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COMPUTER PROGRAMS FOR ESTIMATING AIRCRAFT TAKEOFF PERFORMANCE IN THREE–DIMENSIONAL SPACE

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ABSTRACT

A set of computer programs has been developed to estimate the takeoff and initial climb-out maneuver of a given aircraft in three-dimensional space. The program is applicable to conventional, vectored lift and power-lift concept aircraft. The aircraft is treated as a point mass flying over a flat earth with no side slip, and the rotational dynamics have been neglected. The required input is described and a sample case presented.

INTRODUCTION

A set of computer programs has been developed to estimate the takeoff and initial climb-out maneuver of a given aircraft in three-dimensional space. The program is applicable to conventional, vectored lift and power-lift concept aircraft. The aircraft is treated as a point mass flying over a flat earth with zero sideslip, and the rotational dynamics have been neglected.

The user is required to provide two subroutines which compute the total force coefficients along and normal to the flight path, and determine various required engine characteristics.

This report describes the various subroutines and the required input, the equations used, and the computational techniques involved. Also included is a sample case and a listing of the program.

NOTATION

Symbol	Fortran name	
a_t	T(6), S(10)	acceleration along flight path (m/sec^2, ft/sec^2)
C_L	CL	aircraft lift coefficient
C_D	CD	aircraft drag coefficient
C_X	CX	force coefficient along flight path
C_Y	CY	force coefficient normal to flight path and in plane of symmetry of the aircraft
ENP	ENP	number of engines
g	G	acceleration due to gravity (m/sec^2, ft/sec^2)
h	HABS, S(7)	altitude (m, ft)
i_w	EYEW, EYEWNG	incidence of wing (deg)
LF	XLF	load factor
q		dynamic pressure (N/m^2, lb/ft^2)

R/C	S(15), ROC, RTCL	rate of climb (m/sec, m/min, ft/sec, ft/min)
R/C_{min}	ROCMIN	minimum rate of climb during turning flight (m/min, ft/min)
S	SW, SWING	reference wing area (m^2, ft^2)
T	THRUST	thrust, net or gross, per engine (N, lb)
V	T(4), S(4), VEL	aircraft velocity (m/sec, ft/sec)
V_R	VR	rotation speed, EAS (m/sec, knots)
W	W, WG	aircraft weight (N, lb)
W_f	WF, WFUEL	fuel flow (N/hr, lb/hr)
x_w		wind axis coordinate, tangent to flight path (m, ft)
X	S(8)	earth fixed coordinate, along runway (m, ft)
y_w		wind axis coordinate, perpendicular to x_w and z_w (m, ft)
Y	S(9)	earth fixed coordinate, perpendicular to X and Z (m, ft)
z_w		wind axis coordinate, perpendicular to x_w and in plane of symmetry (m, ft)
Z	-S(7)	earth fixed coordinate, normal to earth surface (m, ft)
α	ALPHA	angle of attack (deg)
γ	S(5), GAMMA	flight path angle (rad, deg)
δ_f	DELFD	flap deflection (deg)
δ_s	DELSPL	spoiler deflection (deg)
θ	THETAF	pitch altitude (fuselage angle) (deg)
μ	MU	rolling coefficient of friction
ν	ANGLE	vectored thrust deflection angle (deg)

ρ	RHO	air density (kg/m^3, slugs/ft^3)
ϕ	PHI	roll angle, right wing down positive (deg)
ψ	S(6)	heading angle (deg)

SUBROUTINE TAKOFF

The subroutine TAKOFF simulates the takeoff and initial climb out maneuver of a given aircraft in three-dimensional space. The program is applicable to conventional, vectored lift and powered lift aircraft. The aircraft is treated as a point mass and the rotational dynamics of the aircraft are neglected. This simplification necessitates an estimation of all rotational rates involved. These rates are either input by the user or are approximated by a finite difference form. In addition, the following assumptions are made:

- flat earth
- constant acceleration of gravity
- zero sideslip angle

The final assumption implies that the velocity vector and the resultant aerodynamic forces are contained in the plane of symmetry (ref. 1).

The takeoff maneuver is divided into four basic segments: ground roll and rotation, liftoff and initial segment climb, acceleration to final climb speed at a constant rate of climb, and finally, the pullup maneuver to establish the final climb speed. Provisions in the program are made for gear retraction, flap retraction, changing of vectored thrust angle and power setting, and changes in heading angle.

The ground roll is made at a specified power setting and flap deflection. When the rotation speed is reached, the aircraft is "rotated" by increasing the angle of attack linearly with time until liftoff occurs or the tail scrape angle is reached. If the latter occurs, the ground roll is continued with the fuselage angle equal to the tail scrape angle.

The flight path control is obtained by monitoring four dynamic variables — acceleration along the flight path, load factor, fuselage angle (pitch attitude) and rate of climb. The aircraft is not permitted to decelerate and the load factor and fuselage angle are restricted to values less than or equal to a specified maximum value. If any of these conditions are violated, the angle of attack is reduced until all constraints are satisfied. During turning flight, if the rate of climb is less than a specified minimum value, the roll angle is reduced until the time rate of change of the rate of climb is non-negative. In addition, if the time rate of change of the flight path angle is less than -1.0 deg/sec, the roll angle is also reduced.

Once a specified altitude is attained, called the maneuvering altitude, the aircraft is pitched down by a reduction in angle of attack until a specified rate of climb is obtained. The aircraft then accelerates at this rate of climb until the desired final climb speed is reached.

When the final climb speed is attained, the pullup maneuver is executed in order to bring the aircraft to a zero rate of acceleration along the flight path. This maneuver is accomplished by increasing the angle of attack and pulling a load factor of 1.20, which will result in an increase in the rate of climb to a final value at the desired climb speed. It may be necessary to throttle the engines in order to maintain the desired constant climb speed subject to the fuselage angle restriction.

Program Inputs

The inputs to subroutine TAKOFF are through the argument list, input by NAMELIST and common blocks /UNIV/ and /AERO/. Either metric or English units may be used in the program. On the first input data card, starting in col. 1, the word METRIC or ENGLISH should appear, depending on the user's choice of units.

The call to TAKOFF is as follows: CALL TAKOFF (INPC, IDCN, WGROSS, SWING, XENG, VR, VEND) where

INPC - program control = 1 - input data loaded
= 2 - program executed
= 3 - data input and program executed

IDCN - print control = 1 - no print out
= 9 - print out

WGROSS - aircraft gross weight (N, lb)

SWING - reference wing area (m^2, ft^2)

XENG - number of engines

VR - rotation speed (m/sec, knots)

VEND - final climb speed (m/sec, knots)

All speeds are indicated in air speeds.

There are three namelist inputs to TAKOFF, /NAM1/, /NAM2/ and NAM3/.

The namelist /NAM1/ input variables are as follows:

CDGEAR - drag increment due to gear

DFLPDT - flap retraction rate (deg/sec)

DTABS - temperature increment above standard temperature (°C, °F)

DTGR - time required to retract gear (sec)

DTPDWN - throttling down rate (percent/sec)

DTPUP - throttling advance rate (percent/sec)

DTVECT - vectored thrust angle reduction rate (deg/sec)

EYEWNG - wing incidence angle (deg)

HAPT - airport altitude (m, ft)

HDT - obstacle height (m, ft)

HGR - altitude at which gear retraction is started (m, ft)

HMAN - maneuvering altitude (m, ft)

HMAX - takeoff termination altitude (m, ft)

UM - rolling coefficient of friction

NPAGE - number of lines printed per page

PMARG - pullup speed margin

ROCMIN - minimum rate of climb during turning flight (m/min, fpm)

ROLLMX - maximum allowable roll angle (deg)

ROLRAT - roll rate (deg/sec)

RTCL - rate of climb during accelerate segment (m/min, fpm)

THTFLY - maximum allowable fuselage angle while airborne (deg)

THTSCP - tail scrape angle (deg)

XLFMAX - maximum allowable load factor

The user may input all, some, or none of the above input variables. The default values of these input variables are listed below:

GDGEAR = 0.0, DFLPDT = 3.0 deg/sec, DTABS = 0.0° F,

DTGR = 5.0 sec, DTPDWN = 5.0 percent/sec,

DTPUP = 6.0 percent/sec, DTVECT = 10 deg/sec,

EYEWNG = 1.0 deg, HAPT = 0.0 ft, HDT = 35 ft,

HGR = 25.0 ft, HMAN = 1000 ft, UM = 0.02,

PMARG = 0.04, ROCMDN = 250 fpm, ROLLMX = 15.0 deg,

ROLRAT = 5.0 deg/sec, RTCL = 750 fpm,

THTFLY = 15.0 deg, THTSCP = 10 deg, XLFMAX = 1.15.

Note that all default values contained in the program are in English units.

If the default value of CDGEAR is used, the program will calculate, based on an empirical formula, a value for the gear drag as a function of gross weight and wing area.

The second set of namelist variables, /NAM2/, constitute the flap, throttle and vectored thrust schedules. These are tables that manage the flap setting, power setting and vectored thrust angle as a function of the aircraft speed and altitude. These variables are arrays of dimension 5.

XDELFD (I) - flap deflection (deg)

XHFLAP (I) - flap retraction altitude (m, ft)

SVFLAP (I) - flap retraction speed (m/sec, knots)

XPOWER (I) - power setting

XHPWR (I) - power setting change altitude (m, ft)

XVPWR (I) - power setting change speed (m/sec, knots)

XNV (I) - vectored thrust angle (deg)

XHVECT (I) - vectored thrust angle change altitude (m, ft)

XVVECT (I) - vectored thrust angle change speed (m/sec, knots)

All altitudes are absolute altitudes and all speeds are indicated air speeds.

These schedules are constructed as follows: If the speed or altitude of the aircraft is equal to, say, XVFLAP (I) or XHFLAP (I), respectively, then the flaps are retracted at the rate DFLPDT to the value XDELFD (I). The power setting and vectored thrust angle management work in a similar manner. The power setting may either be increased or decreased. The flap setting and vectored thrust angle setting can only be reduced with altitude or speed. The values of XDELFD (1), XNU (1) and XPOWER (1) are all for the ground run. The user is permitted four changes in flap, power, vectored thrust angle settings during the airborne portion of the takeoff.

The default values for /NAM2/ are as follows:

- 100 percent throttle throughout takeoff
- 0 degrees vectored thrust
- 15.0 degrees flaps during ground roll, retracted to 5.0 degrees at 250-ft altitude, retraction to 2.0 degrees at 200 knots, and finally, complete retraction at 210 knots.

Again, the user may choose to use all, some, or none of the above schedule values. Note that the default values contained in the program are in English units. No changes to any of these settings are allowed during the pullup maneuver.

The final set of namelist variables, /NAM3/, define the departure headings as functions of absolute altitude and ground distance from the start of takeoff roll point. The heading angle, with values $-180 \leq \psi \leq 180$, is positive for right turns proceeding along the flight path. These input variables are arrays of dimension 5.

XHEAD (I) - flight heading (deg)

XHHEAD (I) - heading change altitude (m, ft)

XRANGE (I) - heading change ground distance (km, n.mi.)

The departure heading schedule works in a similar fashion to the flap, power and vectored thrust angle setting schedules. If the absolute altitude or ground distance from the starting point of the takeoff roll is equal to XHHEAD (I) or XRANGE (I), respectively, the aircraft begins to turn to a heading value of XHEAD (I). The runway heading is defined to be a heading angle of 0 degrees. Changes in aircraft heading are accomplished by increasing or decreasing (for right or left turns, respectively) the roll angle at a rate equal to ROLRAT. The absolute value of the roll angle is restricted to a maximum value of ROLLMX. The roll-out maneuver to establish the required heading is performed by rolling the aircraft back from the banked attitude to zero degrees roll (wings level) at a time such that when the wings are level, the aircraft is on the desired heading. The roll rate for the rollout maneuver is also equal to a value of ROLRAT. The default values for the heading schedule is for a straight out departure (no turns). Four changes in heading angle are permitted during the takeoff.

Program Output

The program output consists of a time history of several aircraft and flight path parameters. The output will be in meters or English units, depending on the choice of the user. See the sample listing presented in Appendix B. The output variables are as follows:

- TIME - time from start of takeoff roll (sec)
- X DIST - ground track distance along the earth fixed X coordinate (m, ft)
- Y DIST - ground track distance along the earth fixed Y coordinate (m, ft)
- ALT - aircraft altitude (m, ft)
- TAS - true airspeed along flight path (m/sec, knots)
- EAS - indicated airspeed (m/sec, knots)
- MACH NO - Mach number
- ACCEL - acceleration along flight path (m/sec^2, ft/sec^2)
- CL - aerodynamic lift coefficient

CD	-	aerodynamic drag coefficient
ALPHA	-	angle of attack (deg)
GAMMA	-	flight path angle (deg)
R/C	-	rate of climb (m/min, fpm)
LOAD FACTOR	-	load factor
THRUST	-	total thrust, net or gross (N, lb)
FUS. ANG.	-	fuselage pitch angle (deg)
ROLL ANGLE	-	roll angle (deg)
HEADNG	-	heading angle (deg)

In addition, the user may also obtain the following values through the common block /EXCHNG/:

SROLL	-	distance to liftoff (m, ft)
S35	-	track distance to obstacle height (m, ft)
V35	-	speed (EAS) at obstacle height (m/sec, knots)

The program will terminate normally when the end speed is reached (VEND) or when the maximum specified altitude (HMAX) is attained. Abnormal termination will occur under several conditions:

- flight path constraints cannot be met by further reduction in angle of attack
- aircraft cannot accelerate at input rate of climb (RTCL)
- aircraft altitude becomes negative
- ground track distance in ±X or ±Y direction is greater than 10 n.mi.
- ground run exceeds 90 sec
- elapsed time greater than 300 sec

For further definitions and explanations refer to the listing of TAKOFF and supporting subroutines contained in Appendix C, and the sample case presented in Appendix B.

