(J)                             PBGN1050
 4201  CVCTR(J) = ZERO(J)                                                  PBGN1060
      CALL ESCAPE(1)                                                       PBGN1070
      CALL TURKEY(1)                                                       PBGN1080
      DO 1001  J = 1,3                                                     PBGN1090
        DX(J) = YD(J) - XD(J)                                              PBGN1100
 1001 L(J) = Y(J) - X(J)                                                   PBGN1110
      RANGE = D(1)*D(1) + D(2)*D(2) + D(3)*D(3)                            PBGN1120
      RSQ = RANGE                                                          PBGN1130
      RANGL = SQRT( RANGE )                                                PBGN1140
      RST = SQRT( R )                                                      PBGN1150
      RDIFF = R - GUNS(3)                                                  PBGN1160
      DO 2002  I = 1 , 3                                                   PBGN1170
      SUM = 0.0                                                            PBGN1180
      DO 2001  J = 1 , 3                                                   PBGN1190
 2001 SUM = SUM   +  IBE( J,I ) * D(J)                                     PBGN1200
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1210          EPVCTR(I) = SUM                                                    PBGN1210
1220     2002 CONTINUE                                                           PBGN1220
1230   C  NOTE THAT THE VEL AND THE ACC OF THE PIPPER IS ASSUMED TO BE APPROX 0PBGN1230
1240          DO  561 I = 1 , 3                                                 PBGN1240
1250          SUM = 0.0                                                         PBGN1250
1260          DO  560  K = 1 , 3                                                PBGN1260
1270     560  SUM = SUM + W(I,K) * EV(K)                                        PBGN1270
1280     561  TE(I) = SUM                                                       PBGN1280
1290          DO 565  I = 1 , 3                                                 PBGN1290
1300          SUM = 0.0                                                         PBGN1300
1310          DO 564  K = 1 , 3                                                 PBGN1310
1320     564  SUM = SUM + TBE(K,I) *   DX(K)                                    PBGN1320
1330     565  TE(I) = SUM - TE(I)                                               PBGN1330
1340          RDOT = TE(1)*EV(1)+TE(3)*EV(3)+TE(2)*EV(2)                        PBGN1340
1350          RDOT = RDOT / R                                                   PBGN1350
1360     405  CONTINUE                                                          PBGN1360
1370          CALL SSIGHT( 1 )                                                  PBGN1370
1380          IF( EV(3) .EQ. 0.0 ) EV(3) = 1.0E-06                              PBGN1380
1390          IF( EV(2) .EQ. 0.0 ) EV(2) = 1.0E-06                              PBGN1390
1400          ERS3 = EV(3) * EV(3)                                              PBGN1400
1410          ERS2 = EV(2) * EV(2)                                              PBGN1410
1420          ERS1 = EV(1)* EV(1)                                               PBGN1420
1430          VIVZ2 = ERS1 + ERS2                                               PBGN1430
1440          SINY =  - ERVCTR( 3 ) / RANGE                                     PBGN1440
1450          CYANK2 = 1.0 - SYANK*SYANK                                        PBGN1450
1460          CYANK = SQRT( CYANK2 )                                            PBGN1460
1470          SYANKD = ( - TE(3)*R + EV(3)*RDOT ) / RSQ                         PBGN1470
1480          YANK = ARSIN(SYANK )   - ALPHUD - YHUD                            PBGN1480
1490          YANKD = SYANKD / CYANK - YHUDD                                    PBGN1490
1500          SYANK = SYANK * YANKD * SYANKD                                    PBGN1500
1510          SYANKD = 2.0 * R * RDOT * SYANKD                                  PBGN1510
1520          SKSQR = SQRT( VIVZ2 )                                             PBGN1520
1530          SINS = ERVCTR(2)/SKSQR                                            PBGN1530
1540          COSS = ERVCTR(1)/SKSQR                                            PBGN1540
1550          TSV(25) = RDOT                                                    PBGN1550
1560          SIGMA = ATAN2( SINS,COSS )                                        PBGN1560
1570          TSV(26) = SIGMA                                                   PBGN1570
1580          SIGMA = SIGMA - XHUD                                              PBGN1580
1590          SIGMAD = (TE(2) - RDOT*COSY*SINS + YDOT*R*SINY*SINS)/(R*COSY*COSS)PBGN1590
1600         P       - XHUDD                                                    PBGN1600
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1610          EVTE = 2.0*( EV(1)*TE(1) + EV(2)*TE(2) ) * SIGMAD                    PBGN1610
1620          YKSG2 = YANK*YANK + SIGMA*SIGMA                                      PBGN1620
1630          ERR = SQRT( YKSG2 )                                                  PBGN1630
1640          YNKP = YANK + YHUD + ALPHUD + LKSLZR                                 PBGN1640
1650          BANK = ATAN2( SIGMA,YNKP )                                           PBGN1650
1660          YPSG2 = YNKP*YNKP + SIGMA*SIGMA                                      PBGN1660
1670          BANKD = ( YNKP*SIGMAD - YANKD*SIGMA )/YPSG2                          PBGN1670
1680          YPSG2D = 2.*BANKD*( YANKD*YNKP+SIGMA*SIGMAD )/YPSG2                  PBGN1680
1690          FLAG3 = ERR.LE.EPSBC                                                 PBGN1690
1700          ERRD = ( YANK * YANKD + SIGMA * SIGMAD ) / ERR                       PBGN1700
1710          L = 01                                                               PBGN1710
1720    403   CONTINUE                                                             PBGN1720
1730          DO  410  I = 1 , 4                                                   PBGN1730
1740    410    CVCTR(I) = ZERO(I)                                                  PBGN1740
1750          JOY = ( L + 1 ) / 2                                                  PBGN1750
1760          CVCTR( JOY ) = BOOGIE( 1,L )                                         PBGN1760
1770          ASSIGN 447 TO KRASH                                                  PBGN1770
1780    411   CONTINUE                                                             PBGN1780
1790          CALL TURKEY(2)                                                       PBGN1790
1800    402   CONTINUE                                                             PBGN1800
1810          DO 551  I = 1 , 3                                                    PBGN1810
1820          DDX(I) = YDD(I) - XDD(I)                                             PBGN1820
1830          DO 551  J = 1 , 3                                                    PBGN1830
1840          SUM = 0.0                                                            PBGN1840
1850          DO 550  K = 1 , 3                                                    PBGN1850
1860    550   SUM = SUM + W(I,K) * W(K,J)                                          PBGN1860
1870    551   WS(I,J) = SUM + WD(I,J)                                              PBGN1870
1880          DO  553  I = 1,3                                                     PBGN1880
1890          SUM = 0.0                                                            PBGN1890
1900          SUM1 = 0.0                                                           PBGN1900
1910          DO 552 K = 1,3                                                       PBGN1910
1920          SUM = SUM + WS(I,K) * EV(K)                                          PBGN1920
1930          SUM1 = SUM1 +  W(I,K) * TE(K)                                        PBGN1930
1940    552   CONTINUE                                                             PBGN1940
1950    553   TD(I) = SUM + SUM1 + SUM1                                            PBGN1950
1960          DO 558  I = 1 , 3                                                    PBGN1960
1970          SUM = 0.0                                                            PBGN1970
1980          DO 557  K = 1 , 3                                                    PBGN1980
1990    557   SUM = SUM + TBE(K,I) *  DDX(K)                                       PBGN1990
2000    558   TD(I) = SUM - TD(I)                                                  PBGN2000
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2010          SUM = EV(1)*TD(1)+EV(2)*TD(2)+EV(3)*TD(3)                                  PBGN2010
2020          SUM1 = TE(1)*TE(1)+TE(2)*TE(2)+TE(3)*TE(3) + SUM                           PBGN2020
2030           RDDOT = (SUM1 - RDOT * RDOT )/ R                                          PBGN2030
2040          SIGMDD = ( TD(2)*TE(1)+TE(2)*TD(1) - EVTE ) / VIVZ2                        PBGN2040
2050          YANKDD = ( - TD(3)*R + EV(3)*RDDOT - SYANKD ) / RSQ                        PBGN2050
2060          YANKDD = ( YANKDD * CYANK + SYANK ) / CYANK2                               PBGN2060
2070          BANKDD = ( YNKP*SIGMDD-YANKDD*SIGMA )/YPSG2 - YPSG2D                       PBGN2070
2080          ERRDD = (YANK*YANKDD+SIGMA*SIGMDD+YANKD**2+SIGMAD**2-ERRD**2)/ERR          PBGN2080
2090           GOTO KRASH,(446,447)                                                      PBGN2090
2100    447    CONTINUE                                                                  PBGN2100
2110          BOOGIE(2,L) = ERRDD                                                        PBGN2110
2120          BOOGIE(3,L) = BANKDD                                                       PBGN2120
2130          BOOGIE(4,L) = YANKDD                                                       PBGN2130
2140          BOOGIE(5,L) = RDDOT                                                        PBGN2140
2150          BOOGIE(6,L) = SIGMDD                                                       PBGN2150
2160          L = L + 01                                                                 PBGN2160
2170          IF ( L .LE. 08 ) GOTO 403                                                  PBGN2170
2180          KIK = 04                                                                   PBGN2180
2190          IF( FLAG3 ) KIK = 01                                                       PBGN2190
2200          DO  420  I = 1 , 7 , 2                                                     PBGN2200
2210          IP1 = I + 01                                                               PBGN2210
2220          JOY = IP1 / 2                                                              PBGN2220
2230          J = JOY + 02                                                               PBGN2230
2240          IF( JOY .EQ. KIK ) GOTO 851                                                PBGN2240
2250          ARR = BOOGIE(7,I)                                                          PBGN2250
2260          ARRD = BOOGIE(7,IP1)                                                       PBGN2260
2270          JBP = I                                                                    PBGN2270
2280          JBN = IP1                                                                  PBGN2280
2290          ARRDDP = BOOGIE( J,I )                                                     PBGN2290
2300          ARRDDN = BOOGIE( J,IP1 )                                                   PBGN2300
2310          IF ( ARRDDP .GT. ARRDDN ) GOTO 412                                         PBGN2310
2320          JBP = IP1                                                                  PBGN2320
2330          JBN = I                                                                    PBGN2330
2340          ARRDDP = BOOGIE( J,IP1 )                                                   PBGN2340
2350          ARRDDN = BOOGIE( J,I )                                                     PBGN2350
2360    412    CONTINUE                                                                  PBGN2360
2370    C   K = 01   MOST POSITIVE  -- JBP                                              PBGN2370
2380    C   K = 02   MOST NEGATIVE -- JBN                                               PBGN2380
2390           K = 01                                                                    PBGN2390
2400          IF ( ABS(ARR) .GT. EPSAR ) GOTO 805                                        PBGN2400
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2410          IF( ABS ( ARRD ) .LT. EPSARD ) GOTO 851                                  PBGN2410
2420    805   CONTINUE                                                                 PBGN2420
2430          IF ( ARR .EQ. 0.0 ) GOTO 820                                             PBGN2430
2440          IF ( ARR * ARRD .GE. 0.0 )  GOTO 821                                     PBGN2440
2450    810   T = - ARRD / ARRDDS ( K )                                                PBGN2450
2460          IF ( T .GT. 0.0 ) GOTO 815                                               PBGN2460
2470          K = KWAK( K )                                                            PBGN2470
2480          IF ( ARRDDS( 1 )*ARRDDS( 2 ) .GT. 0.0 ) GOTO 850                         PBGN2480
2490          GOTO 810                                                                 PBGN2490
2500    815    GOOFUS = ARR + ARRD * T + ARRDDS(K) * T * T * 0.50                      PBGN2500
2510          GOOFUS = GOOFUS * SIGN( 1.0,ARR )                                        PBGN2510
2520          IF ( GOOFUS .GT. EPSAR ) GOTO 821                                        PBGN2520
2530          GOTO 850                                                                 PBGN2530
2540    820   IF ( ARRD * ARRDDS(K) .GT. 0.0 ) GOTO 825                               PBGN2540
2550          GOTO 850                                                                 PBGN2550
2560    821    IF ( ARR * ARRDDS(K) .GT. 0.0 )GOTO  825                                PBGN2560
2570          GOTO 850                                                                 PBGN2570
2580    825    CONTINUE                                                                PBGN2580
2590          K = KWAK( K )                                                            PBGN2590
2600          GOTO 850                                                                 PBGN2600
2610    851    CVCTR(JOY) = ZERO(JOY)                                                  PBGN2610
2620          KONOFF( JOY ) = .TRUE.                                                   PBGN2620
2630          GOTO 420                                                                 PBGN2630
2640    850   CONTINUE                                                                 PBGN2640
2650          CVCTR( JOY ) = BOOGIE( 1,J8( K ) )                                       PBGN2650
2660          KONOFF( JOY ) = .FALSE.                                                  PBGN2660
2670    420   CONTINUE                                                                 PBGN2670
2680          DO              4400        J=1,4                                        PBGN2680
2690          IF(  KONOFF(J)  )  GOTO  4400                                            PBGN2690
2700          BOOG = ABS( BOOGIE(7,2*J-1) )                                            PBGN2700
2710          BOOGD = ABS( BOOGIE(7,2*J) )                                             PBGN2710
2720          IF( BOOG.LT.EPS1(J).AND.BOOGD.LT.EPSD1(J) )                              PBGN2720
2730         &              CVCTR(J) = CVCTR(J)*0.5                                   PBGN2730
2740          IF( BOOG.LT.EPS2(J).AND.BOOGD.LT.EPSD2(J) )                              PBGN2740
2750         &              CVCTR(J) = CVCTR(J)*0.5                                   PBGN2750
2760    4400 CONTINUE                                                                  PBGN2760
2770          IF( ABS(BANK) .GT. DUCK1   .OR. ABS(BANKD) .GT. DUCK2 )                  PBGN2770
2780         &       CVCTR( 2 ) = CVCTR( 2 ) * DUCK3                                   PBGN2780
2790    4300 CALL TURKEY(0)                                                            PBGN2790
2800    C    FLAG2 = .TRUE.  PRINT EVERYTHING                                          PBGN2800
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2810          KKK = KKK + 01                                                    PBGN2810
2820          IF( KKK .NE. NF9 ) GOTO 630                                       PBGN2820
2830          KKK = 00                                                          PBGN2830
2840          WRITE(6,45)                                                       PBGN2840
2850          WRITE(6,2)TIME                                                    PBGN2850
2860          DO 445    J = 1 , 15                                              PBGN2860
2870          WRITE(6,5) J,SV(J),SVD(J),TSV(J)                                  PBGN2870
2880    445   CONTINUE                                                          PBGN2880
2890          WRITE(6,42)(CVCTR(J),J=1,4)                                       PBGN2890
2900          DO 900   J = 1 , 4                                               PBGN2900
2910          ZONK( NO , J ) = CVCTR( J )                                       PBGN2910
2920    900    CONTINUE                                                         PBGN2920
2930          IF( FLAG2 ) GOTO 630                                              PBGN2930
2940          WRITE(6,6)(ERVCTR(J),J=1,3)                                       PBGN2940
2950          PRINT52                                                           PBGN2950
2960          ASSIGN 446 TO KRASH                                               PBGN2960
2970          GOTO 411                                                          PBGN2970
2980    446    CONTINUE                                                         PBGN2980
2990          PRINT51,BANK,YANK,R,SIGMA,ERR,BANKD,YANKD,RDOT,SIGMAD,ERRD        PBGN2990
3000         &,BANKDD,YANKDD,RDDOT,SIGMDD,ERRDD                                 PBGN3000
3010          IF(  NO .GT. 150  ) GOTO  5000                                    PBGN3010
3020          NOPN = NO + 304                                                   PBGN3020
3030          NOPM = NO + 152                                                   PBGN3030
3040          BV( NOPN ) = BANK                                                 PBGN3040
3050          YV( NOPN ) = YANK                                                 PBGN3050
3060          RV( NOPN ) = RDIPH                                                PBGN3060
3070          TV( NOPN ) = SIGMA                                                PBGN3070
3080          BV( NOPM ) = BANKDD                                               PBGN3080
3090          YV( NOPM ) = YANKDD                                               PBGN3090
3100          RV( NOPM ) = RDDOT                                                PBGN3100
3110          TV( NOPM ) = SIGMAD                                               PBGN3110
3120    5000   CONTINUE                                                         PBGN3120
3130          PRINT9,XHUD,XHUDD,YHUD,YHUDD                                      PBGN3130
3140          GOTCHA = 0.0                                                      PBGN3140
3150            IF( ABS(ERR).LT.EPSAR .AND. ABS(ERRD).LT.EPSARD ) GOTCHA = 1.0  PBGN3150
3160          IF( GOTCHA .EQ. 1.0 ) PRINT 11                                    PBGN3160
3170    630   CONTINUE                                                          PBGN3170
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      DO              4500      J=1,15                                  PRNM   10
      ST(J) = SV(J)                                                     PRNM   20
      SVDS(J) = SVD(J)                                                  PRNM   30
4500  SV(J) = SV(J) + SVD(J)*AICH                                       PRNM   40
      TIME = TIME + AICH                                                PRNM   50
      CALL TURKEY(0)                                                    PRNM   60
      DO              4600      J=1,15                                  PRNM   70
4600  SV(J) = ST(J) + AICH2*( SVDS(J)+SVD(J) )                          PRNM   80
      GOTO 400                                                          PRNM   90
4700   CALL ESCAPE(0)                                                   PRNM  100
      CALL SSIGHT(0)                                                    PRNM  110
      RETURN                                                            PFMT   10
1     FORMAT(10X,3I10)                                                  PFMT   20
2     FORMAT('0',8X,'ELAPSED TIME',F10.3)                               PFMT   30
3     FORMAT(A6,4X,2I5,6E10.2)                                          PFMT   40
4     FORMAT(A10,7E10.2/(10X,7E10.2))                                   PFMT   50
5     FORMAT( 9X,4X,I2,1P 2E15.4,10X,E15.4)                             PFMT   60
6     FORMAT( 9X,'ERROR VECTOR = ',1P 3E15.4)                           PFMT   70
7     FORMAT(1X,A6,4X,2I5,6E10.2)                                       PFMT   80
8     FORMAT(1X,A10,7E10.2/(10X,7E10.2))                                PFMT   90
9     FORMAT(9X,6HPIPPER1P4E15.4)                                       PFMT  100
11    FORMAT(9X,6HGOTCHA)                                               PFMT  110
42    FORMAT( 9X,'CONTROL VECTOR =',1P4E15.4)                           PFMT  120
45    FORMAT(9X 80(1H*))                                                PFMT  130
48    FORMAT(9X 10HRANGE =      ,F12.1)                                 PFMT  140
51      FORMAT(9X,1P5E15.4)                                             PFMT  150
52    FORMAT(9X,7X,5H BANK10X,5H YANK10X,5HRANGE10X,5HSIGMA10X,5HERROR) PFMT  160
      END                                                               PFMT  170
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      SUBROUTINE TURKEY(NTRY)                                                    TURK   10
      REAL    MASS,MACH                                                          TURK   20
      COMMON    /TDATA/    TDUM1(550),   TDUM2(4700)                           TURK   30
      COMMON /IDATA1/ IDUM1(131)                                                 TURK   40
      COMMON/PIGLET/DUM(25)                                                      TURK   50
      COMMON /FROGS/TWB(3,3),TWE(3,3),TWBD(3,3),W(3,3),WD(3,3)                   TURK   60
      COMMON /STATE/ GSV(80)                                                     TURK   70
      DIMENSIONX(15),XD(15),XXD(3),XXDD(3)                                       TURK   80
     &         ,SV(30),SVD(15),CVCTR(4)                                        TURK   90
     &         ,XDD(3),TBE(3,3)                                                TURK  100
     &      ,QRK(3)                                                            TURK  110
      DIMENSION ALR7M(8),ALR7H(6),ALR7A(5),CLRT(240)                             TURK  120
      DIMENSION  ACYBM(8), ACYBH(6), ACYBA(5), CYBT(240)                         TURK  130
      DIMENSION  ACLBM(8), ACLBH(6), ACLBA(5), CLBT(240)                         TURK  140
      DIMENSION  ALDRM(8), ALDRH(6), ALDRA(5), CLDRT(240)                        TURK  150
      DIMENSION  AMDSM(8), AMDSH(6), AMDSA(5), CMDST(240)                        TURK  160
      DIMENSION  ANB7M(8), ANB7H(6), ANB7A(5), CNBT(240)                         TURK  170
      DIMENSION  AYP7M(8), AYP7H(6), AYP7A(5), CYPT(240)                         TURK  180
      DIMENSION  ANP7M(8), ANP7H(6), ANP7A(5), CNPT(240)                         TURK  190
      DIMENSION  AYDRM(8), AYDRH(6),           CYDRT(48)                         TURK  200
      DIMENSION  AYR7M(8), AYR7H(6), AYR7A(5), CYRT(240)                         TURK  210
      DIMENSION  AZQ7M(8), AZQ7H(6),           CZQT(48)                          TURK  220
      DIMENSION  AZADM(8), AZADH(6),           CZADT(48)                         TURK  230
      DIMENSION  AZDSM(8), AZDSH(6), AZDSA(5), CZDST(240)                        TURK  240
      DIMENSION  ALDAM(8), ALDAH(6), ALDAA(5), CLDAT(240)                        TURK  250
      DIMENSION  AMADM(8), AMADH(6),           CMADT(48)                         TURK  260
      DIMENSION  AMQ7M(8), AMQ7H(6),           CMQT(48)                          TURK  270
      DIMENSION  ANDRM(8), ANDRH(6),           CNDRT(48)                         TURK  280
      DIMENSION  ALP7M(8), ALP7H(6), ALP7A(5), CLPT(240)                         TURK  290
      DIMENSION  ANDAM(8), ANDAH(6), ANDAA(5), CNDAT(240)                        TURK  300
      DIMENSION  AYDAM(8),                     CYDAT(8)                          TURK  310
      DIMENSION  ANR7M(8), ANR7H(6), ANR7A(5), CNRT(240)                         TURK  320
      DIMENSION  ACL7M(8), ACL7H(6), ACL7A(5), CLT(240)                          TURK  330
      DIMENSION  ACM7M(8), ACM7H(6), ACM7A(5), CMT(240)                          TURK  340
      DIMENSION  ADT7M(8), ADT7R(6)                                              TURK  350
      DIMENSION  CRHOT(70),  CDT(80)                                             TURK  360
      DIMENSION  ALTRM(8), ALTRH(6), ALTRA(5), CLTRT(240)                        TURK  370
      DIMENSION  ARHO(100)                                                       TURK  380
      EQUIVALENCE (DUM(1),DE),(DUM(2),S),(DUM(3),B),(DUM(4),MASS),               TURK  390
     1 (DUM(5),G),(DUM(6),RC),(DUM(7),TIXX),(DUM(8),TIYY),(DUM(9),TIZZ),TURK  400
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     2 (DUM(10),TIXZ),(DUM(11),ALW),(DUM(12),AMT),                                                    TURK  410
     3 (DUM(13),DRUL),(DUM(14),DRLL),(DUM(15),DDSUL),(DUM(16),DDSLL),                                 TURK  420
     4 (DUM(17),DAUL),(DUM(18),DALL),(DUM(19),THRST1),                                                TURK  430
     5 (DUM(20),THRST2),(DUM(21),THRST3),(DUM(22),THRST4)                                             TURK  440
     &               ,(DUM(23),ALPMX),(DUM(24),BETMX) ,(DUM(25),GMX)                                  TURK  450
      EQUIVALENCE(X(7),V),(X(8),PHI),(X(9),THETA),(X(10),PSI)                                         TURK  460
     &               ,(X(11),ALPHA),(X(12),BETA),(X(13),P),(X(14),Q)                                  TURK  470
     &               ,(X(15),R)                                                                       TURK  480
     &               ,(XD(1),XXD(1)),(XD(4),XXDD(1)),(XD(7),VD)                                       TURK  490
     &               ,(XD(8),PHID),(XD(9),THETAD),(XD(10),PSID),                                      TURK  500
     &               (XD(11),ALPHAD),(XD(12),BETAD),(XD(13),PD)                                       TURK  510
     &               ,(XD(14),QD),(XD(15),RD)                                                         TURK  520
     &               ,(GSV(17),TBE(1,1)),(GSV(26),RHO)                                                TURK  530
     &               ,(SV(1),X(1)),(SVD(1),XD(1)),(SV(26),CVCTR(1))                                   TURK  540
      EQUIVALENCE(ACYBM(1),TDUM1(   1)),(ACYBH(1),TDUM1(   9))                                        TURK  550
      EQUIVALENCE(ACYBA(1),TDUM1(  15)),(ACLBM(1),TDUM1(  20))                                        TURK  560
      EQUIVALENCE(ACLBH(1),TDUM1(  28)),(ACLBA(1),TDUM1(  34))                                        TURK  570
      EQUIVALENCE(ALDRM(1),TDUM1(  39)),(ALDRH(1),TDUM1(  47))                                        TURK  580
     &          ,(SVD(1),GSV(62))                                                                    TURK  590
     &       ,(GSV(2),SV(1))                                                                         TURK  600
      EQUIVALENCE(ALDRA(1),TDUM1(  53)),(ALR7M(1),TDUM1(  58))                                        TURK  610
      EQUIVALENCE(ALR7H(1),TDUM1(  66)),(ALR7A(1),TDUM1(  72))                                        TURK  620
      EQUIVALENCE(AMDSM(1),TDUM1(  77)),(AMDSH(1),TDUM1(  85))                                        TURK  630
      EQUIVALENCE(AMDSA(1),TDUM1(  91)),(ANB7M(1),TDUM1(  96))                                        TURK  640
      EQUIVALENCE(ANB7H(1),TDUM1( 104)),(ANB7A(1),TDUM1( 110))                                        TURK  650
      EQUIVALENCE(AYP7M(1),TDUM1( 115)),(AYP7A(1),TDUM1( 123))                                        TURK  660
      EQUIVALENCE(AYP7H(1),TDUM1( 128)),(ANP7M(1),TDUM1( 134))                                        TURK  670
      EQUIVALENCE(ANP7A(1),TDUM1( 142)),(ANP7H(1),TDUM1( 147))                                        TURK  680
      EQUIVALENCE(AYDRM(1),TDUM1( 153)),(AYDRH(1),TDUM1( 161))                                        TURK  690
      EQUIVALENCE(AYR7M(1),TDUM1( 167)),(AYR7H(1),TDUM1( 175))                                        TURK  700
      EQUIVALENCE(AZQ7M(1),TDUM1( 181)),(AZQ7H(1),TDUM1( 189))                                        TURK  710
      EQUIVALENCE(AZADM(1),TDUM1( 195)),(AZADH(1),TDUM1( 203))                                        TURK  720
      EQUIVALENCE(AZDSM(1),TDUM1( 209)),(AZDSA(1),TDUM1( 217))                                        TURK  730
      EQUIVALENCE(AZDSH(1),TDUM1( 222)),(ALDAM(1),TDUM1( 228))                                        TURK  740
      EQUIVALENCE(ALDAH(1),TDUM1( 236)),(AMADM(1),TDUM1( 242))                                        TURK  750
      EQUIVALENCE(AMADH(1),TDUM1( 250)),(AMQ7M(1),TDUM1( 256))                                        TURK  760
      EQUIVALENCE(AMQ7H(1),TDUM1( 264)),(ANDRM(1),TDUM1( 270))                                        TURK  770
      EQUIVALENCE(ANDRH(1),TDUM1( 278))                                                               TURK  780
      EQUIVALENCE(ALP7H(1),TDUM1( 291)),(ANDAM(1),TDUM1( 297))                                        TURK  790
      EQUIVALENCE(ANDAA(1),TDUM1( 305)),(ANDAH(1),TDUM1( 310))                                        TURK  800
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      EQUIVALENCE(AYDAM(1),TDUM1( 316)),(ANR7M(1),TDUM1( 324))                TURK 810
      EQUIVALENCE(ACL7A(1),TDUM1( 332)),(ACL7M(1),TDUM1( 337))                TURK 820
      EQUIVALENCE(ACL7H(1),TDUM1( 345)),(ACM7A(1),TDUM1( 351))                TURK 830
      EQUIVALENCE(ACM7M(1),TDUM1( 356)),(ACM7H(1),TDUM1( 364))                TURK 840
      EQUIVALENCE(ADT7R(1),TDUM1(370)),(ADT7M(1),TDUM1(380))                  TURK 850
      EQUIVALENCE(ALTRA(1),TDUM1( 388)),(ALTRM(1),TDUM1( 393))                TURK 860
      EQUIVALENCE( ALTRH(1),TDUM1(401)),(ARHO(1),TDUM1(407))                  TURK 870
      EQUIVALENCE(AYR7A(1),TDUM1( 515)),(ALDAA(1),TDUM1( 520))                TURK 880
      EQUIVALENCE(ALP7A(1),TDUM1( 525)),(ANP7H(1),TDUM1( 530))                TURK 890
      EQUIVALENCE(ANR7A(1),TDUM1( 536))                                       TURK 900
      EQUIVALENCE(ALP7M(1),TDUM1( 541))                                       TURK 910
      EQUIVALENCE( CYBT(1)  ,TDUM2(   1)),  ( CLBT(1) ,TDUM2( 241))          TURK 920
      EQUIVALENCE( CLDRT(1) ,TDUM2( 481)),  ( CLRT(1) ,TDUM2( 721))          TURK 930
      EQUIVALENCE( CMDST(1) ,TDUM2( 961)),  ( CNBT(1) ,TDUM2(1201))          TURK 940
      EQUIVALENCE( CYPT(1)  ,TDUM2(1441)),  ( CNPT(1) ,TDUM2(1681))          TURK 950
      EQUIVALENCE( CYDRT(1) ,TDUM2(1921))                                     TURK 960
      EQUIVALENCE( CZQT(1)  ,TDUM2(2017)),  ( CZADT(1),TDUM2(2065))          TURK 970
      EQUIVALENCE( CZDST(1) ,TDUM2(2113))                                     TURK 980
      EQUIVALENCE( CMADT(1) ,TDUM2(2401)),  ( CMQT(1) ,TDUM2(2449))          TURK 990
      EQUIVALENCE( CNDRT(1) ,TDUM2(2497))                                     TURK1000
      EQUIVALENCE( CNDAT(1) ,TDUM2(2593)),  ( CYDAT(1),TDUM2(2833))          TURK1010
      EQUIVALENCE( CLT(1)   ,TDUM2(2849))                                     TURK1020
      EQUIVALENCE( CMT(1)           ,  TDUM2(3089) )                          TURK1030
      EQUIVALENCE( CDT(1)  ,TDUM2(3329)),(CRHOT(1),TDUM2(3409))               TURK1040
      EQUIVALENCE( CLTRT(1)         ,  TDUM2(3479) )                          TURK1050
      EQUIVALENCE( CYRT(1)  ,TDUM2(3727)),  (CLDAT(1),TDUM2(3967))           TURK1060
      EQUIVALENCE( CLPT(1)  ,TDUM2(4207)),  (CNRT(1) ,TDUM2(4447))           TURK1070
      EQUIVALENCE(NCYBM,IDUM1(  1)),(NCYBH,IDUM1(  2)),(NCYBA,IDUM1( 3))TURK1080
      EQUIVALENCE(NCLBM,IDUM1(  4)),(NCLBH,IDUM1(  5)),(NCLBA,IDUM1( 6))TURK1090
      EQUIVALENCE(NLDRM,IDUM1(  7)),(NLDRH,IDUM1(  8)),(NLDRA,IDUM1( 9))TURK1100
      EQUIVALENCE(NLR7M,IDUM1( 10)),(NLR7H,IDUM1( 11)),(NLR7A,IDUM1(12))TURK1110
      EQUIVALENCE(NMDSM,IDUM1( 13)),(NMDSH,IDUM1( 14)),(NMDSA,IDUM1(15))TURK1120
      EQUIVALENCE(NNB7M,IDUM1( 16)),(NNB7H,IDUM1( 17)),(NNB7A,IDUM1(18))TURK1130
      EQUIVALENCE(NYP7M,IDUM1( 19)),(NYP7A,IDUM1( 20)),(NYP7H,IDUM1(21))TURK1140
      EQUIVALENCE(NNP7M,IDUM1( 22)),(NNP7A,IDUM1( 23)),(NNP7H,IDUM1(24))TURK1150
      EQUIVALENCE(NYDRM,IDUM1( 25)),(NYDRH,IDUM1( 26))                        TURK1160
      EQUIVALENCE(NYR7M,IDUM1( 27)),(NYR7H,IDUM1( 28))                        TURK1170
      EQUIVALENCE(NZQ7M,IDUM1( 29)),(NZQ7H,IDUM1( 30))                        TURK1180
      EQUIVALENCE(NZADM,IDUM1( 31)),(NZADH,IDUM1( 32))                        TURK1190
      EQUIVALENCE(NZDSM,IDUM1( 33)),(NZDSA,IDUM1( 34)),(NZDSH,IDUM1(35))TURK1200
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1210          EQUIVALENCE(NLDAM,IDUM1( 36)),(NLDAH,IDUM1( 37))                                    TURK1210
1220          EQUIVALENCE(NMADM,IDUM1( 38)),(NMADH,IDUM1( 39))                                    TURK1220
1230          EQUIVALENCE(NMQ7M,IDUM1( 40)),(NMQ7H,IDUM1( 41))                                    TURK1230
1240          EQUIVALENCE(NNDRM,IDUM1( 42)),(NNDRH,IDUM1( 43))                                    TURK1240
1250          EQUIVALENCE(NLP7M,IDUM1( 44)),(NLP7H,IDUM1( 45))                                    TURK1250
1260          EQUIVALENCE(NNDAM,IDUM1( 46)),(NNDAA,IDUM1( 47)),(NNDAH,IDUM1(67))                  TURK1260
1270          EQUIVALENCE(NYDAM,IDUM1( 48))                                                       TURK1270
1280          EQUIVALENCE(NNR7M,IDUM1( 49))                                                       TURK1280
1290          EQUIVALENCE(NCL7A,IDUM1( 50)),(NCL7M,IDUM1( 51)),(NCL7H,IDUM1(52))                  TURK1290
1300          EQUIVALENCE(NCM7A,IDUM1( 53)),(NCM7M,IDUM1( 54)),(NCM7H,IDUM1(55))                  TURK1300
1310          EQUIVALENCE(NYR7A,IDUM1( 56)),(NLDAA,IDUM1( 57)),(NLP7A,IDUM1(58))                  TURK1310
1320          EQUIVALENCE(NDT7R,IDUM1(59)),(NDT7M,IDUM1(60))                                      TURK1320
1330          EQUIVALENCE(NRHO ,IDUM1( 61))                                                       TURK1330
1340          EQUIVALENCE(NNR7H,IDUM1( 62)),(NNR7A,IDUM1( 63))                                    TURK1340
1350          EQUIVALENCE   ( INDTBE          ,  IDUM1( 73))                                      TURK1350
1360          EQUIVALENCE   ( IRETAF          ,IDUM1( 83))                                        TURK1360
1370          EQUIVALENCE   ( INDERR    ,  IDUM1( 98))                                            TURK1370
1380          EQUIVALENCE(NLTRH ,IDUM1(101)),(NLTRM ,IDUM1(102))                                  TURK1380
1390          EQUIVALENCE(NLTRA ,IDUM1(103))                                                      TURK1390
1400          DATA RCP / 968.12 /                                                                 TURK1400
1410          DATA DDR /57.29578/                                                                 TURK1410
1420          DATA JUMP/0/                                                                        TURK1420
1430          IF( NTRY.GE.00 ) GOTO 2000                                                          TURK1430
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      IF( JUMP.GT.00 ) GOTO 1000                                        TKIN   10
      JUMP = 01                                                         TKIN   20
      READ1,IDUM1                                                       TKIN   30
      READ2,IDUM1                                                       TKIN   40
      READ2,IDUM2                                                       TKIN   50
      READ2,DUM                                                         TKIN   60
      PRINT 3, DUM                                                      TKIN   70
      DO  12   I = 13 , 18                                              TKIN   80
      DUM( I ) = DUM( I ) / DDR                                         TKIN   90
12    CONTINUE                                                          TKIN  100
      DUM( 01 ) = DUM( 01 ) / DDR                                       TKIN  110
      DUM( 11 ) = DUM( 11 ) / DDR                                       TKIN  120
      DUM( 23 ) = DUM( 23 ) / DDR                                       TKIN  130
      DUM( 24 ) = DUM( 24 ) / DDR                                       TKIN  140
      COSDE  = COS( DE )                                                TKIN  150
      SINDE  = SIN( DE )                                                TKIN  160
      ACCMX = G*GMX                                                     TKIN  170
1000  IF( NTRY .LT. -01 ) GOTO 1100                                     TKIN  180
      READ2,MASS,TIXX,TIYY,TIZZ,TIXZ                                    TKIN  190
      PRINT 3,MASS,TIXX,TIYY,TIZZ,TIXZ                                  TKIN  200
      GM =  MASS * G                                                    TKIN  210
      THMEAN = 0.25*( THRST1+THRST2+THRST3+THRST4 )                     TKIN  220
      CVCTR(1) = DAUL                                                   TKIN  230
      CVCTR(2) = DDSUL                                                  TKIN  240
      CVCTR(3) = THRST1 - THMEAN                                        TKIN  250
      CVCTR(4) = DRUL                                                   TKIN  260
      DO              1050       J=1,3                                  TKIN  270
      WD(J,J) = 0.0                                                     TKIN  280
1050  W(J,J) = 0.0                                                      TKIN  290
      XXI = TIYY - TIZZ                                                 TKIN  300
      YYI = TIZZ - TIXX                                                 TKIN  310
      ZZI = TIXX - TIYY                                                 TKIN  320
      DET = TIXX*TIZZ - TIXZ**2                                         TKIN  330
      RETURN                                                            TKIN  340
1100  CVCTR(1) = DALL                                                   TKIN  350
      CVCTR(2) = DDSLL                                                  TKIN  360
      CVCTR(3) = THRST4 - THMEAN                                        TKIN  370
      CVCTR(4) = DRLL                                                   TKIN  380
      RETURN                                                            TKIN  390
2000  IF( NTRY .EQ. 02 ) GOTO 3000                                      TKIN  400
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410         R = - X( 3 )                                                                                    TKIN 410
420         W(1,2) = -R                                                                                     TKIN 420
430         W(1,3)  = +Q                                                                                    TKIN 430
440         W(2,3) = -P                                                                                     TKIN 440
450         W(2,1) =  - W(1,2)                                                                              TKIN 450
460         W(3,1) = - W(1,3)                                                                               TKIN 460
470         W(3,2) = - W(2,3)                                                                               TKIN 470
480         COSTHE = COS( THETA )                                                                           TKIN 480
490         SINTHE = SIN( THETA )                                                                           TKIN 490
500         COSPHI = COS( PHI )                                                                             TKIN 500
510         SINPHI = SIN( PHI )                                                                             TKIN 510
520         COSPSI = COS( PSI )                                                                             TKIN 520
530         SINPSI = SIN( PSI )                                                                             TKIN 530
540            TBE(1,1) = COSPSI * COSTHE                                                                   TKIN 540
550            TBE(2,1) = SINPSI * COSTHE                                                                   TKIN 550
560            TBE(3,1) =  - SINTHE                                                                         TKIN 560
570            TBE(1,2) = COSPSI * SINTHE * SINPHI - SINPSI * COSPHI                                        TKIN 570
580            TBE(2,2) = SINPSI * SINTHE * SINPHI + COSPSI * COSPHI                                        TKIN 580
590            TBE(3,2) = COSTHE * SINPHI                                                                   TKIN 590
600            TBE(1,3) = COSPSI * SINTHE * COSPHI + SINPSI * SINPHI                                        TKIN 600
610            TBE(2,3) = SINPSI * SINTHE * COSPHI - COSPSI * SINPHI                                        TKIN 610
620            TBE(3,3) = COSTHE * COSPHI                                                                   TKIN 620
630         SUM = 0.0                                                                                       TKIN 630
640         COSALP = COS( ALPHA )                                                                           TKIN 640
650         SINALP = SIN( ALPHA )                                                                           TKIN 650
660         COSBTA = COS( BETA )                                                                            TKIN 660
670         SINBTA = SIN( BETA )                                                                            TKIN 670
680            TWB(1,1) =  COSALP * COSBTA                                                                  TKIN 680
690            TWB(1,2) = - COSALP * SINBTA                                                                 TKIN 690
700            TWB(1,3) =  SINALP                                                                           TKIN 700
710            TWB(2,1) = SINBTA                                                                            TKIN 710
720            TWB(2,2) = COSBTA                                                                            TKIN 720
730            TWB(2,3) = 0.0                                                                               TKIN 730
740            TWB(3,1) = SINALP * COSBTA                                                                   TKIN 740
750            TWB(3,2) =  - SINALP * SINBTA                                                                TKIN 750
760            TWB(3,3) =  - COSALP                                                                         TKIN 760
770         DO  100 I = 1 , 3                                                                               TKIN 770
780         DO  100 J = 1 , 3                                                                               TKIN 780
790         SUM = 0.0                                                                                       TKIN 790
800         DO 101  K = 1 , 3                                                                               TKIN 800
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      SUM = SUM + TBE(I,K) * TWB(K,J)                                          TKIN 810
  101 CONTINUE                                                                 TKIN 820
        TWE(I,J) = SUM                                                         TKIN 830
  100 CONTINUE                                                                 TKIN 840
      IF( NTRY.EQ.00 ) GOTO 2100                                               TKIN 850
      IF( H .LT. 36000.0 ) MACH = V/(49.0 * SQRT(518.7 - H * 3.565E-3))        TKIN 860
      IF( H .GT. 36000.0 ) MACH = V / RCP                                      TKIN 870
      ALPHAW = ( ALPHA + ALW ) * DDR                                           TKIN 880
C   ALPHAW IS NOW IN DEGREES .....................                             TKIN 890
      CALL LOOK3                                                               TKIN 900
     $(CLDR,H,MACH,ALPHAW,ALDRH,NLDRH,ALDRM,NLDRM,ALDRA,NLDRA,CLDRT,0)         TKIN 910
      CALL LOOK3                                                               TKIN 920
     $(CLR,H,MACH,ALPHAW,ALR7H,NLR7H,ALR7M,NLR7M,ALR7A,NLR7A,CLRT,0)           TKIN 930
      CALL LOOK3                                                               TKIN 940
     $(CMDS,H,MACH,ALPHAW,AMDSH,NMDSH,AMDSM,NMDSM,AMDSA,NMDSA,CMDST,0)         TKIN 950
      CALL LOOK3                                                               TKIN 960
     $(CYP,H,MACH,ALPHAW,AYP7H,NYP7H,AYP7M,NYP7M,AYP7A,NYP7A,CYPT,0)           TKIN 970
      CALL LOOK3                                                               TKIN 980
     $(CNP,H,MACH,ALPHAW,ANP7H,NNP7H,ANP7M,NNP7M,ANP7A,NNP7A,CNPT,0)           TKIN 990
      CALL LOOK2                                                               TKIN1000
     $(CYDR,H,MACH,AYDRH,NYDRH,AYDRM,NYDRM,CYDRT,0)                            TKIN1010
      CALL LOOK3                                                               TKIN1020
     $(CYR,H,MACH,ALPHAW,AYR7H,NYR7H,AYR7M,NYR7M,AYR7A,NYR7A,CYRT,0)           TKIN1030
      CALL LOOK2                                                               TKIN1040
     $(CZQ,H,MACH,AZQ7H,NZQ7H,AZQ7M,NZQ7M,CZQT,0)                              TKIN1050
      CALL LOOK2                                                               TKIN1060
     $(CZAD,H,MACH,AZADH,NZADH,AZADM,NZADM,CZADT,0)                            TKIN1070
      CALL LOOK3                                                               TKIN1080
     $(CZDS,H,MACH,ALPHAW,AZDSH,NZDSH,AZDSM,NZDSM,AZDSA,NZDSA,CZDST,0)         TKIN1090
      CALL LOOK3                                                               TKIN1100
     $(CLDA,H,MACH,ALPHAW,ALDAH,NLDAH,ALDAM,NLDAM,ALDAA,NLDAA,CLDAT,0)         TKIN1110
      CALL LOOK2                                                               TKIN1120
     $(CMAD,H,MACH,AMADH,NMADH,AMADM,NMADM,CMADT,0)                            TKIN1130
      CALL LOOK2                                                               TKIN1140
     $(CMQ,H,MACH,AMQ7H,NMQ7H,AMQ7M,NMQ7M,CMQT,0)                              TKIN1150
      CALL LOOK2                                                               TKIN1160
     $(CNDR,H,MACH,ANDRH,NNDRH,ANDRM,NNDRM,CNDRT,0)                            TKIN1170
      CALL LOOK3                                                               TKIN1180
     $(CLP,H,MACH,ALPHAW,ALP7H,NLP7H,ALP7M,NLP7M,ALP7A,NLP7A,CLPT,0)           TKIN1190
      CALL LOOK3                                                               TKIN1200
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      $(CNDA,H,MACH,ALPHAW,ANDAH,NNDAH,ANDAM,NNDAM,ANDAA,NNDAA,CNDAT,0)   TKIN1210
       CALL LOOK1(CYDA,MACH,AYDAM,NYDAM,CYDAT,0)                         TKIN1220
       CALL LOOK3                                                        TKIN1230
      $(CNR,H,MACH,ALPHAW,ANR7H,NNR7H,ANR7M,NNR7M,ANR7A,NNR7A,CNRT,0)    TKIN1240
       CALL LOOK3                                                        TKIN1250
      $(CL,H,MACH,ALPHAW,ACL7H,NCL7H,ACL7M,NCL7M,ACL7A,NCL7A,CLT,0)      TKIN1260
       CALL LOOK3                                                        TKIN1270
      $(CM,H,MACH,ALPHAW,ACM7H,NCM7H,ACM7M,NCM7M,ACM7A,NCM7A,CMT,0)      TKIN1280
       CALL LOOK1( RHO,H,ARHO,NRHO,CRHOT,0)                              TKIN1290
       QS = 0.5 * RHO * V * V                                            TKIN1300
       CALL LOOK3                                                        TKIN1310
      $(CYB,H,MACH,ALPHAW,ACYBH,NCYBH,ACYBM,NCYBM,ACYBA,NCYBA,CYBT,0)     TKIN1320
       CALL LOOK3                                                        TKIN1330
      $(CLB,H,MACH,ALPHAW,ACLBH,NCLBH,ACLBM,NCLBM,ACLBA,NCLBA,CLBT,0)     TKIN1340
       CALL LOOK3                                                        TKIN1350
      $(CNB,H,MACH,ALPHAW,ANB7H,NNB7H,ANB7M,NNB7M,ANB7A,NNB7A,CNBT,0)     TKIN1360
       CALL LOOK3                                                        TKIN1370
      $(CLTR,H,MACH,ALPHAW,ALTRH,NLTRH,ALTRM,NLTRM,ALTRA,NLTRA,CLTRT,0)   TKIN1380
       ALPHAW=ALPHAW/DDR                                                 TKIN1390
C   ALPHAW IS NOW IN RADIANS ..........................                  TKIN1400
       CALL LOOK2(CD,MACH,ALPHAW,ADT7M,NDT7M,ADT7R,NDT7R,CDT,0)          TKIN1410
 2100    CONTINUE                                                        TKIN1420
       ALPSE = ALPHA + DE                                                TKIN1430
       CALPSE = COS(ALPSE)                                               TKIN1440
       SALPSE = SIN(ALPSE)                                               TKIN1450
       SINGAM = - TWB(3,1)                                               TKIN1460
       TWOV = 2.00*V                                                     TKIN1470
       BD2V = B / TWOV                                                   TKIN1480
       CUAN1 =  P * COSALP + R * SINALP                                  TKIN1490
       CUAN2 =  R * COSALP - P * SINALP                                  TKIN1500
       QBS = QB*S                                                        TKIN1510
       QBSRC = QBS*RC                                                    TKIN1520
       DRAG = QBS*CD                                                     TKIN1530
       RCD2V = RC / TWOV                                                 TKIN1540
       STUFF = RCD2V * QBS                                               TKIN1550
       VM = V * MASS                                                     TKIN1560
       B1 =   + QBS    *   TWB( 3,1 )                                   TKIN1570
       B2 =   + QBS    *   TWB( 1,1 )                                   TKIN1580
       B3 =   - QBS    *   TWB( 3,3 )                                   TKIN1590
       B4 =   - QBS    *   TWB( 1,3 )                                   TKIN1600
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1610          T1 = ( CLP*QUAN1 + CLR*QUAN2 )*BD2V + CLB*BETA                    TKIN1610
1620          T2 = ( CNP*QUAN1 + CNR*QUAN2 )*BD2V + CNB*BETA                    TKIN1620
1630          STUFF1 = XXI*Q*R + TIXZ*Q*P + ( B2*T1 + B4*T2 )*B                 TKIN1630
1640          STUFF2 = ZZI*P*Q - TIXZ*R*Q +( B1*T1 + B2*T2 )*B                  TKIN1640
1650          A1 = ( STUFF1*TIZZ + STUFF2*TIXZ )/DET                            TKIN1650
1660          A2 = ( STUFF2*TIXX + STUFF1*TIXZ )/DET                            TKIN1660
1670          B1 = B1 / DET                                                     TKIN1670
1680          B2 = B2 / DET                                                     TKIN1680
1690          B3 = B3 / DET                                                     TKIN1690
1700          B4 = B4 / DET                                                     TKIN1700
1710          AJUNK = B1*TIXZ + B2*TIZZ                                         TKIN1710
1720          BJUNK = B3*TIXZ + B4*TIZZ                                         TKIN1720
1730          A11 = AJUNK*CLDR + BJUNK*CNDR                                     TKIN1730
1740          A12 = AJUNK*CLDA + BJUNK*CNDA                                     TKIN1740
1750          AJUNK = B2*TIXZ + B1*TIXX                                         TKIN1750
1760          BJUNK = B4*TIXZ + B3*TIXX                                         TKIN1760
1770          A21 = AJUNK*CLDR + BJUNK*CNDR                                     TKIN1770
1780          A22 = AJUNK*CLDA + BJUNK*CNDA                                     TKIN1780
1790          IF( NTRY.EQ.01 ) RETURN                                           TKIN1790
1800     3000 CONTINUE                                                          TKIN1800
1810          DA    = CVCTR( 1 )                                                TKIN1810
1820          DDS = CVCTR(2)                                                    TKIN1820
1830          CDHM = CVCTR(3) + THMEAN                                          TKIN1830
1840          DR    = CVCTR( 4 )                                                TKIN1840
1850          COM = CYDR*DR + CYB*BETA + CYDA*DA + BD2V*(CYP*QUAN1 + CYR*QUAN2) TKIN1850
1860          SFC = QBS*COM                                                     TKIN1860
1870          XXLF = QBS*(-CL + CZDS*DDS + RCD2V * CZQ * Q )                    TKIN1870
1880          VD = (CDSBTA*(CDHM*CALPSE - DRAG) + SINBTA*SFC)/MASS - G*SINGAM   TKIN1880
1890          ALPHAD = (-CDHM*SALPSE - GM*TWE(3,3) + XXLF                       TKIN1890
1900         &      + VM * ( Q * CDSBTA - SINBTA * QUAN1 ))                     TKIN1900
1910         2        / (VM * CDSBTA - STUFF * CZAD )                          TKIN1910
1920          BETAD = (SINBTA*(-CDHM*CALPSE + DRAG) + CDSBTA*SFC)/ VM          TKIN1920
1930         &         +   TWE(3,2) * G / V - QUAN2                            TKIN1930
1940          IF( ALPHA.GE.ALPMX .AND. ALPHAD.GE.0.0 ) ALPHAD = 0.0             TKIN1940
1950          IF( ALPHA.LE.-ALPMX .AND. ALPHAD.LE.0.0 ) ALPHAD = 0.0            TKIN1950
1960          IF( BETA.GE.BETMX .AND. BETAD.GE.0.0 ) BETAD = 0.0                TKIN1960
1970          IF( BETA.LE.-BETMX .AND. BETAD.LE.0.0 ) BETAD = 0.0               TKIN1970
1980          PD = A1 +(A11*DR + A12*DA)*B                                      TKIN1980
1990          RD = A2 +(A21*DR + A22*DA)*B                                      TKIN1990
2000          QJUNK = YYI*R*P + ( R*R - P*P )*TIXZ                              TKIN2000
```