Subroutines ARODYN and ENGINE

The takeoff subroutine described above requires the user to provide two subroutines to compute total force coefficients and determine various required engine characteristics (e.g., thrust and fuel flow per engine). The format and structure of these subroutines is left to the discretion of the user. The units used in these subroutines should be the same as those of the input data.

I. Subroutine ARODYN

This subroutine computes the total force coefficients along the flight path and normal to the flight path in the plane of symmetry as a function of angle of attack and thrust. A force coefficient in a particular direction $\vec{e}_s$ is defined to be the sum of all aerodynamic and propulsion system forces in that particular direction, divided by the dynamic pressure times the wing area.

$$C_s \triangleq \frac{\vec{e}_s \cdot \Sigma\vec{F}}{qS}$$

The transfer of the various computer variable values to and from subroutine ARODYN is through labeled common blocks /UNIV/ and /AERO/. Of primary concern is the common block /AERO/:

```
COMMON /AERO/ VEL, QS, HABS, THRUST, TVECT, ANGLE, DELFD, DELSPL, ALPHA,
              CS, CY, CL, CD, RHO, GRCD, IFAST
```

The input variables from TAKOFF are:

VEL - aircraft velocity along flight path (m/sec, ft/sec)

QS - dynamic pressure times wing area (N, lbs)

HABS - absolute altitude of aircraft (m, ft)

THRUST - thrust (net or gross) per engine (N, lbs)

TVECT - total vectored thrust (N, lbs)

ANGLE - angle of vectored thrust relative to aircraft center line, positive down (deg)

DELFD - flap deflection (deg)

DELSPL - spoiler deflection (deg)

ALPHA - angle of attack (deg)

RHO - air density (kg/m^3, $slugs/ft^3$)

GRCD - drag increment due to gear

The return from ARODYN should be:

CX - total force coefficient along flight path

CY - total force coefficient normal to flight path in plane of symmetry

The output variables CL and CD are provided to the user as a means to distinguish between pure aerodynamic coefficients and total force coefficients. The output variables CL and CD are printed out in the time history, but are not used in the actual calculations. If desired, in subroutine ARODYN, CL and CD may be directly equated to CY and CX, respectively.

There is a certain amount of redundancy among some of the input variables. The user may utilize only those variables he desires and disregard the others. Due to the wide range of velocities encountered during the takeoff, there will be a correspondingly large variation in the magnitude of the force coefficients which must be accommodated in subroutine ARODYN.

II. Subroutine ENGINE

This subroutine provides the various propulsion data to subroutines TAKOFF and ARODYN.

The inputs to subroutine ENGINE are through the argument list and labeled common blocks /AERO/ and /UNIV/.

The call to ENGINE is as follows:

CALL ENGINE (ALT, DTABS, EN, PWRSET, WFUEL, KENG)

where

ALT	- aircraft altitude (m, ft)
DTABS	- temperature increment above standard temperature (°C, °F)
EN	- aircraft Mach number
PWRSET	- power setting (see below)
WFUEL	- fuel flow (N/hr, lbs/hr)
KENG	- engine control parameter = 0

The variable PWRSET is defined to be:

$$PWRSET = \frac{\text{net thrust}}{\text{net thrust available}}$$

and is the parameter used in controlling the thrust level. It is used for power setting management during the takeoff.

The user may choose to work with either the gross thrust per engine or the net thrust per engine, provided he uses the variable THRUST properly in the calculation of the total force coefficients. For example, when using gross thrust per engine, the ram drag must be included in the total summation of forces. If the gross thrust vector and ram drag vector can be considered collinear, the user may choose instead to work simply with the net thrust.

Refer to the sample case presented for an illustration of subroutines ARODYN and ENGINE.

REFERENCES

1. Williams, J.: Aircraft Performance - Prediction Methods and Optimization, AGARD-LS-56, 1972.
2. Miele, Angelo: Flight Mechanics, Vol. 1, Addison-Wesley Publishing Company, Inc., 1962.
3. Bowles, Jeff V., and Galloway, Thomas L.: Computer Programs for Estimating Aircraft Takeoff and Landing Performance, NASA TM X-62,333, July 1973.

APPENDIX A

EQUATIONS

1. Equation of motion during ground roll

$$dV/dt = (g/W)[-W\mu + qS(C_y\mu - C_x)]$$

2. Equation of motion along flight path

$$dV/dt = (g/W)(-C_x qS - W \sin \gamma)$$

3. Equation of motion normal to flight path and in the plane of symmetry

$$d\psi/dt \sin \phi \cos \gamma + d\gamma/dt \cos \phi = (g/WV)(C_y qS - W \cos \gamma \cos \phi)$$

4. Equation of motion normal to the flight path and normal to plane of symmetry

$$-d\psi/dt \cos \phi \cos \gamma + d\gamma/dt \sin \phi = (g/WV) \sin \phi \cos \gamma$$

where

g = gravity constant

W = aircraft weight

q = dynamic pressure

S = wing area

γ = flight path angle

ψ = heading angle

ϕ = roll angle

V = aircraft velocity

C_x = total force coefficient along flight path

C_y = total force coefficient normal to flight path and in plane of symmetry

The coordinate systems used are presented in figure 1. The XYZ is the right handed earth fixed coordinate system, with the X-axis aligned with the runway. The Z axis is vertical and positive downward. The wind axis system is defined as follows: the x_w axis is tangent to the flight path and positive in the direction of flight; the z_w is normal to the x_w axis, in the plane of symmetry of the aircraft, and is positive downward in level flight; the y_w axis is normal to the x_w and z_w axis in the right handed sense. The x, y, z coordinate system is the translation of the XYZ axis system to the location of the point mass representation of the aircraft (ref. 2).

In order to make the system of equations of motion more amenable to numerical integration, the equations are manipulated in order to obtain explicit relations for the time rates of change of the velocity, flight path angle and heading angle.

The equation for dV/dt is already in the desired form. Note that the acceleration along the flight path is independent of the roll attitude. To obtain an expression for $d\gamma/dt$ alone, equation 3 is multiplied by $\cos\phi$, equation 4 multiplied by $\sin\phi$ and the resulting equations subtracted to give:

5. $$d\gamma/dt = [g/(WV)](C_y qS \cos\phi - W \cos\gamma)$$

An expression for $d\psi/dt$ alone is obtained in a similar manner:

6. $$d\psi/dt = [g/(WV \cos\gamma)]\ C_y qS \sin\phi$$

The system of equations 2, 5, and 6 are then numerically integrated using the Adams-Moulton fixed step-size method.

7. Load factor

$$XLF = \frac{qSC_y}{W}$$

8. Constant rate of climb equation

$$\text{Rate of climb} \triangleq \text{ROC} = V \sin \gamma$$

For ROC to be constant with time,

$$\frac{dROC}{dt} \equiv 0$$

or,

$$\frac{dROC}{dt} = \frac{d}{dt}(V \sin \gamma) = \frac{dV}{dt} \sin \gamma + V \cos \gamma \frac{d\gamma}{dt} = 0$$

Substituting for terms dV/dt and $d\gamma/dt$ from equations 2 and 5, and simplifying:

$$qS(C_y \cos \gamma \cos \phi - C_x \sin \gamma) - W = 0$$

9. Rotational rate approximations by finite difference

$$\theta = \gamma + \alpha - i_w$$

where

θ - pitch attitude (fuselage angle)

γ - flight path angle

α - angle of attack

i_w - incidence of wing

Differentiating with respect to time we obtain:

$$\frac{d\theta}{dt} = \frac{d\alpha}{dt} + \frac{d\gamma}{dt}$$

where $\frac{d\gamma}{dt}$ is given by equation 5.

$\frac{d\alpha}{dt}$ is approximated by the finite difference form:

$$\frac{d\alpha}{dt} = (\alpha_{now} - \alpha_{past})/\Delta t$$

where

α_{now} = current value of the angle of attack

α_{past} = previous value of angle of attack

Δt = integration time interval

10. Roll-out control equation

As the desired heading angle ψ_f is approached with the aircraft banked at some angle of roll ϕ_T, the roll angle is reduced at the rate of roll ROLRAT to zero in such a way that when the wings are level (implying $d\psi/dt = 0$), $\psi = \psi_f$. To perform this roll-out maneuver, an open loop type control procedure is used. The problem is to determine at what heading angle ψ the roll-out should be initiated.

From equation 6

$$\frac{d\psi}{dt} = \frac{gqSC_y}{WV \cos \gamma} \sin \phi \approx \frac{gqSC_y}{WV \cos \gamma} \phi$$

for moderate angles of bank.

Using a finite difference form approximation for $d\psi/dt$ and the definitions of figure 2,

$$\frac{d\psi}{dt} \approx \frac{\psi_f - \psi}{\Delta t} = \frac{\Delta\psi}{t_f} = \frac{gqSC_y}{WV \cos \gamma} \phi_{ave}$$

It is desired that the time average of ϕ over the time interval $0 < t' < t_f$ equals ϕ_{ave}, where

$$\phi = \phi_T + \frac{d\phi}{dt} t' \text{ , } \frac{d\phi}{dt} \text{ being constant}$$

therefore

$$\phi_{ave} t_f = \int_0^{t_f} \left(\phi_T + \frac{d\phi}{dt} t'\right) dt'$$

or, upon integration,

10a. $$\frac{\Delta\psi}{t_f}\frac{WV\cos\gamma}{gqSC_y}t_f = \phi_T t_f + \frac{1}{2}\frac{d\phi}{dt}t_f^2$$

Now, for $\phi(t_f) = 0$,

$$\frac{d\phi}{dt} = \frac{0 - \phi_T}{t_f} = -\frac{\phi_T}{t_f}$$

Solving for t_f and substituting in equation 10a

10b. $$|\Delta\psi| = \frac{\phi_T{}^2 gqSC_y}{2(d\phi/dt)WV\cos\gamma}$$

The value of $\Delta\psi$ is monitored during turning flight, and whenever $|\psi_f - \psi| \leq |\Delta\psi|$, the roll-out maneuver is begun. This estimate of $\Delta\psi$ is not exact, since the velocity V and the flight path angle γ will change over the time period t_f, but for moderate roll angles and roll rates, t_f will be small, and hence changes in V and γ correspondingly small.

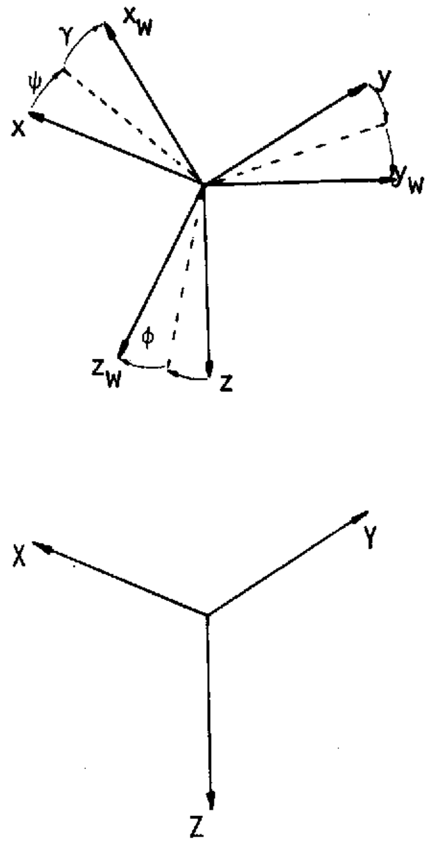
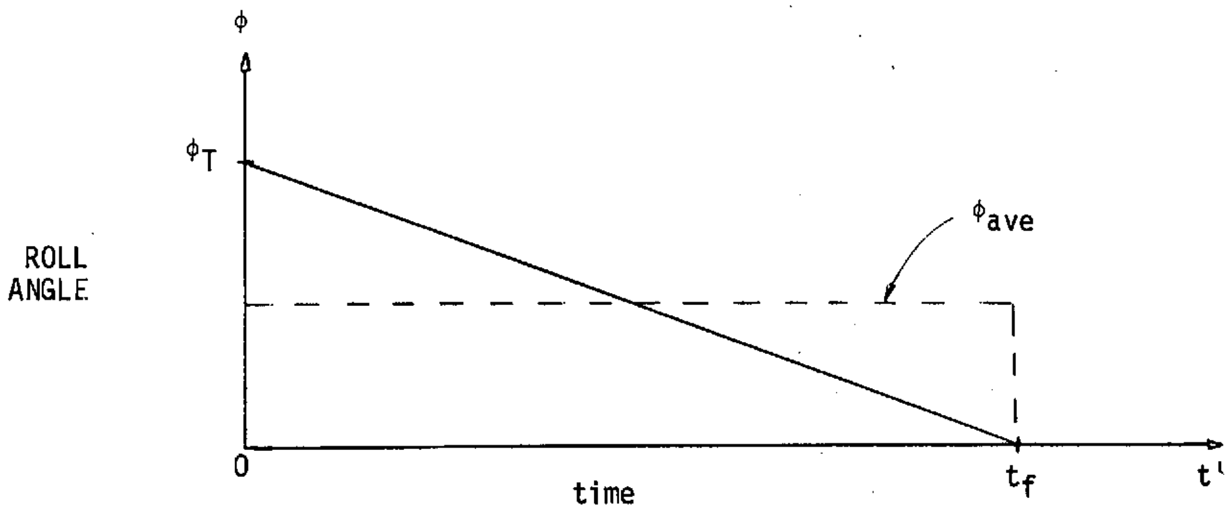


Figure 1.- Coordinate axis systems



t'=0 - start of rollout maneuver

$\phi(0) = \phi_T$, $\phi(t_f) = 0$

Figure 2.- Rollout maneuver parameters

APPENDIX B

SAMPLE CASE

Shown below is an example of the input, calling format, subroutines ARODYN and ENGINE, and the print out obtained from the takeoff program.

The main calling program TEST1 is set up to do the takeoff of a Boeing 727-200. The required common blocks are shown, but others may be added if needed. This example was done in English units.

The input was as follows:

```
ENGLISH
 $NAM1  NPAGE = 48, RTCL = 550.,
    THTFLY = 20., HMAN = 2000.,
    ROLLMX = 30., ROCMIN - 500.   $END
 $NAM2  XPOWER(2) = 0.75, XHPWR(2) = 750.,
    XPOWER(3) = 0.95, XHPWR(3) = 1750.   $END
 $NAM3  XHEAD(1) = 45., XHHEAD(1) = 800.,
    XHEAD(2) = -15., XHHEAD(2) = 2250.   $END
```

Subroutine ARODYN calculates the lift and drag coefficients of the 727-200 as a function of angle of attack, flap and spoiler deflection. The increments of lift and drag due to flaps is determined by a table look-up format. Once the lift and drag coefficients are computed, the thrust components, normalized by dynamic pressure times wing area (QS), are added in to determine the total force coefficients CX and CY.

Subroutine ENGINE computes the thrust and fuel flow of the JT8D engine, based on a simplified model. The thrust lapse is assumed to be linear with Mach number, and the fuel flow assumed linear with power setting.

This particular run was made on the Lawrence Berkeley Laboratory CDC 7600, requiring a field length of 41700 words to load and 2.47 sec to execute.

TEST1

```
              PROGRAM TEST1(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
              COMMON /UNIV/ NPC    ,NSC    ,IDC    ,H      ,ST     ,R      ,W      ,
             1WF     ,EM     ,VMO    ,EMMO   ,ALPHLO,CLALPH,SW     ,AR     ,B      ,
             2LYEW   ,ENP    ,TA     ,WG     ,WGS    ,KWRITE,DLMC4
             3,KSIZE
              COMMON /AERO/ VEL,QS,HABS,THRUST,TVECT, ANGLE,DELFD,DELSPL,ALPHA,
             9CX,CY,CL,CD,RHO,GRCD,IFAST
              WG = 172000.
      3       SWING = 1720.
      5       ENP = 3.0
      6       DELSPL = 0.0
      7       RHO = 0.0023
     10       SW = SWING
     12       W = WG
     14       CALL TAKOFF(3,9,WG,SW,3.0,135.0,250.)
     22       END
```

PROGRAM LENGTH INCLUDING I/O BUFFERS

01116

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

BLOCK NAMES AND LENGTHS
UNIV   = 000030/01 AERO   = 000020/02

VARIABLE ASSIGNMENTS
DELSPL = 000007/02 ENP   = 000021/01 RHO   = 000015/02 SW   = 000015/01 SWING = 000047   W   = 000006/01
WG   = 000023/01