```
2010          &          + QBSRC*( CM + RCD2V*( CMAD*ALPHAD + CMQ*Q ) )                TKIN2010
2020           QD = ( QJUNK + QBSRC*CMDS*DDS + AMT*CDHM ) / TIYY                      TKIN2020
2030           PSID = ( R*COSPHI + Q*SINPHI ) / COSTHE                                TKIN2030
2040           THETAD = Q*COSPHI - R*SINPHI                                           TKIN2040
2050           PHID = P + PSID*SINTHE                                                 TKIN2050
2060           QRK(1) = VD                                                            TKIN2060
2070           QRK(2) = V*( BETAD + QUAN2 )                                           TKIN2070
2080           QRK(3) =-V*COSBTA*( ALPHAD+QUAN1*SINBTA/COSBTA-Q )                     TKIN2080
2090           DO  401  I = 1 , 3                                                     TKIN2090
2100            SVD( I ) = SV( I+03 )                                                 TKIN2100
2110           SUM = 0.0                                                              TKIN2110
2120           DO  402  J = 1 , 3                                                     TKIN2120
2130    402     SUM = SUM + TWE(I,J) * QRK(J)                                         TKIN2130
2140    401    SVD( I + 3 ) = SUM                                                     TKIN2140
2150           WD(1,2) = -RD                                                          TKIN2150
2160           WD(1,3) = +QD                                                          TKIN2160
2170           WD(2,3) = -PD                                                          TKIN2170
2180           WD(2,1) = - WD(1,2)                                                    TKIN2180
2190           WD(3,1) = - WD(1,3)                                                    TKIN2190
2200           WD(3,2) = -WD(2,3)                                                     TKIN2200
2210           SUM = SQRT( XXDD(1)**2+XXDD(2)**2+XXDD(3)**2 )                         TKIN2210
2220           IF( SUM.LE.ACCMX) GOTO 4003                                            TKIN2220
2230           SUM = ACCMX/SUM                                                        TKIN2230
2240           DO              4304        J = 1,3                                    TKIN2240
2250    4304 XXDD(J) = XXDD(J)*SUM                                                    TKIN2250
2260    4003  CONTINUE                                                               TKIN2260
2270           RETURN                                                                 TKIN2270
2280    1      FORMAT(20I4)                                                           TKIN2280
2290    2      FORMAT(8E10.2)                                                         TKIN2290
2300    3      FORMAT(' TURKEY',1P10E12.3)                                            TKIN2300
2310           END                                                                    TKIN2310
```