START OF CONSTANTS=000025   TEMPS==000045   INDIRECTS=000047

7600 COMPILATION -- RUN76 LEVEL 98   74/07/15.

ROUTINE COMPILES IN 044000

```
ARODYN
                SUBROUTINE ARODYN
                REAL NU
                COMMON /UNIV/ NPC    ,NSC    ,IDC    ,H      ,ST     ,R      ,W      ,
               1WF     ,EM     ,VMO    ,EMMO   ,ALPHLO,CLALPH,SW     ,AR     ,B      ,
               2EYEW   ,ENP    ,TA     ,WG     ,WGS    ,KWRITE,DLMC4
               3,KSIZE
                COMMON /AERO/ VEL,QS,HABS,THRUST,TVECT, ANGLE,DELFD,DELSPL,ALPHA,
               9CX,CY,CL,CD,RHO,GRCD,IFAST
                DIMENSION XDELFD(6),XDELCL(6),XDELCD(6),XVDEL6(6)
                DATA XDELFD/0.0,5.0,10.,15.,20.,25./
                DATA XDELCL/0.0,0.186,0.347,0.482,0.60,0.702/
                DATA XDELCD/0.0,.0148,.0295,.0451,.0607,.0837/
                DATA XVDEL6/1.0,.995,.990,.980,.970,.955/
                CALL ITRLN(XDELFD,XDELCD,DELFD,DELCDF,6)
      5         CALL ITRLN(XDELFD,XDELCL,DELFD,DELCLF,6)
     11         CALL ITRLN(XDELFD,XVDEL6,DELFD,VDEL6,6)
     17         SA5 = 0.016
     20         CLALPH = 4.5
     22         ALPHLO = -1.5
     23         SA7 = 0.0546
     25         SIGMA = 0.6
     26         DCLSPL = 0.31*(DELSPL/90.)
     30         DCDSPL = 0.12*(DELSPL/90.)
     32         CL = CLALPH*(ALPHA - ALPHLO)*.017453 + DELCLF
     36         CL = CL - DCLSPL
     40         CD = SA5 + DELCDF +(SA7/VDEL6)*(CL - SIGMA*DELCLF)**2 + GRCD
     47         CD = CD + DCDSPL
     51       1 ALPHX = ALPHA * .0174533
     53         IF(QS .EQ. 0.0)QS = 0.1
     55         CX = CD - THRUST*ENP*COS(ALPHX)/QS
     63         CY = CL + THRUST*ENP*SIN(ALPHX)/QS
     72         RETURN
     72         END


SUBPROGRAM LENGTH

00167

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS
1       - 000052

BLOCK NAMES AND LENGTHS
UNIV   - 000030/01  AERO    - 000020/02

VARIABLE ASSIGNMENTS
ALPHA  - 000010/02  ALPHLO - 000013/01  ALPHX  - 000166     CD     - 000014/02  CL     - 000013/02  CLALPH - 000014/01
CX     - 000011/02  CY     - 000012/02  DCDSPL - 000165     DCLSPL - 000164     DELCDF - 000156     DELCLF - 000157
DELFD  - 000006/02  DELSPL - 000007/02  ENP    - 000021/01  GRCD   - 000016/02  NU     - 000125     QS     - 000001/02
SA5    - 000161     SA7    - 000162     SIGMA  - 000163     THRUST - 000003/02  VDEL6  - 000160     XDELCD - 000142
XDELCL - 000134     XDELFD - 000126     XVDEL6 - 000150

START OF CONSTANTS-000075      TEMPS--000112     INDIRECTS-000125
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```
ENGINE
            SUBROUTINE ENGINE(ALT,DTABS,EN,PWRSET,WFUEL,KENG)
            COMMON /AERO/ VEL,QS,HABS,THRUST,TVECT, ANGLE,DELFD,DELSPL,ALPHA,
           9CX,CY,CL,CD,RHO,GRCD,IFAST
            IF(KENG ,EQ. 1)GO TO 10
            TO = 14000.
            THRUST = (TO - 6.0*EN*1100.)*PWRSET
         11 WFUEL = THRUST*0.63*PWRSET
            RETURN
         10 PWRSET = THRUST/(TO - 6.0*EN*1100.)
            GO TO 11
            END


SUBPROGRAM LENGTH

00043

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS
10      - 000022     11      - 000017

BLOCK NAMES AND LENGTHS
AERO    - 000020/01

VARIABLE ASSIGNMENTS
THRUST - 000003/01  TO      - 000042

START OF CONSTANTS=000031        TEMPS==000036    INDIRECTS=000042

7600 COMPILATION == RUN76 LEVEL 98       74/07/15.

ROUTINE COMPILES IN 044000
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** INPUTS TO TAKE OFF - ALTITUDE = 0.0 TEMPERATURE = 59.0 DEG.

A/C CHARACTERISTICS
GROSS RAMP WT. = 172000 WING AREA = 1720 STATIC SEA LEVEL THRUST = 14000
WING LOADING = 100.0 THRUST/WEIGHT = .244

A/C PARAMETERS,
NO. ENGINES = 3.0 CDGEAR = .0287 EYEWNG = 1.0 TAIL SCRAPE ANGLE = 10.0

FLIGHT PATH CONTROL PARAMETERS
MAX LOAD FACTOR = 1.10 GEAR RETRACTION ALT. = 25.0 MAX FLOOR ANGLE = 20.0
MANEUVER ALT. = 2000 ACCELERATE RATE OF CLIMB = 550

PARAMETER VARIATION RATES
DAOT = 1.0 DFLPDT = 3.0 DTGR = 5.0 DTPDWN = 5.0
DTDUP = 6.0 DTVECT = 10.0

POWER, VECTORED THRUST, AND FLAP SCHEDULES

THROTTLE/POWER SETTING

PWRSET	1.00	.75	.95	1.00	1.00
SPEED	0.0	0.0	0.0	999.0	999.0
ALTITUDE	0	750	1750	0	0

VECTORED THRUST ANGLE

ANGLE	0.0	0.0	0.0	0.0	0.0
SPEED	0.0	999.0	999.0	999.0	999.0
ALTITUDE	0	0	0	0	0

FLAP DEFLECTION ANGLE

DELFD	15.0	5.0	2.0	0.0	0.0
SPEED	0.0	0.0	200.0	210.0	0.0
ALTITUDE	0	250	0	0	0

ALL SPEEDS ARE INDICATED AIR SPEEDS AND ALL ALTITUDES ARE ABSOLUTE ALTITUDES

DEPARTURE HEADINGS

RANGE	100.0	100.0	100.0	100.0	100.0
ALTITUDE	800.0	2250.0	99999.0	99999.0	99999.0
HEADING	45.0	-15.0	0.0	0.0	0.0

TAKEOFF (ELEVATION = 0 FT)

TIME (SEC)	X DIST (FEET)	Y DIST (FEET)	ALT. (FEET)	TAS (KTS)	EAS (KTS)	MACH NO.	ACCEL (FPS2)	CL	CD	ALPHA (DEG)	GAMMA (DEG)	R/C (FPM)	LOAD FACT	THRUST (LBS)	FUS. ANG.	ROLL ANGLE	HEADNG (DEG)
0.0	0.0	0.0	0.0	0.0	0.0	0.000	7.22	.678	.0982	1.00	0.00	0.0	0.00	42000	0.0	0.0	0.0
1.0	3.6	0.0	0.0	4.3	4.3	.006	7.20	.678	.0982	1.00	0.00	0.0	0.00	41885	0.0	0.0	0.0
2.0	14.4	0.0	0.0	8.5	8.5	.012	7.17	.678	.0982	1.00	0.00	0.0	0.00	41758	0.0	0.0	0.0
3.0	32.4	0.0	0.0	12.8	12.8	.019	7.14	.678	.0982	1.00	0.00	0.0	0.00	41631	0.0	0.0	0.0
4.0	57.5	0.0	0.0	17.0	17.0	.025	7.10	.678	.0982	1.00	0.00	0.0	0.00	41504	0.0	0.0	0.0
5.0	89.7	0.0	0.0	21.2	21.2	.031	7.06	.678	.0982	1.00	0.00	0.0	0.00	41379	0.0	0.0	0.0
6.0	129.0	0.0	0.0	25.3	25.3	.038	7.02	.678	.0982	1.00	0.00	0.0	0.00	41254	0.0	0.0	0.0
7.0	175.3	0.0	0.0	29.5	29.5	.044	6.98	.678	.0982	1.00	0.00	0.0	0.00	41130	0.0	0.0	0.0
8.0	228.6	0.0	0.0	33.6	33.6	.050	6.93	.678	.0982	1.00	0.00	0.0	0.00	41006	0.0	0.0	0.0
9.0	288.8	0.0	0.0	37.7	37.7	.056	6.88	.678	.0982	1.00	0.00	0.0	0.00	40884	0.0	0.0	0.0
10.0	355.9	0.0	0.0	41.8	41.8	.063	6.83	.678	.0982	1.00	0.00	0.0	0.00	40762	0.0	0.0	0.0
11.0	429.8	0.0	0.0	45.8	45.8	.069	6.78	.678	.0982	1.00	0.00	0.0	0.00	40642	0.0	0.0	0.0
12.0	510.5	0.0	0.0	49.8	49.8	.075	6.72	.678	.0982	1.00	0.00	0.0	0.00	40522	0.0	0.0	0.0
13.0	597.9	0.0	0.0	53.7	53.7	.081	6.66	.678	.0982	1.00	0.00	0.0	0.00	40403	0.0	0.0	0.0
14.0	692.0	0.0	0.0	57.7	57.7	.087	6.60	.678	.0982	1.00	0.00	0.0	0.00	40286	0.0	0.0	0.0
15.0	792.6	0.0	0.0	61.5	61.5	.092	6.53	.678	.0982	1.00	0.00	0.0	0.00	40169	0.0	0.0	0.0
16.0	899.8	0.0	0.0	65.4	65.4	.098	6.47	.678	.0982	1.00	0.00	0.0	0.00	40054	0.0	0.0	0.0
17.0	1013.5	0.0	0.0	69.2	69.2	.104	6.40	.678	.0982	1.00	0.00	0.0	0.00	39940	0.0	0.0	0.0
18.0	1133.6	0.0	0.0	73.0	73.0	.110	6.33	.678	.0982	1.00	0.00	0.0	0.00	39827	0.0	0.0	0.0
19.0	1260.0	0.0	0.0	76.7	76.7	.115	6.25	.678	.0982	1.00	0.00	0.0	0.00	39715	0.0	0.0	0.0
20.0	1392.6	0.0	0.0	80.4	80.4	.121	6.18	.678	.0982	1.00	0.00	0.0	0.00	39605	0.0	0.0	0.0
21.0	1531.4	0.0	0.0	84.0	84.0	.126	6.10	.678	.0982	1.00	0.00	0.0	0.00	39496	0.0	0.0	0.0
22.0	1676.4	0.0	0.0	87.6	87.6	.132	6.03	.678	.0982	1.00	0.00	0.0	0.00	39388	0.0	0.0	0.0
23.0	1827.3	0.0	0.0	91.1	91.1	.137	5.95	.678	.0982	1.00	0.00	0.0	0.00	39282	0.0	0.0	0.0
24.0	1984.2	0.0	0.0	94.6	94.6	.143	5.87	.678	.0982	1.00	0.00	0.0	0.00	39177	0.0	0.0	0.0
25.0	2147.0	0.0	0.0	98.1	98.1	.148	5.79	.678	.0982	1.00	0.00	0.0	0.00	39073	0.0	0.0	0.0
26.0	2315.6	0.0	0.0	101.5	101.5	.153	5.71	.678	.0982	1.00	0.00	0.0	0.00	38971	0.0	0.0	0.0
27.0	2489.8	0.0	0.0	104.9	104.9	.158	5.62	.678	.0982	1.00	0.00	0.0	0.00	38871	0.0	0.0	0.0
28.0	2669.7	0.0	0.0	108.2	108.2	.163	5.54	.678	.0982	1.00	0.00	0.0	0.00	38772	0.0	0.0	0.0
29.0	2855.2	0.0	0.0	111.4	111.4	.168	5.46	.678	.0982	1.00	0.00	0.0	0.00	38674	0.0	0.0	0.0
30.0	3046.1	0.0	0.0	114.6	114.6	.173	5.37	.678	.0982	1.00	0.00	0.0	0.00	38578	0.0	0.0	0.0
31.0	3242.3	0.0	0.0	117.8	117.8	.178	5.29	.678	.0982	1.00	0.00	0.0	0.00	38483	0.0	0.0	0.0
32.0	3443.9	0.0	0.0	120.9	120.9	.182	5.20	.678	.0982	1.00	0.00	0.0	0.00	38390	0.0	0.0	0.0
33.0	3650.7	0.0	0.0	123.9	123.9	.187	5.12	.678	.0982	1.00	0.00	0.0	0.00	38299	0.0	0.0	0.0
34.0	3862.5	0.0	0.0	126.9	126.9	.191	5.03	.678	.0982	1.00	0.00	0.0	0.00	38209	0.0	0.0	0.0
35.0	4079.4	0.0	0.0	129.9	129.9	.196	4.94	.678	.0982	1.00	0.00	0.0	0.00	38120	0.0	0.0	0.0
36.0	4301.3	0.0	0.0	132.8	132.8	.200	4.86	.678	.0982	1.00	0.00	0.0	0.00	38033	0.0	0.0	0.0

ROTATION (TIME = 36.8 AND TAS = 135.1 EAS = 135.1)

37.0	4528.0	0.0	0.0	135.6	135.6	.205	4.76	.694	.0989	1.20	0.00	0.0	0.00	37948	.2	0.0	0.0
38.0	4759.4	0.0	0.0	138.4	138.4	.209	4.63	.773	.1028	2.20	0.00	0.0	0.00	37864	1.2	0.0	0.0
39.0	4995.5	0.0	0.0	141.1	141.1	.213	4.47	.851	.1074	3.20	0.00	0.0	0.00	37783	2.2	0.0	0.0
40.0	5236.1	0.0	0.0	143.7	143.7	.217	4.29	.930	.1127	4.20	0.00	0.0	0.00	37705	3.2	0.0	0.0
41.0	5480.9	0.0	0.0	146.2	146.2	.221	4.10	1.008	.1186	5.20	0.00	0.0	0.00	37631	4.2	0.0	0.0
42.0	5729.8	0.0	0.0	148.6	148.6	.224	3.88	1.087	.1252	6.20	0.00	0.0	0.00	37560	5.2	0.0	0.0
43.0	5982.6	0.0	0.0	150.8	150.8	.228	3.63	1.165	.1326	7.20	0.00	0.0	0.00	37493	6.2	0.0	0.0

LIFTOFF (TIME = 43.9 DIST = 6213.3 TAS = 152.7 EAS = 152.7)

44.0	6239.1	0.0	.0	152.9	152.9	.231	3.35	1.244	.1406	8.20	.01	3.0	1.02	37430	7.2	0.0	0.0
45.0	6498.8	0.0	.8	154.7	154.7	.234	2.79	1.311	.1479	9.05	.46	126.2	1.10	37374	8.5	0.0	0.0
46.0	6761.4	0.0	4.6	156.2	156.2	.236	2.39	1.287	.1453	8.75	1.15	318.6	1.10	37328	8.9	0.0	0.0
47.0	7026.2	0.0	11.5	157.5	157.5	.238	2.00	1.267	.1431	8.50	1.84	511.7	1.10	37288	9.3	0.0	0.0
48.0	7293.0	0.0	21.6	158.6	158.5	.240	1.62	1.248	.1410	8.25	2.52	707.1	1.10	37255	9.8	0.0	0.0

TAKEOFF CONTINUED

TIME (SEC)	X DIST (FEET)	Y DIST (FEET)	ALT. (FEET)	TAS (KTS)	EAS (KTS)	MACH NO.	ACCEL (FPS2)	CL	CD	ALPHA (DEG)	GAMMA (DEG)	R/C (FPM)	LOAD FACT	THRUST (LBS)	FUS. ANG.	ROLL ANGLE	HEADNG (DEG)
GEAR RETRACTION STARTED AT 48.3 SEC, COMPLETE AT 53.3 SEC																	
DISTANCE TO OBSTACLE HEIGHT = 7560.6 SCREEN SPEED(EAS) = 159.4																	
49.0	7561.3	0.0	35.0	159.5	159.4	.241	1.33	1.236	.1363	8.10	3.20	903.3	1.10	37228	10.3	0.0	0.0
50.0	7830.7	0.0	51.7	160.2	160.1	.242	1.09	1.228	.1297	8.00	3.89	1101.2	1.10	37206	10.9	0.0	0.0
51.0	8101.0	0.0	71.8	160.7	160.6	.243	.87	1.220	.1232	7.90	4.58	1300.0	1.10	37188	11.5	0.0	0.0
52.0	8371.9	0.0	95.1	161.2	161.0	.244	.64	1.212	.1166	7.80	5.27	1500.9	1.10	37174	12.1	0.0	0.0
53.0	8643.1	0.0	121.8	161.5	161.2	.244	.42	1.208	.1105	7.75	5.97	1702.3	1.10	37164	12.7	0.0	0.0
54.0	8914.4	0.0	151.8	161.7	161.3	.245	.09	1.208	.1082	7.75	6.67	1902.4	1.10	37158	13.4	0.0	0.0
55.0	9185.4	0.0	184.9	161.7	161.2	.245	.00	1.142	.1016	6.90	7.19	2049.4	1.03	37157	13.1	0.0	0.0
56.0	9456.3	0.0	219.6	161.7	161.2	.245	.00	1.110	.0987	6.50	7.35	2095.5	1.00	37156	12.8	0.0	0.0
FLAPS RETRACTED TO 5.0 DEG, IN 3.3 SEC.																	
57.0	9727.1	0.0	254.6	161.7	161.1	.245	.02	1.102	.0974	6.50	7.39	2108.8	1.00	37156	12.9	0.0	0.0
58.0	9997.9	0.0	289.8	161.7	161.1	.245	.13	1.100	.0921	7.50	7.43	2119.4	1.00	37154	13.9	0.0	0.0
59.0	10268.9	0.0	325.3	161.8	161.1	.245	.24	1.091	.0870	8.50	7.47	2131.5	.99	37150	15.0	0.0	0.0
60.0	10540.0	0.0	360.8	162.0	161.2	.245	.37	1.072	.0821	9.50	7.44	2126.8	.98	37144	15.9	0.0	0.0
61.0	10811.5	0.0	396.3	162.2	161.3	.246	.15	1.128	.0875	10.50	7.51	2149.6	1.04	37138	17.0	0.0	0.0
62.0	11083.0	0.0	433.0	162.2	161.2	.246	.00	1.117	.0862	10.35	7.86	2247.9	1.03	37137	17.2	0.0	0.0
63.0	11354.4	0.0	470.8	162.2	161.1	.246	.01	1.093	.0837	10.05	8.00	2287.6	1.00	37136	17.0	0.0	0.0
64.0	11625.7	0.0	509.1	162.2	161.0	.246	.01	1.085	.0828	9.95	8.04	2300.7	.99	37135	17.0	0.0	0.0
65.0	11897.0	0.0	547.5	162.2	160.9	.246	.00	1.085	.0828	9.95	8.06	2306.0	.99	37134	17.0	0.0	0.0
66.0	12168.3	0.0	585.9	162.2	160.9	.246	.00	1.085	.0828	9.95	8.07	2306.9	.99	37134	17.0	0.0	0.0
67.0	12439.6	0.0	624.4	162.2	160.8	.246	.00	1.085	.0828	9.95	8.07	2306.6	.99	37133	17.0	0.0	0.0
68.0	12710.9	0.0	662.8	162.2	160.7	.246	.01	1.085	.0828	9.95	8.07	2307.1	.99	37132	17.0	0.0	0.0
69.0	12982.2	0.0	701.3	162.2	160.6	.246	.01	1.085	.0828	9.95	8.06	2305.7	.99	37131	17.0	0.0	0.0
70.0	13253.5	0.0	739.7	162.3	160.5	.246	.01	1.085	.0828	9.95	8.06	2305.6	.99	37130	17.0	0.0	0.0
RETARD THROTTLE SETTING TO 75.0 PERCENT IN 5.0 SEC.																	
71.0	13524.8	0.0	778.0	162.3	160.4	.246	.01	1.034	.0775	9.30	7.93	2267.9	.94	35830	16.2	0.0	0.0
BEGIN TURN TO HEADING 45.0 DEG.																	
72.0	13796.4	.0	814.8	162.3	160.3	.246	.01	1.007	.0748	8.95	7.47	2138.7	.91	33973	15.4	2.0	.0
73.0	14068.3	1.2	849.0	162.3	160.3	.246	.01	1.003	.0744	8.90	6.88	1968.6	.90	32116	14.8	7.0	.5
74.0	14340.5	5.9	880.3	162.3	160.2	.246	.00	1.015	.0755	9.05	6.21	1780.1	.91	30259	14.3	12.0	1.5
75.0	14612.9	16.7	908.3	162.3	160.1	.246	.01	1.030	.0771	9.25	5.50	1576.5	.92	28402	13.8	17.0	3.1
76.0	14885.2	36.2	932.8	162.3	160.1	.246	.10	1.093	.0837	10.05	4.81	1378.8	.98	27844	13.9	22.0	5.2
77.0	15156.6	67.6	954.6	162.4	160.1	.246	.11	1.172	.0925	11.05	4.32	1240.3	1.05	27843	14.4	27.0	8.1
78.0	15426.2	114.3	974.4	162.4	160.1	.246	.12	1.223	.0985	11.70	3.98	1142.7	1.10	27841	14.7	30.0	11.6
79.0	15692.3	178.2	992.7	162.5	160.2	.247	.29	1.223	.0985	11.70	3.67	1055.1	1.10	27839	14.4	30.0	15.3
80.0	15954.2	259.2	1009.5	162.8	160.4	.247	.47	1.219	.0981	11.65	3.35	965.3	1.10	27833	14.0	30.0	19.0
81.0	16210.9	357.1	1024.9	163.1	160.7	.247	.65	1.215	.0976	11.60	3.04	875.8	1.10	27826	13.6	30.0	22.7
82.0	16461.4	471.6	1038.7	163.5	161.1	.248	.85	1.207	.0966	11.50	2.72	786.3	1.10	27816	13.2	30.0	26.4
83.0	16704.8	602.3	1051.1	164.1	161.6	.249	1.03	1.199	.0957	11.40	2.40	696.5	1.10	27804	12.8	30.0	30.1
84.0	16940.4	748.9	1062.0	164.8	162.2	.250	1.22	1.191	.0948	11.30	2.08	606.1	1.10	27789	12.4	30.0	33.7
85.0	17167.4	910.5	1071.6	165.5	162.9	.251	1.31	1.183	.0938	11.20	1.91	559.7	1.10	27772	12.1	25.0	37.1