```
      SUBROUTINE SSIGHT( NTRY )                                          SIGH  10
C  VREL = RELATIVE VELOCITY   (INERTIAL SYSTEM)                          SIGH  20
C  PREL = RELATIVE POSITION                                              SIGH  30
C  AREA = RELATIVE ACCELERATION                                          SIGH  40
C  RELPT = TOTAL RELATIVE POSITION                                       SIGH  50
C  RANGE = RANGE (HEH-HEH)                                               SIGH  60
C  UBAR = AVE PROJECTILE VELOCITY                                        SIGH  70
C  TF = TIME OF FLIGHT                                                   SIGH  80
C  RPI = ITERATIVE RANGE VECTOR TO TARGET                                SIGH  90
C  RPIT = TOTAL RPI VECTOR                                               SIGH 100
C  AVELA = VELOCITY VECTOR OF ATTACKER IN ATTACKER BODY COORDINATES       SIGH 110
C  AACCA = ATTACKER ACCELERATION VECTOR IN ATTACKER BODY COORDINATES      SIGH 120
C  AVPRJ = PROJECTILE VELOCITY VECTOR IN ATTACKER BODY COORDINATES        SIGH 130
C  PFP = PROJECTILE FUTURE POSITION (IMPACT POINT)  IN ATTACKER BODY COOSIGH 140
      COMMON/GUN/VELMUZ,GUNALP,GHR,DA,DE                                 SIGH 150
      DIMENSION VREL(3),PREL(3),AREL(3),RPI(3),UNITZ(3)                  SIGH 160
      DIMENSION POSA(3),VELA(3),ACCA(3),POST(3),VELT(3),ACCT(3)          SIGH 170
      DIMENSION ATARG(3),PFP(3),VTARG(3),PTARG(3)                        SIGH 180
      DIMENSION AVPRJ(3),AACCA(3),AVELA(3)                               SIGH 190
     &         ,EULER(3,3)                                               SIGH 200
      COMMON /PILOTS/ BOOGIE(56),PREL,VREL                               SIGH 210
      COMMON /PIGLET/ BROOD(25)                                          SIGH 220
      COMMON /STATE/GSV(80)                                              SIGH 230
      EQUIVALENCE(GSV(2),POSA(1)),(GSV(5),VELA(1)),(GSV(65),ACCA(1))     SIGH 240
     &          ,(BROOD(5),GEE)                                         SIGH 250
     &          ,(GSV(14),P),(GSV(15),Q),(GSV(16),R)                    SIGH 260
     &          ,(GSV(26),RHO),(GSV(1),TIME),(GSV(17),EULER(1,1))       SIGH 270
     &          ,(GSV(32),POST(1)),(GSV(35),VELT(1)),(GSV(8),VELAT)     SIGH 280
     &          ,(GSV(39),ACCT(1)),(GSV(31),EGNAR)                      SIGH 290
     &          ,(GSV(77),HUDX),(GSV(78),HUDY),(GSV(79),HUDXD)          SIGH 300
     &          ,(GSV(80),HUDYD)                                        SIGH 310
      COMMON /SIGHTS/ HALP,SIG                                           SIGH 320
      DATA UNITZ/0.,0.,1./                                               SIGH 330
      DATA MXLP/20/                                                      SIGH 340
      IF( NTRY.GE.00 )GOTO 5005                                          SIGH 350
      TOLD = TIME                                                        SIGH 360
      READ  1,LABEL,IORD,VELMUZ,GUNALP,GHR,DA,DE,HALP,SIG                SIGH 370
      PRINT 2,LABEL,IORD,VELMUZ,GUNALP,GHR,DA,DE,HALP,SIG                SIGH 380
      HALP = HALP/57.3                                                   SIGH 390
      GUNALP = GUNALP/57.3                                               SIGH 400
```