86.0	17386.5	1084.9	1081.0	166.3	163.7	.252	1.27	1.172	.0925	11.05	2.01	590.6	1.10	27754	12.1	20.0	39.8
87.0	17598.9	1269.3	1091.6	167.0	164.4	.253	1.10	1.164	.0916	10.95	2.32	685.4	1.10	27738	12.3	15.0	42.0
88.0	17805.9	1461.2	1104.2	167.6	164.9	.254	.84	1.156	.0906	10.85	2.80	828.7	1.10	27724	12.6	10.0	43.6
89.0	18009.2	1658.1	1119.4	168.0	165.3	.255	.53	1.148	.0898	10.75	3.38	1005.1	1.10	27714	13.1	5.0	44.5
90.0	18210.6	1857.4	1137.7	168.2	165.4	.255	.16	1.148	.0898	10.75	4.02	1195.9	1.10	27709	13.8	2.0	44.9
91.0	18411.0	2057.6	1159.2	168.2	165.4	.255	.01	1.101	.0845	10.15	4.59	1364.4	1.05	27708	13.7	0.0	45.0
92.0	18611.2	2257.9	1182.6	168.2	165.3	.255	.00	1.066	.0807	9.70	4.83	1434.1	1.02	27707	13.5	0.0	45.0
93.0	18811.3	2458.2	1206.8	168.2	165.3	.255	.01	1.050	.0791	9.50	4.91	1458.8	1.00	27707	13.4	0.0	45.0
94.0	19011.5	2658.4	1231.1	168.2	165.2	.255	.01	1.046	.0787	9.45	4.93	1466.5	1.00	27707	13.4	0.0	45.0
95.0	19211.6	2858.6	1255.6	168.2	165.2	.255	.01	1.046	.0787	9.45	4.94	1468.9	1.00	27706	13.4	0.0	45.0
96.0	19411.7	3058.9	1280.1	168.2	165.1	.256	.01	1.046	.0787	9.45	4.95	1470.1	1.00	27706	13.4	0.0	45.0

TAKEOFF CONTINUED

TIME (SEC)	X DIST (FEET)	Y DIST (FEET)	ALT, (FEET)	TAS (KTS)	EAS (KTS)	MACH NO,	ACCEL (FPS2)	CL	CD	ALPHA (DEG)	GAMMA (DEG)	R/C (FPM)	LOAD FACT	THRUST (LBS)	FUS, ANG,	ROLL ANGLE	HEADNG (DEG)
97,0	19611,8	3259,1	1304,6	168,3	165,1	,256	,01	1,046	,0787	9,45	4,95	1470,1	1,00	27705	13,4	0,0	45,0
98,0	19812,0	3459,4	1329,1	168,3	165,0	,256	,01	1,046	,0787	9,45	4,94	1468,9	1,00	27705	13,4	0,0	45,0
99,0	20012,1	3659,6	1353,6	168,3	165,0	,256	,00	1,050	,0791	9,50	4,94	1469,0	1,00	27704	13,4	0,0	45,0
100,0	20212,2	3859,9	1378,1	168,3	164,9	,256	,00	1,050	,0791	9,50	4,94	1469,0	1,00	27704	13,4	0,0	45,0
101,0	20412,4	4060,2	1402,6	168,3	164,8	,256	,00	1,050	,0791	9,50	4,94	1469,4	1,00	27704	13,4	0,0	45,0
102,0	20612,6	4260,4	1427,1	168,3	164,8	,256	,00	1,050	,0791	9,50	4,95	1470,6	1,00	27703	13,4	0,0	45,0
103,0	20812,7	4460,7	1451,6	168,3	164,7	,256	,00	1,050	,0791	9,50	4,95	1470,5	1,00	27703	13,4	0,0	45,0
104,0	21012,9	4661,0	1476,1	168,3	164,7	,256	,01	1,050	,0791	9,50	4,94	1469,2	1,00	27702	13,4	0,0	45,0
105,0	21213,0	4861,3	1500,5	168,3	164,6	,256	,01	1,050	,0791	9,50	4,94	1468,0	,99	27702	13,4	0,0	45,0
106,0	21413,2	5061,5	1525,0	168,3	164,6	,256	,01	1,050	,0791	9,50	4,94	1467,9	,99	27702	13,4	0,0	45,0
107,0	21613,4	5261,8	1549,5	168,3	164,5	,256	,00	1,054	,0795	9,55	4,94	1467,5	1,00	27701	13,5	0,0	45,0
108,0	21813,6	5462,1	1573,9	168,3	164,4	,256	,00	1,054	,0795	9,55	4,94	1468,5	1,00	27701	13,5	0,0	45,0
109,0	22013,8	5662,4	1598,4	168,3	164,4	,256	,01	1,054	,0795	9,55	4,94	1468,3	1,00	27700	13,5	0,0	45,0
110,0	22214,0	5862,7	1622,9	168,3	164,3	,256	,01	1,054	,0795	9,55	4,93	1466,9	1,00	27700	13,5	0,0	45,0
111,0	22414,2	6063,1	1647,3	168,3	164,3	,256	,00	1,058	,0799	9,60	4,93	1466,2	1,00	27700	13,5	0,0	45,0
112,0	22614,4	6263,4	1671,7	168,3	164,2	,256	,00	1,058	,0799	9,60	4,93	1465,9	1,00	27699	13,5	0,0	45,0
113,0	22814,6	6463,7	1696,2	168,3	164,2	,256	,00	1,058	,0799	9,60	4,93	1466,0	1,00	27699	13,5	0,0	45,0
114,0	23014,8	6664,0	1720,6	168,3	164,1	,256	,00	1,058	,0799	9,60	4,93	1466,9	1,00	27698	13,5	0,0	45,0
115,0	23215,0	6864,4	1745,1	168,3	164,1	,256	,01	1,058	,0799	9,60	4,93	1466,5	1,00	27698	13,5	0,0	45,0
ADVANCE THROTTLE SETTING TO 95,0 PERCENT IN 3,3 SEC,																	
116,0	23415,2	7064,7	1769,6	168,3	164,0	,256	,04	1,113	,0858	10,30	5,05	1501,3	1,05	29248	14,3	0,0	45,0
117,0	23615,4	7264,9	1795,8	168,3	164,0	,256	,01	1,156	,0906	10,85	5,58	1658,2	1,09	31463	15,4	0,0	45,0
118,0	23815,3	7465,0	1825,1	168,4	163,9	,256	,04	1,160	,0911	10,90	6,24	1853,2	1,10	33678	16,1	0,0	45,0
119,0	24015,0	7664,8	1857,6	168,4	163,8	,256	,01	1,136	,0884	10,60	6,90	2049,9	1,08	35081	16,5	0,0	45,0
120,0	24214,5	7864,4	1892,8	168,4	163,8	,256	,01	1,081	,0824	9,90	7,24	2151,9	1,02	35080	16,1	0,0	45,0
121,0	24413,9	8063,9	1929,0	168,4	163,7	,256	,01	1,062	,0803	9,65	7,37	2189,9	1,00	35079	16,0	0,0	45,0
122,0	24613,3	8263,4	1965,7	168,4	163,6	,256	,01	1,054	,0795	9,55	7,42	2203,4	,99	35078	16,0	0,0	45,0
123,0	24812,6	8462,9	2002,4	168,4	163,5	,256	,01	1,054	,0795	9,55	7,43	2207,0	,99	35078	16,0	0,0	45,0
ACCELERATE TO CLIMB SPEED OF 250,0																	
124,0	25012,0	8662,4	2039,0	168,5	163,5	,256	,20	1,015	,0755	9,05	7,32	2173,8	,96	35076	15,4	0,0	45,0
125,0	25211,7	8862,2	2074,5	168,7	163,6	,257	,51	,975	,0717	8,55	6,96	2070,1	,92	35070	14,5	0,0	45,0
126,0	25411,9	9062,5	2107,7	169,1	163,9	,257	,95	,936	,0681	8,05	6,36	1899,4	,88	35058	13,4	0,0	45,0
127,0	25613,1	9263,8	2137,4	169,8	164,5	,259	1,49	,897	,0646	7,55	5,55	1665,5	,85	35038	12,1	0,0	45,0
128,0	25815,6	9466,4	2162,9	170,9	165,5	,260	2,07	,873	,0626	7,25	4,58	1384,1	,84	35008	10,8	0,0	45,0
129,0	26019,9	9670,8	2183,5	172,3	166,8	,262	2,66	,854	,0610	7,00	3,56	1084,0	,83	34968	9,6	0,0	45,0
130,0	26226,2	9877,3	2199,0	174,0	168,5	,265	3,26	,834	,0594	6,75	2,50	770,7	,83	34919	8,3	0,0	45,0
131,0	26435,1	10086,3	2209,3	176,0	170,4	,268	3,24	,976	,0718	8,56	1,70	530,1	1,00	34860	9,3	0,0	45,0
132,0	26646,3	10297,6	2218,1	178,0	172,2	,271	3,25	,956	,0700	8,31	1,68	530,0	1,00	34805	9,0	0,0	45,0
133,0	26859,9	10511,3	2227,0	179,9	174,1	,274	3,26	,937	,0682	8,07	1,67	530,1	1,00	34750	8,7	0,0	45,0
134,0	27075,7	10727,3	2235,8	181,8	175,9	,277	3,28	,918	,0665	7,82	1,65	530,0	1,00	34694	8,5	0,0	45,0
135,0	27293,9	10945,6	2244,6	183,8	177,8	,280	3,29	,900	,0649	7,59	1,63	530,0	1,00	34638	8,2	0,0	45,0
BEGIN TURN TO HEADING -15,0 DEG,																	
136,0	27514,4	11166,2	2253,5	185,7	179,7	,283	3,29	,883	,0634	7,37	1,61	530,0	1,00	34582	8,0	-1,5	45,0
137,0	27737,9	11388,4	2262,3	187,7	181,5	,286	3,29	,871	,0624	7,22	1,60	529,8	1,00	34526	7,8	-6,5	44,6
138,0	27966,3	11610,3	2271,1	189,6	183,4	,289	3,26	,866	,0620	7,15	1,58	529,8	1,02	34470	7,7	-11,5	43,7
139,0	28201,6	11829,7	2280,0	191,5	185,2	,292	3,20	,867	,0621	7,18	1,56	529,8	1,04	34415	7,7	-16,5	42,2
140,0	28445,7	12044,2	2288,8	193,4	187,0	,294	3,12	,877	,0630	7,30	1,55	529,8	1,07	34361	7,9	-21,5	40,3
141,0	28700,3	12251,1	2297,6	195,2	188,7	,297	3,06	,884	,0635	7,39	1,52	525,5	1,10	34309	7,9	-26,5	37,8
142,0	28966,7	12447,6	2306,1	197,1	190,5	,300	3,12	,865	,0619	7,15	1,43	499,7	1,09	34256	7,6	-24,1	35,1
143,0	29244,4	12633,8	2314,4	198,9	192,2	,303	3,12	,852	,0609	6,98	1,42	499,8	1,10	34203	7,4	-24,4	32,6
144,0	29532,5	12809,1	2322,7	200,7	194,0	,306	3,12	,837	,0596	6,78	1,41	500,2	1,10	34150	7,2	-24,7	30,1

TAKEOFF CONTINUED

TIME (SEC)	X DIST (FEET)	Y DIST (FEET)	ALT. (FEET)	TAS (KTS)	EAS (KTS)	MACH NO.	ACCEL (FPS2)	CL	CD	ALPHA (DEG)	GAMMA (DEG)	R/C (FPM)	LOAD FACT	THRUST (LBS)	FUS. ANG.	ROLL ANGLE	HEADNG (DEG)
145.0	29830.8	12973.4	2331.1	202.6	195.7	.309	3.13	.822	.0585	6.60	1.39	499.6	1.10	34097	7.0	-24.3	27.6
146.0	30138.6	13126.1	2339.4	204.4	197.5	.311	3.14	.804	.0571	6.37	1.38	500.3	1.09	34044	6.8	-24.1	25.2
147.0	30455.5	13266.8	2347.7	206.3	199.3	.314	3.13	.795	.0564	6.25	1.37	500.3	1.10	33990	6.6	-24.7	22.7
FLAPS RETRACTED TO 2.0 DEG. IN 1.0 SEC.																	
148.0	30780.9	13395.2	2356.1	208.2	201.1	.317	3.21	.778	.0532	6.75	1.36	500.0	1.10	33937	7.1	-24.2	20.3
149.0	31114.5	13511.0	2364.4	210.1	202.9	.320	3.29	.764	.0503	7.28	1.35	500.3	1.10	33881	7.6	-24.7	18.0
150.0	31455.7	13613.8	2372.7	212.1	204.8	.323	3.30	.751	.0492	7.11	1.33	500.3	1.10	33825	7.4	-24.8	15.6
151.0	31804.1	13703.4	2381.1	214.0	206.6	.326	3.31	.735	.0480	6.91	1.32	500.4	1.09	33769	7.2	-25.0	13.3
152.0	32159.0	13779.5	2389.4	216.0	208.5	.329	3.31	.725	.0472	6.78	1.31	500.1	1.10	33712	7.1	-24.7	10.9
FLAPS RETRACTED TO 0.0 DEG. IN .7 SEC.																	
153.0	32519.9	13841.8	2397.8	217.9	210.4	.332	3.34	.709	.0457	6.72	1.30	499.3	1.09	33656	7.0	-23.9	8.6
154.0	32886.4	13890.2	2406.1	220.0	212.3	.335	3.44	.696	.0425	7.37	1.29	500.1	1.10	33598	7.7	-25.2	6.4
155.0	33258.0	13924.4	2414.4	222.0	214.2	.338	3.45	.685	.0416	7.22	1.27	500.3	1.10	33539	7.5	-24.6	4.1
156.0	33634.0	13944.3	2422.8	224.0	216.2	.341	3.46	.672	.0407	7.06	1.26	500.5	1.10	33480	7.3	-24.5	1.9
157.0	34014.0	13949.8	2431.1	226.1	218.1	.344	3.46	.660	.0398	6.90	1.25	499.9	1.09	33422	7.1	-24.0	-.3
158.0	34397.3	13940.7	2439.4	228.1	220.1	.348	3.46	.649	.0390	6.77	1.24	500.4	1.10	33363	7.0	-24.5	-2.4
159.0	34783.5	13916.8	2447.8	230.2	222.0	.351	3.46	.639	.0383	6.63	1.23	499.8	1.10	33304	6.9	-24.3	-4.6
160.0	35172.0	13878.1	2456.1	232.2	224.0	.354	3.46	.628	.0375	6.50	1.22	500.3	1.10	33245	6.7	-24.6	-6.8
161.0	35562.2	13824.5	2464.4	234.3	225.9	.357	3.48	.615	.0366	6.32	1.21	500.2	1.09	33185	6.5	-24.0	-8.9
162.0	35953.6	13756.1	2472.8	236.4	227.9	.360	3.52	.591	.0351	6.03	1.20	500.4	1.07	33126	6.2	-21.0	-10.9
163.0	36346.1	13674.8	2481.1	238.5	229.9	.363	3.58	.565	.0334	5.69	1.19	500.4	1.04	33066	5.9	-16.0	-12.4
164.0	36740.2	13583.7	2489.5	240.6	231.9	.367	3.62	.544	.0321	5.42	1.18	500.5	1.02	33004	5.6	-11.0	-13.5
165.0	37136.3	13485.6	2497.8	242.7	234.0	.370	3.64	.528	.0312	5.22	1.17	500.4	1.00	32942	5.4	-6.0	-14.2
166.0	37535.1	13383.4	2506.1	244.9	236.0	.373	3.65	.516	.0305	5.07	1.16	500.7	1.00	32880	5.2	-2.0	-14.5
167.0	37937.1	13278.9	2514.5	247.1	238.1	.376	3.64	.507	.0301	4.96	1.15	500.7	1.00	32818	5.1	-2.0	-14.6
168.0	38342.4	13172.4	2522.8	249.2	240.1	.380	3.63	.499	.0296	4.86	1.14	500.5	1.00	32756	5.0	-2.0	-14.8
EXECUTE PULLUP AT DADT = .13																	
169.0	38750.8	13063.9	2531.4	251.3	242.1	.383	3.51	.509	.0302	4.98	1.20	534.9	1.03	32695	5.2	-2.0	-15.0
170.0	39168.4	12953.6	2541.1	253.4	244.0	.386	3.31	.519	.0307	5.11	1.43	640.7	1.07	32636	5.5	0.0	-15.0
171.0	39577.1	12842.4	2553.1	255.2	245.8	.389	3.02	.529	.0313	5.23	1.81	818.0	1.11	32582	6.0	0.0	-15.0
172.0	39994.6	12730.4	2568.7	256.9	247.4	.392	2.64	.539	.0318	5.36	2.34	1064.8	1.14	32533	6.7	0.0	-15.0
173.0	40414.5	12617.8	2589.0	258.3	248.7	.394	2.19	.548	.0324	5.48	3.02	1378.5	1.17	32490	7.5	0.0	-15.0
174.0	40836.1	12504.8	2615.0	259.5	249.7	.396	1.69	.554	.0328	5.56	3.82	1752.6	1.20	32456	8.4	0.0	-15.0
175.0	41259.0	12391.4	2647.5	260.4	250.4	.397	1.21	.552	.0327	5.53	4.66	2143.4	1.20	32429	9.2	0.0	-15.0
176.0	41682.6	12277.8	2686.4	260.9	250.8	.398	.74	.550	.0325	5.51	5.50	2533.4	1.20	32411	10.0	0.0	-15.0
177.0	42106.3	12164.2	2731.9	261.2	250.9	.399	.28	.548	.0324	5.48	6.34	2923.5	1.20	32400	10.8	0.0	-15.0
178.0	42529.6	12050.7	2783.8	261.3	250.8	.399	.00	.511	.0303	5.01	7.11	3276.5	1.11	32397	11.1	0.0	-15.0
179.0	42952.4	11937.3	2839.7	261.3	250.6	.399	.01	.470	.0281	4.48	7.38	3403.1	1.02	32395	10.9	0.0	-15.0
180.0	43375.1	11824.0	2896.7	261.3	250.4	.399	.01	.460	.0276	4.36	7.45	3432.9	1.00	32394	10.8	0.0	-15.0
181.0	43797.7	11710.6	2954.0	261.3	250.2	.399	.01	.458	.0275	4.33	7.47	3442.1	.99	32392	10.8	0.0	-15.0
181.7	44093.6	11631.3	2994.2	261.3	250.0	.399	.01	.457	.0274	4.32	7.47	3443.8	.99	32391	10.8	0.0	-15.0

END OF TAKEOFF

APPENDIX C - PROGRAM LISTING

TAKOFF

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      SUBROUTINE TAKOFF(INPC,IDCN,WGROSS,SWING,XENG,VR,VEND)
C
C   SUBROUTINE TAKOFF COMPUTES THE TAKEOFF MANEUVER OF A GIVEN AIRCRAFT,
C   INCLUDING GROUND ROLL AND CLIMBOUT.
C
C   PROVISIONS ARE MADE FOR CHANGES IN FLAP,VECTORED THRUST ANGLE AND POWER
C   SETTINGS AS FUNCTIONS OF SPEED AND ALTITUDE.
C
C   HEADING ANGLES ARE DETERMINED BY ALTITUDE AND GROUND DISTANCES.
C
C   FOLLWING SOME COMMENT CARDS WILL BE TWO NUMBERS IN PARENTHESIS WHICH
C   WILL GIVE THE APPROXIMATE STATEMENT-NUMBER RANGE OF THE FUNCTION
C   DESCRIBED IN THAT COMMENT.
C
      EXTERNAL DERIV1
      EXTERNAL DERIV2
      REAL MU,METRIC
      COMMON /UNIV/ NPC    ,NSC    ,IDC    ,H      ,ST     ,R      ,W      ,
     1WF     ,EM     ,VMO    ,EMMO   ,ALPHLO,CLALPH,SW     ,AR     ,B      ,
     2EYEW   ,ENP    ,TA     ,WG     ,WGS    ,KWRITE,DLMC4
     3,KSIZE
      COMMON /AERO/ VEL,QS,HABS,THRUST,TVECT, ANGLE,DELFD,DELSPL,ALPHA,
     9CX,CY,CL,CD,RHO,GRCD,IFAST
      COMMON /ROLL/ PHI,ROCMIN
      COMMON /EXCHNG/ SROLL,S35,V35,T5J
      COMMON /XROLL/T(30),NEQ,MU,NREV
      COMMON /XFLATE/ S(/5),ROC,THEMAX,THETAF,XLF,XLFMAX,K
      COMMON /UNIT/IUNIT,G
      DIMENSION ANS(8)
      DIMENSION XDELFD(5),XHFLAP(5),XVFLAP(5)
      DIMENSION XHPWR(5),XVPWR(5),XPOWER(5)
      DIMENSION XNU(5),XHVECT(5),XVVECT(5)
      DIMENSION XRANGE(5),XHHEAD(5),XHEAD(5)
      YYY(XXX,Y1,Y2,X1,X2) = Y1 + (Y2-Y1)*(XXX-X1)/(X2-X1)
      DATA XDELFD/15.0,5.0,2.0,0.0,0.0/, XHFLAP/0.0,250.,0.0,0.0,0.0/,
     9XVFLAP/0.0,0.0,200.,210.,0.0/, XPOWER/1.0,1.0,1.0,1.0,1.0/, XHPWR/
     90.0,0.0,0.0,0.0,0.0/, XVPWR/0.0,999.,999.,999.,999./, XNU/0.0,0.0,
     90.0,0.0,0.0/, XHVECT/0.0,0.0,0.0,0.0,0.0/, XVVECT/0.0,999.,999.,
     9999.,999./
      DATA XRANGE/5* 100.00/, XHHEAD/5*99999./, XHEAD/5*0./
      DATA CDGEAR,DFLPDT,DTABS,DTGR,DTPDWN,DTPUP,DTVECT,EYEWNG,HAPT,
     9HGR,HMAN,IOUT,UM,PMARG,RTCL,THTFLY,THTSCP/0.0,3.0,0.0,5.0,5.0,6.0,
     910.,1.0,0.0,25.0,1000.,0,0.02,0.04,750.,15.,10.0/
      DATA ROLLMX,ROLRAT,ROCMIN,HDT/15.0,5.0,250.,35./
      DATA METRIC/1HM/
      NAMELIST/NAM1/CDGEAR,DADT,DFLPDT,DTABS,DTGR,DTPDWN,DTPUP,DTVECT,
     9EYEWNG,HAPT,HGR,HMAN,HMAX,IOUT,UM,NPAGE,PMARG,RTCL,THTFLY,
     9THTSCP,XLFMAX,ROLLMX,ROLRAT,ROCMIN,HDT
      NAMELIST/NAM2/XDELFD,XHFLAP,XVFLAP,XPOWER,XHPWR,XVPWR,XNU,XHVECT,
     9XVVECT
      NAMELIST/NAM3/XRANGE,XHHEAD,XHEAD
      GO TO(5,6,5),INPC
    5 NPAGE = 33
      DADT = 1.0
      HMAX = 5000.
      XLFMAX = 1.10
```