```
410         IF( IORD.NE.03 ) GOTO 5701                                          SIGH 410
420    5005 IF( IORD.EQ.03 ) GOTO 5500                                          SIGH 420
430         VPROJ = VELMUZ + VELAT                                              SIGH 430
440         CALL PROJ(ACOEF1,CDH1,CDH2,POSA(3) )                                SIGH 440
450         RANGE = EGNAR                                                       SIGH 450
460         DO    30    LOOP = 1,MXLP                                         SIGH 460
470         CON1 = CDH1*RANGE                                                   SIGH 470
480         CON2 = CDH1 * VPROJ + CDH2                                          SIGH 480
490         CON3 = ACOEF1 * CDH1                                                SIGH 490
500         CON4 = 1.0-EXP(-ACOEF1*CDH1*RANGE)                                  SIGH 500
510         UBAR = (1.0/CON1)*(CON2/CON3*CON4-CDH2*RANGE)                       SIGH 510
520         IF( UBAR .GT. 0. ) GO TO 7003                                       SIGH 520
530         PRINT 7004, RANGE                                                   SIGH 530
540         GO TO 9999                                                          SIGH 540
550    7003 CONTINUE                                                            SIGH 550
560         TF = RANGE/UBAR                                                     SIGH 560
570    7002 FORMAT(11F11.4)                                                     SIGH 570
580         DO    40    I = 1,3                                               SIGH 580
590         RPI(I) = PREL(I) + VELT(I)*TF                                       SIGH 590
600         IF( IORD .EQ. 1 ) GO TO 200                                         SIGH 600
610         RPI(I) = RPI(I) + ACCT(I) * .5 * TF * TF                            SIGH 610
620     200 CONTINUE                                                            SIGH 620
630      40 CONTINUE                                                            SIGH 630
640         RPIT = SQRT(RPI(1)*RPI(1) + RPI(2)*RPI(2) + RPI(3)*RPI(3) )         SIGH 640
650         IF( ABS( RPIT-RANGE ).LT.1.0 ) GOTO 50                              SIGH 650
660         RANGE = ABS(RPIT)                                                   SIGH 660
670      30 CONTINUE                                                            SIGH 670
680      50 CONTINUE                                                            SIGH 680
690         P5TF2 = 0.5*TF*TF                                                   SIGH 690
700    C    TRANSFORM RELATIVE POSITION,VELOCITY AND PROJECTILE FUTURE POSITION SIGH 700
710    C    TO ATTACKER SYSTEM                                                  SIGH 710
720         DO    500    I = 1,3                                               SIGH 720
730         AVELA(I) = 0.                                                       SIGH 730
740         VTARG(I) = 0.                                                       SIGH 740
750         ATARG(I) = 0.                                                       SIGH 750
760         DO    500    J = 1,3                                               SIGH 760
770         ATARG(I) = ATARG(I) + EULER(J,I) * ACCA(J)                          SIGH 770
780         VTARG(I) = VTARG(I) + EULER(J,I) * VREL(J)                          SIGH 780
790         AVELA(I) = AVELA(I) + EULER(J,I) * VELA(J)                          SIGH 790
800     500 CONTINUE                                                            SIGH 800
```