TAKOFF

```
C
C     SET UP FOR UNITS CONVERSION
C
        VELFTR = 0.592087
        RNGFTR = 6076.
        DSTOP = 60760.
          CDGFTR = 1.00
        G = 32.2
        IUNIT = 1
        READ(5,500)UNITS
  500   FORMAT(A1)
        IF(UNITS .NE. METRIC)GO TO 501
        VELFTR = 1.00
        RNGFTR = 1000.
        DSTOP = 18530.
        CDGFTR = 0.02798
        G = 9.8
        IUNIT = 2
  501   CONTINUE
C
C     CALL INPUT TO TAKOFF THRU NAMELIST /NAM1/, /NAM2/, AND /NAM3/
C
        READ(5,NAM1)
        READ(5,NAM2)
        READ(5,NAM3)
        IF(INPC .EQ. 1)RETURN
      6 ENP = XENG
        SW = SWING
        W = WGROSS
        EYEW = EYEANG
        MU = UM
        S(7) = HAPT
        DO 7 I = 2,4
        IF(XHPWR(I) .NE. 0.0)XVPWR(I) = 0.0
        IF(XHVECT(I) .NE. 0.0)XVVECT(I) = 0.0
      7 CONTINUE
C
C     SET UP LOGIC CONTROL VARIABLES
C
        NEQ = 2
        IPAGE = 0
        KENG = 0
        JJ1 = 1
        JJ2 = 1
        IUP = 1
        IDOWN = 1
        IFLY = 1
        IFLAP = 2
        MFLAP = 1
        JROUTE = 1
        IPOWER = 1
        MPOWER = 2
        MVECT = 1
        IVECT = 2
        I35 = 1
        IG = 0
```

TAKOFF

```
   166        IROLL = 1
   166        MROLL = 0
   167        IHEAD = 1
   170        PHIMAX = ROLLMX/57.3
   172        TINT = 10.0
        C
        C   FIND GEAR DRAG IF DEFAULT OF CDGEAR=0.0 USED
        C
   174        IF(CDGEAR .EQ. 0.0)CDGEAR = (0.0032/SW)****0.80
   204        CDGEAR = CDGFTR*CDGEAR
   206        GRCD = CDGEAR
   206        IF(IDCN .NE. 9)GO TO 299
   210        TEMP = 59.0 + DTABS
   212        WG = WGROSS
   213        WOS = W/SW
        C
        C   FIND STATIC THRUST/WEIGHT
        C
   215        CALL ENGINF(0.0,0.0,0.0,1.0,WF,KENG)
   221        TOW = ENP * THRUST / W
        C
        C   WRITE OUT PROGRAM INPUTS
        C
   224        WRITE(6,201)HAPT,TEMP
          201 FORMAT(//, 36H ** INPUTS TO TAKE OFF - ALTITUDE = ,F6.1,2X,14HTEMP
             9ERATURE = ,F5.1,7H DEG,  )
   243        WRITE(6,202)WG,SW,THRUST
          202 FORMAT(/,6X,19HA/C CHARACTERISTICS,/,9X,17HGROSS RAMP WT. = ,F8.0,
             93X,12HWING AREA = ,F6.0,3X,26HSTATIC SEA LEVEL THRUST = ,F6.0)
   260        WRITE(6,203)WOS,TOW
          203 FORMAT(9X,15HWING LOADING = ,F5.1,3X,16HTHRUST/WEIGHT = ,F4.3)
   273        WRITE(6,204)ENP,CDGEAR,EYEW,THTSCP
          204 FORMAT(/,6X, 15HA/C PARAMETERS,/,9X,14HNO. ENGINES = ,F3.1,3X, 9HC
             9DGEAR = ,F6.4,3X,9HEYEWNG = ,F4.1,3X,20HTAIL SCRAPE ANGLE = ,F4.1)
   312        WRITE(6,205)XLFMAX,HGR,THTFLY,HMAN,RTCL
          205 FORMAT(/,6X,30HFLIGHT PATH CONTROL PARAMETERS,/,9X,18HMAX LOAD FAC
             9TOR = ,F4.2,3X,23HGEAR RETRACTION ALT. = ,F5.1,3X,18HMAX FLOOR ANG
             9LE = ,F4.1,/,9X,16HMANEUVER ALT. = ,F5.0,5X,27HACCELERATE RATE OF
             9CLIMB = ,F5.0)
   333        WRITE(6,206)DADT,DFLPDT,DTGR,DTPDWN,DTPUP,DTVECT
          206 FORMAT(/,6X,25HPARAMETER VARIATION RATES,/,9X, 7HDADT = ,F4.1,3X
             9,9HDFLPDT = ,F4.1,3X,7HDTGR = ,F4.1,3X,9HDTPDWN = ,F4.1,/,9X,8HDTD
             9UP = ,F4.1,3X,9HDTVECT = ,F4.1)
   356        WRITE(6,207)
          207 FORMAT(//,6X,42HPOWER, VECTORED THRUST, AND FLAP SCHEDULES)
   365        WRITE(6,208)(XPOWER(I),I = 1,5)
          208 FORMAT(/,9X,22HTHROTTLE/POWER SETTING,/,12X,8HPWRSET  ,5F9.2)
   376        WRITE(6,209)(XVPWR(I),I= 1,5)
          209 FORMAT(12X,8HSPEED   ,5F9.1)
   407        WRITE(6,210)(XHPWR(I),I = 1,5)
          210 FORMAT(12X,8HALTITUDE,5F9.0)
   420        WRITE(6,211)(XNU(I),I = 1,5)
          211 FORMAT(/,9X,21HVECTORED THRUST ANGLE,/,12X,8HANGLE   ,5F9.1)
   431        WRITE(6,209)(XVVECT(I),I = 1,5)
   436        WRITE(6,210)(XHVECT(I),I = 1,5)
   447        WRITE(6,212)(XDELFD(I),I = 1,5)
```

```
        212 FORMAT(/,9X,21HFLAP DEFLECTION ANGLE,/,12X,8HDELFD    ,5F9.1)
 464        WRITE(6,209)(XVFLAP(I),I = 1,5)
 471        WRITE(6,210)(XHFLAP(I),I = 1,5)
 502        WRITE(6,213)
        213 FORMAT(/,9X,76HALL SPEEDS ARE INDICATED AIR SPEEDS AND ALL ALTITUD
           9ES ARE ABSOLUTE ALTITUDES)
 515        WRITE(6,214)
        214 FORMAT(//,6X,18HDEPARTURE HEADINGS,/)
 524        WRITE(6,215)(XRANGE(I),I=1,5)
        215 FORMAT(12X,8HRANGE    ,5F10.1)
 535        WRITE(6,216)(XHHEAD(I),I = 1,5)
        216 FORMAT(12X,8HALTITUDE ,5F10.1)
 546        WRITE(6,217)(XHEAD(I),I=1,5)
        217 FORMAT(12X,8HHEADING  ,5F10.1)
 557    299 CONTINUE
 557        IF(IDCN .EQ. 9)
           +WRITE(6,999)HAPT
        999 FORMAT(1H1,//21H TAKEOFF (ELEVATION =,F6.0,4H FT),//)
 572        IF(IDCN .EQ. 9 .AND. IUNIT .EQ. 1)WRITE(6,1000)
 610        IF(IDCN .EQ. 9 .AND. IUNIT .EQ. 2)WRITE(6,2000)
      C
      C   SET FLAPS, VECTORED THRUST ANGLE AND POWER SETTING FOR GROUND RUN
      C
 626        PWRSET = XPOWER(1)
 627        ANGLE = XMU(1)
 631        DELFD = XDELFD(1)
 632        THEMAX = THTSCP
 634        HABS = 0.0
 634        VFL = 0.
 635        ZERO = 0.
 636        Z = 0.0
 636        THETAF = 0.
 637        QS = 0.1
 640        S(7) = HAPT
 642        EM = 0.
      C   GROUND ROLL INTEGRATION VARIABLES
      C     T(1) = NUMBER OF EQUATIONS
      C     T(2) = TIME (SEC.)
      C     T(3) = TIME INTERVAL, STEP SIZE (SEC.)
      C     T(4) = VELOCITY (FT./SEC.) OR (M/SEC.)
      C     T(5) = DISTANCE (FT.) OR (M)
      C     T(6) = ACCELERATION (FT./SEC.**2) OR (M/SEC.**2)
      C
 642        T(1) = 2
 644        T(2) = 0.0
 645        T(3) = 0.1
 646        T(4) = 0.
 646        T(5) = 0.
      C
      C
      C   OBTAIN ATMOSPHERIC VARIABLES
      C
 650        CALL ATMOS(HAPT,DTABS,ANS)
 652        SA = ANS(4)
 653        RHO = ANS(3)
 655        NCOUNT = 0
```

```
TAKOFF
  655          ALPHA = EYEW
         C
         C    FIND INITIAL CONDITIONS OF THRUST AND FORCE COEFF. FOR GROUND ROLL
         C
  657          CALL ENGINE(S(7),DTABS,EM,PWRSET,WF,KENG)
  665          IFAST = 0
  666          CALL ARODYN
  667          CALL INTS(T,2,2,1.,1.,1.,1.,1.,1., DERIV1)
  701          TA = THRUST * ENP
  703          IF(IDCN .EQ. 9)
              +WRITE(6,1002)T(2),T(5),ZERO,ZERO,ZERO,ZERO,ZERO,T(6),CL,CD,ALPHA,
              9ZERO,ZERO,ZERO,TA,ZERO,ZERO,ZERO
         C
         C    MAIN GROUND ROLL INTEGRATION LOOP (1-120)
         C
  767        1 NCOUNT = NCOUNT + 1
  771          ALPHAJ = ALPHA
  772          THETAJ = THETAF
         C
         C    CHECK IF LIFT = WEIGHT - LIFTOFF
         C
  773          IF(QS*CY .GE. W)GO TO 120
         C
         C
         C    CHECK SPEED FOR VR
         C
  777      106 IF(T(4)* VELFTR*SQRT(ANS(7)) .GE. VR)GO TO 101
 1011          GO TO 110
         C
         C    BEGIN ROTATION
         C
 1012      101 IF(JJ2 .EQ. 2)GO TO 103
 1014          JJ2 = 2
 1015          VKTS = T(4) * VELFTR
 1017          EAS = VKTS*SQRT(ANS(7))
 1023          IF(IDCN .EQ. 9)WRITE(6,1009)T(2),VKTS,EAS
          1009 FORMAT(1X,18HROTATION  (TIME = ,F6.1,3X,10HAND TAS = ,F7.1,2X,
              96HEAS = ,F7.1,1H))
         C
         C    INCREASE ALPHA AT RATE DADT AND RESTRICT TO VALUE .LE. TAIL SCRAPE
         C    ANGLE (103-102)
         C
 1047      103 ALPHA = ALPHA + T(3)*DADT
 1052          IF((ALPHA - EYEW) .LE. THEMAX)GO TO 102
 1055          ALPHA = THEMAX + EYEW
 1056          GO TO 110
 1056      102 THETAF = ALPHA - EYEW
 1060      110 EM = T(4)/SA
 1062          QS = 0.5*RHO*SW*T(4)*T(4)
 1066          CALL ENGINE(S(7),DTABS,EM,PWRSET,WF,KENG)
 1073          IFAST = 0
 1074          VEL = T(4)
 1075          TA = ENP*THRUST
 1100          CALL INTM(T,2,2,1.,1.,1.,1.,1.,1., DERIV1)
         C
         C    MAKE INTEGRATION STEP
```

```
          C
1111           W = W - WF*ENP*T(3)/3600.
1115           IF(T(2) .LE. 90.)GO TO 113
1124           WRITE(6,1057)
          1057 FORMAT(/,35H TIME LIMIT FOR GROUND RUN EXCEEDED)
1133           RETURN
1133       113 CONTINUE
          C
          C   COMPUTE ALPHA DOT AND THETA DOT
          C
1133           XDADT = (ALPHA - ALPHAJ)/T(3)
1136           OTHTDT = (THETAF - THETAJ)/T(3)
1140           IF(NCOUNT .LT. 10)GO TO 1
1143           NCOUNT = 0
1143           VKTS = T(4) * VELFTR
1146           EAS = VKTS * SQRT(ANS(7))
1152           IF(IDCN .NE.9)GO TO 1
1160           IF(IDCN .EQ. 9)
              +WRITE(6,1002)T(2),T(5),Z,ZERO,VKTS,EAS,EM,T(6),CL,CD,ALPHA,ZERO,
              9ZERO,ZERO,TA,THETAF,ZERO,ZERO
1237           IPAGE = IPAGE +1
1241           IF(IPAGE .LT. NPAGE)GO TO 1
1243           IPAGE = 0
1243           IF(IDCN .EQ. 9)
              +WRITE(6,998)
           998 FORMAT(1H1,/,19H TAKEOFF CONTINUED ,/)
1254           IF(IDCN .EQ. 9 .AND. IUNIT .EQ. 1)WRITE(6,1000)
1272           IF(IDCN .EQ. 9 .AND. IUNIT .EQ. 2)WRITE(6,2000)
1310           GO TO 1
1311       120 VKTO = T(4) * VELFTR
1313           EASTO = VKTO * SQRT(ANS(7))
1317           SROLL = T(5)
1321           IF(IOUT .EQ. 1)ENP = ENPOUT
1330           IF(IDCN .EQ. 9)WRITE(6,1010)T(2),T(5),VKTO,EASTO
          1010 FORMAT(1X,17HLIFTOFF   (TIME = ,F6.1,2X,7HDIST = ,F8.1,2X
              9,6HTAS = ,F7.1,1X,6HEAS = ,F7.1,1H))
          1000 FORMAT(131H  TIME    X DIST    Y DIST     ALT.     TAS    EAS    MACH  A
              9CCEL      CL       CD     ALPHA  GAMMA     R/C   LOAD    THRUST  FUS.    RO
              9LL  HEADNG,/,131H (SEC)     (FEET)    (FEET)    (FEET)  (KTS) (KTS)
              9NO. (FPS2)                  (DEG)   (DEG)     (FPM)  FACT      (LBS)   ANG
              9.  ANGLE    (DEG),/)
          2000 FORMAT(131H  TIME    X DIST    Y DIST     ALT.     TAS    EAS    MACH  A
              9CCEL      CL       CD     ALPHA  GAMMA     R/C   LOAD    THRUST  FUS.    RO
              9LL  HEADNG,/,131H (SEC)     (MTRS)    (MTRS)    (MTRS)  (M/S) (M/S)
              9NO. (MPS2)                  (DEG)   (DEG)     (M/M)  FACT      (NTS)   ANG
              9.  ANGLE    (DEG),/)
          1002 FORMAT(1X,F5.1,F9.1,F9.1,F9.1,F7.1,F6.1,F6.3,F7.2,F7.3,F7.4,2F7.2,
              9F8.1,F6.2,F9.0,F6.1,F7.1,F8.1)
          C
          C END OF GROUND ROLL - BEGIN AIRBORNE PORTION OF TAKEOFF
          C
1353           VMARG = PMARG*VEND
1355           THEMAX = THTFLY
          C
          C   FLAP, ANGLE AND POWER SCHEDULES SET UP FOR AIRBORNE PORTION
          C
```