```
      AVPRJ(1) = VELMUZ * COS(GUNALP) + AVELA(1)                                SIGH 810
      AVPRJ(2) = AVELA(2)                                                       SIGH 820
      AVPRJ(3) = VELMUZ * SIN(GUNALP) + AVELA(3)                                SIGH 830
      DO   550   I = 1,3                                                        SIGH 840
      PEP(I) = AVPRJ(I)*TF + P5TF2*GEE*EULER(3,I)                               SIGH 850
  550 CONTINUE                                                                  SIGH 860
      TEPY = VTARG(2) * TF                                                      SIGH 870
      TEPZ = VTARG(3) * TF                                                      SIGH 880
      IF( IORD .EQ. 1 ) GO TO 600                                               SIGH 890
      TEPY = TEPY + ATARG(2)*P5TF2                                              SIGH 900
      TEPZ = TEPZ + ATARG(3)*P5TF2                                              SIGH 910
  600 CONTINUE                                                                  SIGH 920
      BPY = PEP(2) - TEPY                                                       SIGH 930
      BPZ = PEP(3) - TEPZ                                                       SIGH 940
      HUDX = BPY/RANGE                                                          SIGH 950
      HUDY = -BPZ/RANGE                                                         SIGH 960
 5700 IF( NTRY.GT.00 ) RETURN                                                   SIGH 970
 5701 DT = TIME-TOLD                                                            SIGH 980
      IF( DT.GE.1.E-4 ) GOTO 5600                                               SIGH 990
      HUDY = 0.0                                                                SIGH1000
      HUDX = 0.0                                                                SIGH1010
      HUDXD = 0.0                                                               SIGH1020
      HUDYD = 0.0                                                               SIGH1030
      GOTO 5610                                                                 SIGH1040
 5600  CONTINUE                                                                 SIGH1050
      HUDXD = ( HUDX - HUDXO ) / DT                                             SIGH1060
      HUDYD = ( HUDY - HUDYO ) / DT                                             SIGH1070
 5610 CONTINUE                                                                  SIGH1080
      HUDXO = HUDX                                                              SIGH1090
      HUDYO = HUDY                                                              SIGH1100
      TOLD = TIME                                                               SIGH1110
      RETURN                                                                    SIGH1120
 9999 CONTINUE                                                                  SIGH1130
      RETURN                                                                    SIGH1140
 5500 CALL SGHT(NTRY )                                                          SIGH1150
      RETURN                                                                    SIGH1160
 7004 FORMAT(10X,' TARGET IS OUT OF RANGE AND PULLING AWAY.  RANGE = ',         SIGH1170
     &            F15.5)                                                       SIGH1180
 7001 FORMAT(10X,'ITERATIVE RANGE VECTOR = ',3F15.5)                            SIGH1190
 7000 FORMAT(10X,'TIME OF FLIGHT= ',F10.4,'RANGE = ',F10.4,                     SIGH1200
```

```
SIGH1210
SIGH1220
SIGH1230
SIGH1240
```

```
1210      ε'      UBAR = ',F15.5)
1220    1   FORMAT(A6,I4,7E10.2)
1230    2   FURMAT(1X,A6,I4,7E10.2)
1240        END
```

```
      SUBROUTINE PROJ( ACOEF1,CDH1,CDH2,PSA3 )                          PROJ   10
      DIMENSION PMACH(5),PCD(5)                                         PROJ   20
      DATA RHOZRO/ .0023769/,CONST1/ .0035683/,CONST2/518.688/          PROJ   30
      DATA G/32.174/                                                    PROJ   40
      DATA AREAP/.00338/,WPROJ/1560./                                   PROJ   50
      DATA PMACH/1.5,2.,3.,4.,5./                                       PROJ   60
      DATA PCD/.522,.461,.369,.313,.293/                                PROJ   70
      PMACH1 = 0.                                                       PROJ   80
      PMACH2 = 0.                                                       PROJ   90
      DO   10   I = 1,5                                                 PROJ  100
      PMACH1 = PMACH1 + (1./PMACH(I) )                                  PROJ  110
   10 PMACH2 = PMACH2 + (1.0/PMACH(I) ) ** 2                            PROJ  120
      D = 1.0/(( 5. * PMACH2) - (PMACH1**2) )                           PROJ  130
      CDRAG1 = 0.                                                       PROJ  140
      CDRAG2 = 0.                                                       PROJ  150
      DO   20   I = 1,5                                                 PROJ  160
      CDRAG1 = CDRAG1 + ((PMACH2 - (PMACH1/PMACH(I))) * PCD(I))         PROJ  170
   20 CDRAG2 = CDRAG2 + (((5./PMACH(I)) - PMACH1) * PCD(I) )            PROJ  180
      CDH1 = D * CDRAG1                                                 PROJ  190
      CDH2 = D * CDRAG2                                                 PROJ  200
      VSONIC = 1117. - .004 * ABS( PSA3)                                PROJ  210
      CDH2 = CDH2 * VSONIC                                              PROJ  220
      CONST3 = ABS(PSA3)                                                PROJ  230
      ATTRHO = RHOZRO * (1.0 - (CONST1*CONST3)/CONST2)**4.2561          PROJ  240
      ACOEF1 = 3499.96 * ATTRHO * G * AREAP / WPROJ                     PROJ  250
      RETURN                                                            PROJ  260
      END                                                               PROJ  270
```

```
      SUBROUTINE SGHT( NTRY )                                                  DSRT   10
      REAL KBRHO,KH,KSIG,LE,LA,LAD,LED                                         DSRT   20
     &                 ,LANEW,LENEW                                          DSRT   30
      COMMON /GUN/ VM,GA,GHR,DA,DE                                             DSRT   40
      COMMON /SIGHTS/ HALP,SIG                                                 DSRT   50
      COMMON /STATE/ GSV(80)                                                   DSRT   60
      COMMON/PILOTS/BOOGIE(56)                                                 DSRT   70
      EQUIVALENCE    (GSV(31),RANGE),(BOOGIE(42),CV)                           DSRT   80
     &               ,(GSV(14),P),(GSV(15),Q),(GSV(16),R)                      DSRT   90
     &               ,(GSV(8),VA),(GSV(36),AN),(GSV(12),ALPHA)                 DSRT  100
     &                  ,(GSV(1),TIME),(GSV(26),RHO)                           DSRT  110
     &               (GSV(77),HUDX),(GSV(78),HUDY),(GSV(79),HUDXD)             DSRT  120
     &               ,(GSV(80),HUDYD)                                          DSRT  130
C  PROGRAM DISRET          DISTURBED RETICLE SIGHT SIMULATION                  DSRT  140
C  RRH IS RECIPROCAL OF GUN HARMONIZATION RANGE(2000 FEET)                     DSRT  150
C  DA AND DE ARE Y AND Z DISTANCES  OF GUN FROM HUD IN FT                      DSRT  160
C  GA IS GUN ANGLE WITH RESPECT TO X AXIS OF AIRCRAFT                          DSRT  170
C  KBRHO IS A BALLISTIC COEFFICIENT DIVIDED BY SEA LEVEL AIR DENSITY           DSRT  180
C  VM IS MUZZLE VELOCITY                                                       DSRT  190
C  RANGE IS IN FEET                                                            DSRT  200
C  VC IS NEGATIVE OF RANGE RATE IN FT/SEC                                      DSRT  210
C  P,Q,R ARE ANGULAR RATES IN BODY AXES, RAD/SEC                               DSRT  220
C  AN IS NORMAL ACCELERATION IN FT/SEC(-32.17 WHEN STRAIGHT & LEVEL)           DSRT  230
C  ALPHA IS ANGLE OF ATTACK IN RADIANS                                         DSRT  240
C  VA IS TRUE AIRSPEED IN FT/SEC                                               DSRT  250
C  RHO IS AIR DENSITY IN SLUGS PER CUBIC FOOT                                  DSRT  260
      DATA JUMP/0/                                                             DSRT  270
      IF( NTRY.GE.00 ) GOTO 2000                                               DSRT  280
      LA = 0.0                                                                 DSRT  290
      LE = 0.0                                                                 DSRT  300
      TOLD = TIME                                                              DSRT  310
      RRH = 1./GHR                                                             DSRT  320
      COSGA = COS(GA)                                                          DSRT  330
      SINGA = SIN(GA)                                                          DSRT  340
C  SIG IS THE SIGHT DAMPING FACTOR                                             DSRT  350
      KSIG = 1./( 1. + SIG )                                                   DSRT  360
 2000 DT = TIME - TOLD                                                         DSRT  370
      KBRHO = .00614/RHO                                                       DSRT  380
      VC = -CV                                                                 DSRT  390
      RDC = 0.                                                                 DSRT  400
```

```
410         SQRV = SQRT( VA + VM )                                                DSRT 410
420         VLS = KBPHO * RHO * RANGE * SQRV                                      DSRT 420
430         VOS = VM + VC - VLS                                                   DSRT 430
440         VCM = (VOS * VOS - 4. * (VA - VC) * VLS )                             DSRT 440
450         VCM = SQRT( VCM )                                                     DSRT 450
460         SLA = LA * (1. - .16667 * LA * LA )                                   DSRT 460
470         SLE = LE * (1. - .16667 * LE * LE )                                   DSRT 470
480         CLE = 1. - .5 * LE * LE                                               DSRT 480
490         CLA = 1. - .5 * LA * LA                                               DSRT 490
500         RCOS = 1. / (CLA*CLA )                                                DSRT 500
510         RDE = ( -VC-RDC*SLE ) * RCOS                                          DSRT 510
520         RE = RANGE * RCOS                                                     DSRT 520
530   C  APPROXIMATION USED FOR SQUARE ROOT                                       DSRT 530
540   C  IF Y = APPROX. SQUARE ROOT OF X, THEN SQRT(X) = .5*(Y+X/Y) IS VERY CL    DSRT 540
550         SQRV = .5 * (SQRV + (VA+VM) / SQRV )                                  DSRT 550
560         VLS = KBRHO * RHO * RE * SQRV                                         DSRT 560
570         VOS = VM - RDE - VLS                                                  DSRT 570
580   C  APPROXIMATION USED FOR SQUARE ROOT                                       DSRT 580
590         VCM = .5 * (VCM + (VOS*VOS - 4. * (VA+RDE) * VLS ) / VCM)             DSRT 590
600         VE = .5 * (VOS+VCM)                                                   DSRT 600
610   C  RTF AND VF ARE 1/TIME OF FLIGHT AND AVG RELATIVE VELOCITY OF BULLET      DSRT 610
620         RTF = VE/RE                                                           DSRT 620
630         VF = VE + RDE                                                         DSRT 630
640         RRANGE = 1./RANGE                                                     DSRT 640
650         KH = 1. - RANGE * RRH                                                 DSRT 650
660         VN = VF - SIG * RDE * VLS * (VF+VA) / (VCM*VF)                        DSRT 660
670         PG = P * COSGA - SINGA * R                                            DSRT 670
680         RG = P * SINGA + R * COSGA                                            DSRT 680
690         RDC = VA * (ALPHA+GA) * (VM-VF) / (VA+VM) + .5 * AN/RTF               DSRT 690
700   C  WJ AND WK ARE COMPUTED SIGHT LINE ANGULAR RATES                          DSRT 700
710         WK = (KH * DA * CLA * RTF - VN * SLA ) * RRANGE                       DSRT 710
720         WJ = ( ( RDC - KH * DE * RTF ) * CLE - VN * CLA * SLE ) * RRANGE      DSRT 720
730         LED = (WJ + SLA * PG - CLA * Q ) * KSIG                               DSRT 730
740         LAD = ( ( WK-SLE*(CLA*PG+SLA*Q) ) / CLE - RG ) * KSIG                 DSRT 740
750         LA = LA + LAD*DT                                                      DSRT 750
760         LE = LE + LED * DT                                                    DSRT 760
770   C  LA AND LE ARE AZIMUTH AND ELEVATION ANGLES OF COMPUTED SIGHT LINE        DSRT 770
780   C  LA AND LE ARE IN RADIANS. COMPUTE PLA AND PLE AS NEGATIVE IN MILLS       DSRT 780
790         LANEW = LE + DT*LAD                                                   DSRT 790
800         LENEW = LE + DT*LED                                                   DSRT 800
```

```
      HUDX = -LANEW                                                     DSRT 810
      HUDXD = -LAD                                                      DSRT 820
      HUDY = LENEW - HALP                                               DSRT 830
      HUDYD = LED                                                       DSRT 840
      IF( NTRY.GT.00 ) RETURN                                           DSRT 850
      LA = LANEW                                                        DSRT 860
      LE = LENEW                                                        DSRT 870
      TOLD = TIME                                                       DSRT 880
      RETURN                                                            DSRT 890
    1 FORMAT(A6,4X 7E10.2)                                              DSRT 900
      END                                                               DSRT 910
```

```
      SUBROUTINE ESCAPE(  NTRY  )                                                    ESCP   10
      DIMENSION ICAL(25,10),RCAL(25,10),TSV(30),TSVOLD(6)                            ESCP   20
     &                 ,TSYSV(80)                                                   ESCP   30
     &                 ,TUV(3,3),TEUA(3),TX(3),TV(3),ICVL(25)                       ESCP   40
     &          ,RCVL(25),F(5),NQL(10),NQU(10),STVLL(10),STVUL(10)                  ESCP   50
     &          ,PTUV(3,3)                                                          ESCP   60
     &          ,AK(3),AT(3)                                                        ESCP   70
     &           ,FTSV(3)                                                           ESCP   80
      COMMON /STATE/ GSV(30)                                                         ESCP   90
      EQUIVALENCE (ICVL(2),NLWR),(ICVL(3),NQL),(ICVL(13),NUPR)                       ESCP  100
     &                 ,(TSYSV(1),GSV(1))                                          ESCP  110
     &          ,(ICVL(14),NQU),(RCVL(1),F(1)),(RCVL(6),STVLL(1))                   ESCP  120
     &          ,(RCVL(16),STVUL(1))                                                ESCP  130
     &          ,(TSV(1),TX(1)),(TSV(4),TV(1)),(TSV(7),V)                           ESCP  140
     &                 ,(GSV(32),TSV(1)),(GSV(1),T),(TSV(13),TEUA(1))               ESCP  150
     &                          ,(AK(1),TSV(8)),(AN,TSV(11))                        ESCP  160
     &          , (TAA,TSV(16) )                                                    ESCP  170
     &        ,(TSV(12),AV)                                                         ESCP  180
      DATA G/32.2/                                                                   ESCP  190
      DATA JUMP/0/                                                                   ESCP  200
      IF( NTRY.GE.00 ) GOTO 250                                                      ESCP  210
      IF( JUMP.NE.00 ) GOTO 51                                                       ESCP  220
      DUM = TAAF(0.,0.,0.)                                                           ESCP  230
      DUM = FAN(0.,0.)                                                               ESCP  240
      DUM = FAVD(0.,0.,0.,0.)                                                        ESCP  250
      DO    50  I=1,10                                                               ESCP  260
      DO    50    J=1,25                                                           ESCP  270
      ICAL(J,I) = 00                                                               ESCP  280
50    RCAL(J,I) = 0.0                                                              ESCP  290
51    READ1,L,JMX                                                                  ESCP  300
      PRINT 2,L,JMX                                                                ESCP  310
      IF( JMX.EQ.00 ) GOTO 200                                                     ESCP  320
      NMNVRS = JMX                                                                 ESCP  330
      DO          100         I=1 ,NMNVRS                                        ESCP  340
      READ 1,L,ICAL(1,I),(RCAL(J,I),J=1,5)                                         ESCP  350
      PRINT 2,L,ICAL(1,I),(RCAL(J,I),J=1,5)                                        ESCP  360
      READ 3,L,JMX,(ICAL(J+2,I),RCAL(J+5,I),J=1,JMX)                               ESCP  370
      ICAL(2,I) = JMX                                                              ESCP  380
      PRINT 4,L,JMX,(ICAL(J+2,I),RCAL(J+5,I),J=1,JMX)                              ESCP  390
      READ 3,L,JMX,(ICAL(J+13,I),RCAL(J+15,I),J=1,JMX)                             ESCP  400
```

```
410           ICAL(13,I) = JMX                                                    ESCP 410
420           PRINT 4,L,JMX,(ICAL(J+13,I),RCAL(J+15,I),J=1,JMX)                   ESCP 420
430     100   CONTINUE                                                            ESCP 430
440     200   READ 1,L,MNVR,(TSV(J),J=1,6)                                        ESCP 440
450           PRINT2,L,MNVR,(TSV(J),J=1,6)                                        ESCP 450
460           DO       210                  J=1,6                                 ESCP 460
470     210   TSVOLD(J) = TSV(J)                                                  ESCP 470
480           DO       220                  J=1,3                                 ESCP 480
490     220   AK(J) = 0.0                                                         ESCP 490
500           TOLD = T                                                            ESCP 500
510     250   IF( MNVR.GT.NMNVRS ) GOTO 900                                       ESCP 510
520     300   VS = 0.0                                                            ESCP 520
530           DLT = T-TOLD                                                        ESCP 530
540           DO       310                  J=1,3                                 ESCP 540
550           TSV(J+3) = TSVOLD(J+3) + AK(J)*DLT                                  ESCP 550
560           VS = VS + TSV(J+3) **2                                              ESCP 560
570           TSV(J) = TSVOLD(J) + 0.5*( TSV(J+3)+TSVOLD(J+3) )*DLT               ESCP 570
580     310   AT(J) = AK(J)                                                       ESCP 580
590           AT(3) = AT(3) - G                                                   ESCP 590
600           V = SQRT( VS )                                                      ESCP 600
610           TSV(7) = V                                                          ESCP 610
620           VM = V/VSND( -TSV(3) )                                              ESCP 620
630           ASSIGN 345 TO KIKBAK                                                ESCP 630
640     315   ANS = 0.0                                                           ESCP 640
650           ATS = 0.0                                                           ESCP 650
660           DO       320                  J=1,3                                 ESCP 660
670           ATS = ATS + AT(J)**2                                                ESCP 670
680           L = MOD(J,3)+1                                                      ESCP 680
690           M = MOD(L,3)+1                                                      ESCP 690
700           TUV(J,2) = TV(L)*AT(M) - TV(M)*AT(L)                                ESCP 700
710     320   ANS = ANS + TUV(J,2)**2                                             ESCP 710
720           IF( ANS.NE.0.0 ) GOTO 325                                           ESCP 720
730           ANS = VS                                                            ESCP 730
740           TUV(2,2) = V                                                        ESCP 740
750     325   DUM = SQRT( ANS )                                                   ESCP 750
760           DO       330 J=1,3                                                  ESCP 760
770           TUV(J,1) = TV(J) / V                                                ESCP 770
780     330   TUV(J,2) = TUV(J,2)/DUM                                             ESCP 780
790           DO    340    J = 1,3                                                ESCP 790
800           L = MOD(J,3) + 1                                                    ESCP 800
```

```
      M = MOD(L,3) + 1                                                          ESCP 810
  340 TUV(J,3) = TUV(L,1) * TUV(M,2) - TUV(M,1) * TUV(L,2)                      ESCP 820
      AVS = 0.0                                                                 ESCP 830
      ANS = 0.0                                                                 ESCP 840
      DO       341       J=1,3                                                  ESCP 850
       AVS = AVS + AT(J)*TUV(J,1)                                               ESCP 860
  341  ANS = ANS + AT(J)*TUV(J,3)                                               ESCP 870
       AV = ABS( AVS )                                                          ESCP 880
       AN = ABS( ANS )                                                          ESCP 890
       GOTO KIKBAK,( 345,600 )                                                  ESCP 900
  345 TAA = TAAF( AN,VM,-TX(3) )                                                ESCP 910
      SAA = SIN( TAA*.0174533 )                                                 ESCP 920
      CAA = COS( TAA*.0174533 )                                                 ESCP 930
      DO   350   J = 1,3                                                        ESCP 940
      RTUV(J,1) = CAA * TUV(J,1) - SAA * TUV(J,3)                               ESCP 950
      RTUV(J,3) = SAA * TUV(J,1) + CAA * TUV(J,3)                               ESCP 960
  350 RTUV(J,2) = TUV(J,2)                                                      ESCP 970
      IF( ABS( RTUV(3,1) ).GT.1.0 ) RTUV(3,1) = SIGN( 1.0,RTUV(3,1) )           ESCP 980
      TEUA(1)  = ATAN2( RTUV(3,2),RTUV(3,3) )*57.2958                           ESCP 990
      TEUA(2) = ARSIN( -RTUV(3,1) )*57.2958                                     ESCP1000
      TEUA(3)  = ATAN2( RTUV(2,1),RTUV(1,1) )*57.2958                           ESCP1010
      IF( NTRY .GT. 00 ) RETURN                                                 ESCP1020
      IF( NTRY .LT. 00 ) GO TO 400                                              ESCP1030
      TOLD = T                                                                  ESCP1040
      DO          355       J=1,6                                               ESCP1050
  355 TSVOLD(J) = TSV(J)                                                        ESCP1060
      DO   360   J = 1,NLWR                                                     ESCP1070
      IF( TSYSV(NOL(J) ) .LE. STVLL(J) ) GO TO 400                              ESCP1080
  360 CONTINUE                                                                  ESCP1090
      DO   370   J = 1,NUPR                                                     ESCP1100
      IF( TSYSV( NOU(J) ) .GE. STVUL(J) ) GO TO 400                             ESCP1110
  370 CONTINUE                                                                  ESCP1120
      GO TO 500                                                                 ESCP1130
  400 MNVR = MNVR + 01                                                          ESCP1140
      IF( MNVR.GT.NMNVRS ) GOTO 900                                             ESCP1150
      KIK = 00                                                                  ESCP1160
      DO   410   J = 1,25                                                       ESCP1170
      ICVL(J) = ICAL(J,MNVR)                                                    ESCP1180
      RCVL(J) = RCAL(J,MNVR)                                                    ESCP1190
  410 CONTINUE                                                                  ESCP1200
```

```
1210          IZG = ICVL(1)                                                  ESCP1210
1220          IF( IZG.GT.00 ) GOTO 440                                       ESCP1220
1230          DO     420       J=1,3                                         ESCP1230
1240    420   FTSV(J) = F(J)                                                 ESCP1240
1250          DO     430         I=1,3                                       ESCP1250
1260          F(I) = 0.0                                                     ESCP1260
1270          DO          430         J=1,3                                 ESCP1270
1280    430   F(I) = F(I) + TUV(I,J)*FTSV(J)                                 ESCP1280
1290    440   IZG = IABS( IZG )                                              ESCP1290
1300          IHOP = 00                                                      ESCP1300
1310          IF( IZG .GT. 3 )  IHOP = 3                                     ESCP1310
1320    500    GOTO    ( 510,520,530,510,520,530,590,560 ), IZG              ESCP1320
1330    510     IZG = 08                                                     ESCP1330
1340          DO          511         J=1,3                                 ESCP1340
1350    511   FTSV(J) = F(J)                                                 ESCP1350
1360          GOTO  550                                                      ESCP1360
1370    520    IZG = 08                                                     ESCP1370
1380    530    DO          540         J=1,3                                ESCP1380
1390    540    FTSV(J) = F(J) + TSVOLD(J+IHOP)                              ESCP1390
1400     550  TFUT = TOLD + F(4)                                            ESCP1400
1410     560  DLT = TFUT - TOLD                                             ESCP1410
1420          IF( IHOP .NE. 0 ) GO TO 570                                    ESCP1420
1430          DLT2 = DLT * DLT                                               ESCP1430
1440          DO    565   J = 1,3                                           ESCP1440
1450     565  AK(J) = 2. * ( FTSV(J) - TSVOLD(J) ) / DLT2                    ESCP1450
1460          GO TO 580                                                      ESCP1460
1470     570  DO    575   J = 1,3                                           ESCP1470
1480     575  AK(J) = ( FTSV(J) - TSVOLD (J+3) )/DLT                        ESCP1480
1490     580  DO    585   J = 1,3                                           ESCP1490
1500     585  AT(J) = AK(J)                                                 ESCP1500
1510          AT(3) = AT(3) - G                                              ESCP1510
1520           ASSIGN 600 TO KIKBAK                                          ESCP1520
1530          GO TO 315                                                      ESCP1530
1540     590  IF( KIK .NE. 0 ) GO TO 592                                     ESCP1540
1550          IF( F(4).EQ.0.0 ) GOTO 591                                     ESCP1550
1560          F(2) = ( F(2)-F(1) )/F(4)                                      ESCP1560
1570    591     TREF = TOLD                                                  ESCP1570
1580     592  RAD = F(1) + F(2) * ( TOLD - TREF )                           ESCP1580
1590          DO      593       J=1,3                                        ESCP1590
1600     593  TUV(J,1) = TV(J)/V                                            ESCP1600
```

```
1610          DUM = 1.0-TUV(3,1)*TUV(3,1)                                    ESCP1610
1620          IF( DUM.LT..0001 ) DUM = .0001                                 ESCP1620
1630          TUV(3,3) = SQRT( DUM )                                         ESCP1630
1640          TUV(2,2) = TUV(1,1)/TUV(3,3)                                   ESCP1640
1650          TUV(1,3) = -TUV(2,2)*TUV(3,1)                                  ESCP1650
1660          TUV(1,2) = -TUV(2,1)/TUV(3,3)                                  ESCP1660
1670          TUV(2,3) = TUV(1,2)*TUV(3,1)                                   ESCP1670
1680          TUV(3,2) = 0.0                                                 ESCP1680
1690          PHI = RAD*.0174533                                             ESCP1690
1700          CPH = COS(PHI)                                                 ESCP1700
1710          SPH = SIN( PHI )                                               ESCP1710
1720          DO   595   J=2,3                                               ESCP1720
1730          DUM = TUV(J,2)*CPH + TUV(J,3)*SPH                              ESCP1730
1740          TUV(J,3) = -TUV(J,2)*SPH + TUV(J,3)*CPH                        ESCP1740
1750    595   TUV(J,2) = DUM                                                 ESCP1750
1760          AN = F(3) * G                                                  ESCP1760
1770           AV = FAVD( AN,VM,-TSVOLD(3),F(5) )                            ESCP1770
1780          AVS = AV                                                       ESCP1780
1790    600   ANMX = FAN( VM,-TSVOLD(3) )                                    ESCP1790
1800          IF( AN .GT. ANMX ) AN = ANMX                                   ESCP1800
1810          AVMX = FAVD( AN,VM,-TSVOLD(3),F(5) )                           ESCP1810
1820          AV = SIGN( AVS,AV )                                            ESCP1820
1830          IF( AVMX .LT. AV ) AV = AVMX                                   ESCP1830
1840          DO   610   J = 1,3                                             ESCP1840
1850     610  AK(J) = AV * TUV(J,1) - AN * TUV(J,3)                         ESCP1850
1860          AK(3) = AK(3) + G                                              ESCP1860
1870          KIK = KIK + 01                                                 ESCP1870
1880          RETURN                                                         ESCP1880
1890    900   DO      910     I=1,6                                          ESCP1890
1900    910   TSV(I) = 1.E75                                                 ESCP1900
1910          DO         920       I=7,30                                    ESCP1910
1920    920   TSV(I) = 0.0                                                   ESCP1920
1930          PRINT5                                                         ESCP1930
1940          RETURN                                                         ESCP1940
1950    1     FORMAT(A6,I4,7E10.2)                                           ESCP1950
1960    2     FORMAT( 1X A7,I4,1P 7E12.3 )                                   ESCP1960
1970       3  FORMAT(A6,I4,4(I5,E10.2)/(10X4(I5,E10.2)))                     ESCP1970
1980      4   FORMAT( 1X A7,I4,1P 4( I5,E12.3 )/( 11X 4( I5,E12.3 ) ) )      ESCP1980
1990    5     FORMAT(13H0***... PCOF )                                       ESCP1990
2000          END                                                            ESCP2000
```

```
10  FUNCTION VSND( H )
20  VSND = 968.12
30  IF( H.GE.36000. ) RETURN
40  VSND = 49.*SQRT(518.7-H*3.565E-3)
50  RETURN
60  END
```

```
VSND  10
VSND  20
VSND  30
VSND  40
VSND  50
VSND  60
```

```
      FUNCTION FAN( VM,H )                                                  FAN    10
      DIMENSION AM(3),AH(3),FMH(9)                                          FAN    20
      DATA NM,NH/3,3/                                                       FAN    30
      DATA JUMP/0/                                                          FAN    40
      IF( JUMP.GT.00 ) GOTO 100                                             FAN    50
      JUMP = 01                                                             FAN    60
      READ1,LABEL,AM                                                        FAN    70
      PRINT2,LABEL, AM                                                      FAN    80
      READ1,LABEL,AH                                                        FAN    90
      PRINT2,LABEL,AH                                                       FAN   100
      READ1,LABEL,FMH                                                       FAN   110
      PRINT2,LABEL,FMH                                                      FAN   120
1     FORMAT(A4,6X 7E10.2/(10X7E10.2))                                      FAN   130
2     FORMAT(1XA10,1P 7E12.3/(11X7E12.3))                                   FAN   140
      FAN = 0.                                                              FAN   150
      RETURN                                                                FAN   160
100   CALL LOOK2( DAFT,VM,H,AM,NM,AH,NH,FMH,0 )                             FAN   170
      FAN = DAFT                                                            FAN   180
      RETURN                                                                FAN   190
      END                                                                   FAN   200
```

```
      FUNCTION FAVD(AN,VM,H,TP )                                        FAND   10
      DIMENSION AAN(3),AM(3),AH(3),TRST(9),DRG(27)                      FAND   20
      DATA NA,NM,NH/3,3,3/                                              FAND   30
      DATA JUMP/0/                                                      FAND   40
      IF( JUMP.GT.00 ) GOTO 100                                         FAND   50
      JUMP = 1                                                          FAND   60
      READ1,LABEL,AAN                                                   FAND   70
      PRINT2,LABEL,AAN                                                  FAND   80
      READ1,LABEL,AM                                                    FAND   90
      PRINT2,LABEL,AM                                                   FAND  100
      READ1,LABEL,AH                                                    FAND  110
      PRINT2,LABEL,AH                                                   FAND  120
      READ1,LABEL,TRST                                                  FAND  130
      PRINT2,LABEL,TRST                                                 FAND  140
      READ1,LABEL,DRG                                                   FAND  150
      PRINT2,LABEL,DRG                                                  FAND  160
1     FORMAT(A4,6X 7E10.2/(10X7E10.2))                                  FAND  170
2     FORMAT(1XA10,1P 7E12.3/(11X7E12.3))                               FAND  180
      FAVD = 0.                                                         FAND  190
      RETURN                                                            FAND  200
100   CALL LOOK3( DRAG,AN,VM,H,AAN,NA,AM,NM,AH,NH,DRG,0 )               FAND  210
      CALL LOOK2( THRST,VM,H,AM,NM,AH,NH,TRST,0 )                       FAND  220
      FAVD = THRST*TP - DRAG*AN                                         FAND  230
      RETURN                                                            FAND  240
      END                                                               FAND  250
```

```
      FUNCTION TAAF( AN,VM,H )                                          TAAF   10
      DIMENSION TAN(3),TM(3),TH(3),TAA(27)                              TAAF   20
      DATA NA,NM,NH/3,3,3/                                              TAAF   30
      DATA JUMP/0/                                                      TAAF   40
      IF( JUMP.GT.00 ) GOTO 50                                          TAAF   50
      JUMP = 01                                                         TAAF   60
      READ1,LABEL,TAN                                                   TAAF   70
      PRINT2,LABEL,TAN                                                  TAAF   80
      READ1,LABEL,TM                                                    TAAF   90
      PRINT2,LABEL,TM                                                   TAAF  100
      READ1,LABEL,TH                                                    TAAF  110
      PRINT2,LABEL,TH                                                   TAAF  120
      READ1,LABEL,TAA                                                   TAAF  130
      PRINT2,LABEL,TAA                                                  TAAF  140
1     FORMAT(A4,6X 7E10.2/(10X7E10.2))                                  TAAF  150
2     FORMAT(1XA10,1P 7E12.3/(11X7E12.3))                               TAAF  160
      TAAF = 0.                                                         TAAF  170
      RETURN                                                            TAAF  180
50    CALL LOOK3( DAFT,AN,VM,H,TAN,NA,TM,NM,TH,NH,TAA,0 )               TAAF  190
      TAAF = DAFT                                                       TAAF  200
      RETURN                                                            TAAF  210
      END                                                               TAAF  220
```

```
      SUBROUTINE LOOK1( OUT,X,AX,NX,FX,NCX )                          LUK1   10
      DIMENSION AX(NX),FX(NX)                                         LUK1   20
      IF( NCX.GT.00 ) GOTO 400                                        LUK1   30
      IF( X.GT.AX(1) ) GOTO 100                                       LUK1   40
      I = 02                                                          LUK1   50
      B = 0.                                                          LUK1   60
      A = 1.                                                          LUK1   70
      GOTO     400                                                    LUK1   80
100   DO       200          I=2,NX                                    LUK1   90
      IF( X.LE.AX(I) ) GOTO 300                                       LUK1  100
200   CONTINUE                                                        LUK1  110
      I = NX                                                          LUK1  120
      B = 1.0                                                         LUK1  130
      A = 0.                                                          LUK1  140
      GOTO     400                                                    LUK1  150
300   B = AX(I)-AX(I-1)                                               LUK1  160
      A = ( AX(I)-X )/B                                               LUK1  170
      B = ( X-AX(I-1) )/B                                             LUK1  180
400   OUT = A*FX(I-1) + B*FX(I)                                       LUK1  190
      RETURN                                                          LUK1  200
      END                                                             LUK1  210
```

```
      SUBROUTINE LOOK2( OUT,X,Y,AX,NX,AY,NY,FXY,NCXY )                  LUK2   10
      DIMENSION AX(NX),AY(NY),FXY(NX,NY)                                LUK2   20
      IF( NCXY.GT.00 ) GOTO 400                                         LUK2   30
      NCX = 00                                                          LUK2   40
      IF( Y.GT.AY(1) ) GOTO 100                                         LUK2   50
      I = 2                                                             LUK2   60
      B = 0.0                                                           LUK2   70
      A = 1.0                                                           LUK2   80
      GOTO 400                                                          LUK2   90
100   DO      200         I=2,NY                                        LUK2  100
      IF( Y.LE.AY(I) ) GOTO 300                                         LUK2  110
200   CONTINUE                                                          LUK2  120
      I = NY                                                            LUK2  130
      A = 0.0                                                           LUK2  140
      B = 1.0                                                           LUK2  150
      GOTO 400                                                          LUK2  160
300   B = AY(I)-AY(I-1)                                                 LUK2  170
      A = ( AY(I)-Y )/B                                                 LUK2  180
      B = ( Y-AY(I-1) )/B                                               LUK2  190
400   CALL LOOK1( FA,X,AX,NX,FXY(1,I-1),NCX)                            LUK2  200
      NCX = 01                                                          LUK2  210
      CALL LOOK1( FB,X,AX,NX,FXY(1,I),NCX)                              LUK2  220
      OUT = FA*A + FB*B                                                 LUK2  230
      RETURN                                                            LUK2  240
      END                                                               LUK2  250
```

```
      SUBROUTINE LOOK3( OUT,X,Y,Z,AX,NX,AY,NY,AZ,NZ,FXYZ,NCXYZ )                  LUK3   10
      DIMENSION AX(NX),AY(NY),AZ(NZ),FXYZ(NX,NY,NZ)                              LUK3   20
      IF( NCXYZ.GT.00 ) GOTO 400                                                 LUK3   30
      NXNY = NX*NY                                                               LUK3   40
      NCXY = 00                                                                  LUK3   50
      IF( Z.GT.AZ(1) ) GOTO 100                                                  LUK3   60
      I = 02                                                                     LUK3   70
      A = 1.0                                                                    LUK3   80
      B = 0.0                                                                    LUK3   90
      GOTO 399                                                                   LUK3  100
  100 DO      200        I=2,NZ                                                  LUK3  110
      IF( Z.LE.AZ(I) ) GOTO 300                                                  LUK3  120
  200 CONTINUE                                                                   LUK3  130
      I = NZ                                                                     LUK3  140
      A = 0.0                                                                    LUK3  150
      B = 1.0                                                                    LUK3  160
      GOTO 399                                                                   LUK3  170
  300 B =  AZ(I)-AZ(I-1)                                                         LUK3  180
      A = ( AZ(I)-Z )/B                                                          LUK3  190
      B = ( Z-AZ(I-1) )/B                                                        LUK3  200
  399  CONTINUE                                                                  LUK3  210
  400 CALL LOOK2( FA,X,Y,AX,NX,AY,NY,FXYZ(1,1,I-1),NCXY)                         LUK3  220
      NCXY = 01                                                                  LUK3  230
      CALL LOOK2( FB,X,Y,AX,NX,AY,NY,FXYZ(1,1,I),NCXY)                           LUK3  240
      OUT = FA*A + FB*B                                                          LUK3  250
      RETURN                                                                     LUK3  260
      END                                                                        LUK3  270
```

	ATTACKER		TARGET	
1	x_1	$\dot{x}_1$	x_1	
2	x_2	$\dot{x}_2$	x_2	
3	x_3	$\dot{x}_3$	x_3	
4	v_1	$\dot{v}_1$	v_1	
5	v_2	$\dot{v}_2$	v_2	
6	v_3	$\dot{v}_3$	v_3	
7	v	$\dot{v}$	v	
8	ϕ	$\dot{\phi}$	A_{k1}	
9	θ	$\dot{\theta}$	A_{k2}	
10	ψ	$\dot{\psi}$	A_{k3}	
11	α	$\dot{\alpha}$	A_n	
12	β	$\dot{\beta}$	A_t	
13	P	$\dot{P}$	ψ	
14	Q	$\dot{Q}$	θ	degrees
15	R	$\dot{R}$	ϕ	

****

ELAPSED TIME 0.0

1	0.0	7.0000E+02	2.0000E+03	
2	0.0	0.0	1.0000E+03	
3	-2.0000E+04	0.0	-2.1000E+04	
4	7.0000E+02	2.9416E+01	7.0000E+02	
5	0.0	-1.0154E+00	0.0	
6	0.0	2.6573E+01	0.0	
7	7.0000E+02	2.9416E+01	7.0000E+02	
8	0.0	0.0	1.7570E+01	
9	0.0	0.0	1.2800E+01	
10	0.0	0.0	1.9200E+01	
11	0.0	3.7962E-02	1.8244E+01	
12	0.0	-1.4506E-03	1.7570E+01	
13	0.0	4.9865E+00	4.4606E+01	
14	0.0	1.1569E+00	2.4237E+00	
15	0.0	1.5278E-01	2.3885E+00	

CONTROL VECTOR =	5.2360E-01	-1.0845E-01	1.3700E+04	0.0
ERROR VECTOR =	2.0000E+03	1.0000E+03	-1.0000E+03	
BANK	YANK	RANGE	SIGMA	ERROR
4.5332E-01	4.1054E-01	2.4495E+03	4.6365E-01	6.1928E-01
0.0	0.0	0.0	0.0	0.0
-4.9590E-01	1.1987E+00	-1.0210E+00	0.0	7.9468E-01
PIPPER 0.0	0.0	4.4899E-02	0.0	

****

```
ELAPSED TIME      2.100
        1      1.4777E+03      6.7397E+02                    3.5083E+03
        2      1.6955E+02      2.1299E+02                    1.0310E+03
        3     -2.0108E+04     -1.2336E+02                   -2.0954E+04
        4      6.7397E+02     -5.4567E+00                    7.3619E+02
        5      2.1299E+02      6.1561E+01                    3.1011E+01
        6     -1.2336E+02      3.0237E+00                    4.6516E+01
        7      7.4712E+02      1.9343E+01                    7.3831E+02
        8      1.0437E+00     -9.1589E-01                    1.6615E+01
        9      2.2939E-01     -4.6674E-01                    1.7204E+01
       10      5.6019E-01     -2.4631E-01                    2.5806E+01
       11      9.1255E-02     -5.7762E-01                    1.8104E+01
       12     -8.9906E-02     -3.0952E-01                    1.6887E+01
       13     -8.5988E-01     -1.9110E+00                    6.5464E+01
       14     -4.4209E-01     -7.7502E-01                   -2.2223E+00
       15      2.8272E-01     -8.6246E-01                    5.4709E+00
CONTROL VECTOR =      -5.2360E-01      4.3382E-02      1.3700E+04      0.0
ERROR VECTOR =         2.3131E+03     -4.5909E+02      1.3686E+02
          BANK              YANK             RANGE             SIGMA             ERROR
    -3.3330E-01      -8.4574E-02       2.3622E+03     -1.6384E-01       1.8438E-01
    -2.9625E-01       3.0627E-01      -7.3673E+01     -2.6304E-01       9.3253E-02
     1.2142E+00       1.3409E+00       2.0223E+01     -5.6170E-02       2.7168E-01
PIPPER     -3.2082E-02     -5.8857E-02      6.1510E-02      1.9118E-01
**********************************************************************************

ELAPSED TIME      2.200
        1      1.5451E+03      6.7451E+02                    3.5820E+03
        2      1.9111E+02      2.1751E+02                    1.0341E+03
        3     -2.0120E+04     -1.2186E+02                   -2.0949E+04
        4      6.7451E+02      5.5252E+00                    7.3785E+02
        5      2.1751E+02      4.3637E+01                    3.2731E+01
        6     -1.2186E+02      1.2690E+01                    4.9096E+01
        7      7.4905E+02      1.9493E+01                    7.4020E+02
        8      9.4354E-01     -9.6992E-01                    1.6528E+01
        9      1.8592E-01     -3.3808E-01                    1.7456E+01
       10      5.3581E-01     -1.4553E-01                    2.6184E+01
       11      3.5192E-02     -4.4658E-01                    1.8172E+01
       12     -1.1410E-01     -1.7349E-01                    1.6848E+01
       13     -9.4302E-01      9.0764E+00                    6.6662E+01
       14     -3.1423E-01     -1.7374E+00                   -2.4787E+00
       15      1.8978E-01     -6.2726E-01                    5.6260E+00
CONTROL VECTOR =       5.2360E-01      1.3963E-01      1.3700E+04      0.0
ERROR VECTOR =         2.2974E+03     -5.1740E+02      1.4053E+01
          BANK              YANK             RANGE             SIGMA             ERROR
    -3.4362E-01      -5.4827E-02       2.3550E+03     -1.8793E-01       1.9577E-01
    -1.9303E-01       1.8288E-01      -7.1497E+01     -1.7980E-01       1.2139E-01
    -6.7944E-02      -1.5343E-01       2.1842E+01     -8.0797E-02       3.8124E-01
PIPPER     -3.3583E-02     -1.4804E-02      8.3763E-02      2.2490E-01
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ELAPSED TIME      7.200
      1      5.2877E+03      8.2590E+02                  7.4399E+03
      2      9.0558E+02      1.2597E+02                  1.4811E+03
      3     -2.0522E+04      1.2991E+02                 -2.0278E+04
      4      8.2590E+02      1.6750E+01                  7.9140E+02
      5      1.2597E+02      5.4855E+01                  1.6281E+02
      6      1.2991E+02      1.6096E+01                  2.4422E+02
      7      8.4752E+02      3.1479E+01                  8.4408E+02
      8     -5.1201E+00     -2.5672E+00                 -1.9027E+00
      9     -1.3822E-01      5.0685E-02                  3.7976E+01
     10      3.2188E-01     -2.4574E-02                  5.6962E+01
     11      5.6871E-02     -1.7313E-01                  4.3560E+01
     12     -4.7920E-02     -5.4028E-02                  1.2706E+01
     13     -2.5706E+00     -1.7404E+00                  1.1927E+02
     14     -2.2460E-03     -1.7932E-01                 -1.8789E+01
     15     -5.6182E-02      6.5184E-01                  1.5234E+01
CONTROL VECTOR =     -5.2355E-01     -1.5586E-02      1.3700E+04     -2.6180E-01
ERROR VECTOR =        2.2362E+03     -1.1278E+02      9.8199E+01
         BANK              YANK             RANGE            SIGMA            ERROR
    -1.1564E-03     -9.1291E-03      2.2412E+03     -5.6362E-04      9.1465E-03
     1.5995E-01     -1.7990E-02     -1.1213E+01      7.7977E-02      1.3151E-02
     1.1484E-02      1.1512E-01     -1.0886E+01     -3.2019E-04      5.6637E-01
PIPPER     -4.9830E-02     -7.9131E-02      2.0307E-04      1.4774E-01
GOTCHA
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ELAPSED TIME      7.300
      1      5.3703E+03      8.2769E+02                  7.5190E+03
      2      9.1843E+02      1.3090E+02                  1.4976E+03
      3     -2.0509E+04      1.3152E+02                 -2.0253E+04
      4      8.2769E+02      2.2477E+01                  7.9121E+02
      5      1.3090E+02      3.6808E+01                  1.6661E+02
      6      1.3152E+02      8.3396E+00                  2.4991E+02
      7      8.5065E+02      3.1810E+01                  8.4631E+02
      8     -5.3831E+00     -2.6818E+00                 -2.8389E+00
      9     -1.3459E-01      3.0891E-02                  3.8590E+01
     10      3.1848E-01     -4.6233E-02                  5.7884E+01
     11      3.8918E-02     -1.8067E-01                  4.4721E+01
     12     -5.1863E-02     -2.6027E-02                  1.2528E+01
     13     -2.6880E+00     -2.4534E+00                  1.1983E+02
     14     -1.6689E-02     -5.5489E-02                 -1.9210E+01
     15     -5.2676E-02      1.5216E+00                  1.5541E+01
CONTROL VECTOR =     -5.2355E-01     -1.5586E-02      1.3700E+04     -5.2360E-01
ERROR VECTOR =        2.2362E+03     -1.1136E+02      6.8372E+01
         BANK              YANK             RANGE            SIGMA            ERROR
     1.9263E-02     -1.3868E-02      2.2400E+03      9.6454E-03      1.6892E-02
     2.4439E-01     -4.7981E-02     -1.2239E+01      1.2148E-01      1.0875E-01
     4.3027E-02     -4.7303E-02     -1.0812E+01     -1.6689E-03      3.4759E-01
PIPPER     -5.9402E-02     -9.6455E-02      1.8244E-02      1.8059E-01
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ELAPSED TIME      9.400
      1      7.1506E+03      8.6723E+02                    9.1569E+03
      2      1.2501E+03      1.8012E+02                    1.9420E+03
      3     -2.0135E+04      2.2684E+02                   -1.9587E+04
      4      8.6723E+02      2.2490E+01                    7.5782E+02
      5      1.8012E+02     -6.7714E+00                    2.6178E+02
      6      2.2684E+02      3.8367E+01                    3.9267E+02
      7      9.1726E+02      2.7241E+01                    8.9275E+02
      8     -9.1426E+00     -2.0926E+00                   -3.5241E+01
      9     -2.1365E-01     -2.9417E-01                    5.3148E+01
     10      2.2445E-01     -2.9391E-01                    7.9720E+01
     11      1.8429E-02      1.7529E-01                    7.9257E+01
     12     -6.8848E-02     -2.2951E-01                    6.5719E+00
     13     -2.1549E+00     -1.5067E+00                    1.2644E+02
     14      3.6251E-01      5.1182E+00                   -2.9583E+01
     15      1.9398E-01     -2.2235E-01                    2.4170E+01
CONTROL VECTOR =      -5.2360E-01     -3.4907E-01      6.8500E+03      0.0
ERROR VECTOR =         2.1783E+03     -2.4365E+02     -2.1387E+01
        BANK                YANK              RANGE              SIGMA              ERROR
    -2.8214E-01      3.2951E-02      2.1920E+03     -1.5681E-01      1.6023E-01
    -1.9845E-01      1.4491E-01     -3.2889E+01     -1.5838E-01      1.8479E-01
    -1.9824E+00     -4.2191E+00     -3.0277E+00     -1.5222E-02     -7.7824E-01
PIPPER      4.5418E-02     -8.5070E-02      1.1710E-02     -1.9946E-01
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ELAPSED TIME      9.500
      1      7.2374E+03      8.6894E+02                    9.2325E+03
      2      1.2680E+03      1.7884E+02                    1.9685E+03
      3     -2.0112E+04      2.3362E+02                   -1.9547E+04
      4      8.6894E+02      1.5433E+01                    7.5429E+02
      5      1.7884E+02     -1.4783E+01                    2.6710E+02
      6      2.3362E+02      7.4990E+01                    4.0064E+02
      7      9.1997E+02      2.6679E+01                    8.9488E+02
      8     -9.3255E+00     -1.6916E+00                   -3.7619E+01
      9     -2.5491E-01     -4.3008E-01                    5.3870E+01
     10      1.9610E-01     -2.3993E-01                    8.0803E+01
     11      4.1818E-02      2.0930E-01                    8.1497E+01
     12     -9.3243E-02     -2.4729E-01                    6.1294E+00
     13     -1.7521E+00     -1.4819E+00                    1.2651E+02
     14      4.5097E-01      1.8304E+00                   -3.0161E+01
     15      1.8843E-01     -3.7888E-01                    2.4727E+01
CONTROL VECTOR =      -5.2360E-01     -1.7453E-01      6.8500E+03      0.0
ERROR VECTOR =         2.1682E+03     -2.9868E+02      1.0888E+01
        BANK                YANK              RANGE              SIGMA              ERROR
    -3.1400E-01      4.0730E-02      2.1887E+03     -1.7089E-01      1.7568E-01
    -1.9256E-01      9.7358E-02     -3.3161E+01     -1.4363E-01      1.6229E-01
    -4.8812E-01     -1.0329E+00     -3.0817E+00     -3.9910E-03     -2.1412E-01
PIPPER      3.3995E-02     -1.1414E-01     -1.0801E-02     -2.2561E-01
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ELAPSED TIME     11.100
      1      8.6002E+03      8.2357E+02                    1.0373E+04
      2      1.5992E+03      2.7492E+02                    2.4690E+03
      3     -1.9585E+04      3.8786E+02                   -1.8796E+04
      4      8.2357E+02     -2.7387E+01                    6.5770E+02
      5      2.7492E+02      9.8240E+01                    3.6101E+02
      6      3.8786E+02     -6.9629E-01                    5.4150E+02
      7      9.5713E+02      1.3156E+01                    9.2527E+02
      8     -1.1155E+01     -3.2599E-01                   -9.2237E+01
      9     -2.4225E-01      5.7703E-02                    6.2921E+01
     10      4.9321E-01     -1.5126E-01                    9.4378E+01
     11      9.5440E-02     -1.9519E-01                    1.2772E+02
     12      1.2646E-01      5.3909E-02                    4.6262E+00
     13     -3.6227E-01      2.7957E+00                    1.2325E+02
     14     -1.3585E-01     -6.6170E-01                   -4.0915E+01
     15     -8.0234E-02      1.2952E+00                    3.7679E+01
CONTROL VECTOR =       5.2360E-01     -8.7175E-03     -1.3050E+04      0.0
ERROR VECTOR =       2.1051E+03      2.7652E+02      1.1874E+02
         BANK              YANK             RANGE             SIGMA             ERROR
    2.9212E-01      3.3067E-02      2.1266E+03      1.4294E-01      1.4672E-01
    3.3421E-01      4.5009E-02     -4.6148E+01      1.8676E-01      1.9210E-01
   -5.4949E-01      9.2016E-01     -6.7562E+00      5.9527E-02      2.6540E-01
PIPPER     -1.2337E-02     -3.0688E-02     -5.4030E-02      1.0006E-01
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ELAPSED TIME     11.200
      1      8.6824E+03      8.2125E+02                    1.0439E+04
      2      1.6271E+03      2.8368E+02                    2.5054E+03
      3     -1.9546E+04      3.8781E+02                   -1.8742E+04
      4      8.2125E+02     -1.6475E+01                    6.4848E+02
      5      2.8368E+02      6.9438E+01                    3.6730E+02
      6      3.8781E+02      2.0070E+00                    5.5094E+02
      7      9.5845E+02      1.3335E+01                    9.2680E+02
      8     -1.1173E+01     -4.3535E-02                   -9.6898E+01
      9     -2.4286E-01     -6.9123E-02                    6.3150E+01
     10      4.8061E-01     -9.6122E-02                    9.4722E+01
     11      7.6662E-02     -1.6933E-01                    1.3136E+02
     12      1.2686E-01     -4.7720E-02                    5.6058E+00
     13     -6.6651E-02      3.2142E+00                    1.2269E+02
     14     -1.0406E-01      2.5834E+00                   -4.1661E+01
     15      5.1528E-02      1.3285E+00                    3.8826E+01
CONTROL VECTOR =       5.2360E-01     -1.7453E-01     -1.3050E+04      0.0
ERROR VECTOR =       2.0991E+03      2.9765E+02      8.7270E+01
         BANK              YANK             RANGE             SIGMA             ERROR
    3.1112E-01      3.9200E-02      2.1219E+03      1.5759E-01      1.6239E-01
    1.3448E-01      6.2372E-02     -4.6574E+01      9.2777E-02      1.0509E-01
    1.2643E+00     -2.1104E+00     -5.1524E+00      2.9846E-02     -4.7151E-01
PIPPER     -1.6730E-02     -4.3833E-02     -4.5435E-02      8.6385E-02
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