TAKOFF

```
      HFLAP = XHFLAP(2)
      VFLAP = XVFLAP(2)
      HPOWER = XHPWR(2)
      VPOWER = XVPWR(2)
      HVECT = XHVECT(2)
      VVECT = XVVECT(2)
      RANGE = XRANGE(1)*RNGFTR
      HHEAD = XHHEAD(1)
      PHI = 0.0
      XLF = 1.0
C
C    AIRBORNE INTERGRATION VARIABLES
C      S(1) = NUMBER OF EQUATIONS
C      S(2) = TIME (SEC.)
C      S(3) = TIME INTERVAL,STEP SIZE (SEC.)
C      S(4) = VELOCITY ALONG FLIGHT PATH (FT./SEC.) OR (M/SEC)
C      S(5) = FLIGHT PATH ANGLE (RAD.)
C      S(6) = HEADING ANGLE(RAD.)
C      S(7) = ALTITUDE (FT.) OR (M)
C      S(8) = X-DISTANCE (FT.)  OR (M)
C      S(9) = Y-DISTANCE (FT.) OR (M)
C      S(10)= ACCELERATION ALONG FLIGHT PATH (FT./SEC.**2) OR (M/SEC**2)
C      S(11)= TIME RATE OF CHANGE OF FLIGHT PATH ANGLE (RAD./SEC.)
C      S(12)= TIME RATE OF CHANGE OF HEADING ANGLE (RAD/SEC)
C      S(13)= RATE OF CLIMB (FT./SEC) OR (M/SEC)
C      S(14)= SPEED ALONG X-DIRECTION
C      S(15)= SPEED ALONG Y-DIRECTION
C
      S(1) = 6
      S(2) = T(2)
      S(3) = 0.1
      S(4) = T(4)
      S(5) = 0.
      S(6) = 0.0
      S(8) = T(5)
      S(9) = 0.0
      CALL INTS(S,6,2,1.,1.,1.,1.,1.,1., DERIV2)
      GO TO 300
C
C    MAIN AIRBORNE INTEGRATION LOOP (2-8)
C
    2 NCOUNT = NCOUNT + 1
      ALPHAJ = ALPHA
      THETAJ = THETAF
      IF((S(7) - HAPT) .GE. HMAX)RETURN
C
C    CHECK PROGRAM PROTECTION LIMITS
C
      IF(ABS(T(5)) .GT. DSTOP)GO TO 9
      IF(ABS(S(9)) .GT. DSTOP)GO TO 9
      IF(S(7) .LT. -0.1)GO TO 9
      IF(S(2) .GT. 300.)GO TO 9
C
C    OBTAIN ATMOSPHERIC VARIABLES
C
  300 CALL ATMOS(S(7),DTABS,ANS)
```

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TAKOFF
  1460        SA = ANS(4)
  1461        RHO = ANS(3)
  1463        EM = S(4)/SA
  1464        HABS = S(7) - HAPT
           C
           C   CALL ENGINE WITH PWRSET (KENG=0)
           C
  1467        CALL ENGINE(S(7),DTABS,EM,PWRSET,WF,KENG)
  1474        W = W - WF*ENP*S(3)/3600.
           C
           C   BEGIN AERODYNAMIC CONTROL
           C
  1500        K = 1
           C
           C   CHECK FOR START OF PULLUP MANEUVER
           C
  1501        IF ((VEND -S(4)*SQRT(ANS(7))* VELFTR).LT. VMARG)GO TO 27
  1521        IF((S(7) - HAPT) .LT. HMAN)GO TO 4
  1525        IF(IFLY .EQ. 2)GO TO 28
  1527        IFLY = 2
  1527        IF(RTCL .GT. ROC)GO TO 9
  1533        IF(IDCN .EQ. 9)
           C
           C   ACCELERATION TO VEND AT CONSTANT RATE OF CLIMB (28-27)
           C
             +WRITE(6,1040)VEND
         1040 FORMAT(1X,29HACCELERATE TO CLIMB SPEED OF ,F6.1)
  1546     28 IF(S(4)*SIN(S(5))*60.0 .LE. RTCL + 10.)GO TO 29
           C
           C   REDUCE ALPHA TO START ACCELERATION PHASE
           C
  1562        ALPHA = ALPHA - DADT*S(3)*0.5
  1565        IF(XLF .LT. 0.85)ALPHA = ALPHA + DADT*S(3)*0.25
  1573        GO TO 26
  1574     29 K = 9
  1575        ROC = RTCL
  1577        GO TO 26
  1577     27 IF(JROUTE .EQ. 2)GO TO 41
  1601        XLFMAX = 1.2
           C
           C   PULLUP MANEUVER - FIND REQUIRED DADT (27-44)
           C
  1603        CALL PULLUP(DADT,KODE,PWRSET,KENG,VEND,HAPT,DTABS)
  1612        IF(KODE .EQ. 9)GO TO 9
  1620        IF(IDCN .EQ. 9)WRITE(6,1056)DADT
         1056 FORMAT(26H EXECUTE PULLUP AT DADT = ,F4.2)
  1632        JROUTE = 2
  1633        GO TO 4
  1634     41 GO TO(42,43,44),KODE
  1643     42 IF(S(4)*SQRT(ANS(7))* VELFTR  .LT. VEND .AND. S(10).LT. .02)GO TO
             98
  1664        GO TO 4
  1664     43 IF(S(4)*SQRT(ANS(7))* VELFTR .GE. VEND )GO TO 8
  1677        GO TO 4
  1700     44 IF(S(10).LT. 0.02)GO TO 8
           C
```

TAKOFF

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        C   INCREASE ANGLE OF ATTACK EACH TIME BEFORE INTEGRATION STEP TAKEN
        C   (EXCEPT FOR CONSTANT RATE OF CLIMB PORTION).  FOR LOAD FACTOR
        C   .LT. 1.0 , ADDITIONAL INCREASE IN ALPHA.  IF THE INCREASE IN ALPHA
        C   RESULTS IN ANY VIOLATION OF FLIGHT PATH CONSTRAINTS(ACCEL.,XLF,THETAF),
        C   ALPHA WILL BE REDUCED ACCORDINGLY IN DERIV2.
        C
  1703        4 ALPHA = ALPHA + DADT*S(3)
  1706          IF(XLF  .LT. 0.9)ALPHA = ALPHA + DADT*S(3)
  1712          IF(XLF  .LT. 0.8)ALPHA = ALPHA + DADT*S(3)
  1717       26 CONTINUE
        C
        C   ROLL ANGLE CONTROL (26-49)
        C
  1717          IF(MROLL .EQ. 0)GO TO 49
  1720          HEAD = S(6)*57.3
  1722          IF(IROLL .GE. 2)GO TO 45
  1725          DELPSI = ABS(PHI*PHI*G*QS*CY/(2.*DPHIDT*W*S(4)*COS(S(5))))
  1740          IF(ABS(HEADF-HEAD) .LT. 57.3*DELPSI)GO TO 45
  1751          PHI = PHI +DPHIDT*S(3)
  1753          IF(ABS(PHI) .GT. PHIMAX .AND. PHI .GT. 0.0)PHI = PHIMAX
  1764          IF(ABS(PHI) .GT. PHIMAX .AND. PHI .LT. 0.0)PHI = -PHIMAX
  1774          GO TO 49
  1775       45 GO TO(46,47,49),IROLL
  2004       46 IROLL = 2
  2005       47 IF((ITURN .GT. 0 .AND. HEAD .GE. HEADF) .OR. (ITURN .LT. 0 .AND.
               9HEAD .LT. HEADF))GO TO 48
  2023          PHI = PHI - DPHIDT*S(3)
  2026          IF(ABS(PHI) .LE. 2./57.3)PHI = ((HEADF-HEAD)/ABS(HEADF-HEAD))
               9*2./57.3
  2036          GO TO 49
  2037       48 IROLL = 3
  2040          PHI = 0.0
  2041          S(6) = HEADF/57.3
  2043          MROLL = 0
  2044       49 CONTINUE
        C
        C   MAKE INTEGRATION STEP
        C
  2044        3 CALL INTM(S,6,2,1.,1.,1.,1.,1.,1., DERIV2)
  2056          IF(K .EQ. 99)GO TO 9
  2064          T(5) = S(8)
  2065          IF(I35 .EQ. 2)GO TO 22
        C
        C   SAVE VALUES FOR OBSTACLE HEIGHT INTERPOLATION
        C
  2067          IF((S(7) - HAPT) .GE. HDT)GO TO 21
  2073          VJ = S(4)
  2074          TJ5 = T(5)
  2075          HJ = S(7)
  2077          GO TO 22
        C
        C   FIND VALUES AT OBSTACLE HEIGHT (21-1015)
        C
  2100       21 I35 = 2
  2101          S35 = YYY(HDT,TJ5,T(5),HJ,S(7))
  2111          V35 = YYY(HDT,VJ,S(4),HJ,S(7))*SQRT(ANS(7))*0.592087
```

```
TAKOFF
   2130          IF(IDCN .EQ. 9)
                +WRITE(6,1015)S35,V35
           1015 FORMAT(30H DISTANCE TO OBSTACLE HEIGHT =,F7.1,20H SCREEN SPEED(EAS
                9) =,F6.1)
   2151        22 IF(IG .EQ. 2)GO TO 25
   2153           IF(IG .EQ. 1)GO TO 23
          C
          C    GEAR RETRACTION (22-23)
          C
   2155           IF((S(7) - HAPT) .LT. HGR)GO TO 25
   2160           TG = S(2)
   2161           TGU = S(2) + DTGR
   2163           IF(IDCN .EQ. 9)
                 +WRITE(6,1025)TG,TGU
           1025 FORMAT(1X,27HGEAR RETRACTION STARTED AT ,F6.1,17H SEC,COMPLETE AT
                 9,F6.1,4H SEC)
   2200           IG = 1
          C
          C    GEAR DRAG INCREMENT REDUCED LINEARLY WITH TIME IN DTGR SECONDS
          C
   2201        23 GRCD =CDGEAR*(1.0 - (S(2) - TG)/DTGR)
   2205           IF(GRCD .GE. 0.0)GO TO 25
   2207           GRCD = 0.0
   2210           IG = 2
   2211        25 CONTINUE
   2211           IF(JROUTE .EQ. 2)GO TO 39
          C
          C    FLAP RETRACTION (25-16)
          C
   2213           IF(DELFD .EQ. 0.0)GO TO 16
   2214           GO TO(10,15),MFLAP
   2222        10 IF((S(7)- HAPT) .LT. HFLAP .OR. S(4)*SQRT(ANS(7))*.592087 .LT.
                 9 VFLAP)GO TO 16
   2244           MFLAP = 2
   2244           TIME =(DELFD - XDELFD(IFLAP))/DFLPDT
   2250           IF(IDCN .EQ. 9)
                 +WRITE(6,1030)XDELFD(IFLAP),TIME
           1030 FORMAT(1X,19HFLAPS RETRACTED TO ,F4.1,9H DEG. IN ,F4.1,5H SEC.)
   2267        15 DELFD = DELFD - DFLPDT*S(3)
   2272           IF(DELFD .GT. XDELFD(IFLAP))GO TO 16
   2276           DELFD = XDELFD(IFLAP)
   2300           MFLAP = 1
   2300           IFLAP = IFLAP + 1
   2302           HFLAP = XHFLAP(IFLAP)
   2304           VFLAP = XVFLAP(IFLAP)
          C
          C    VECTORED THRUST ANGLE REDUCTION (16-56)
          C
   2307        16 CONTINUE
   2307           IF(ANGLE .EQ. 0.0)GO TO 56
   2310           GO TO(50,55),MVECT
   2316        50 IF((S(7)-HAPT) .LT. HVECT .OR. S(4)*SQRT(ANS(7))* VELFTR  .LT.
                 9 VVECT)GO TO 56
   2340           MVECT = 2
   2340           TIME = (ANGLE - XNU(IVECT))/DTVECT
   2344           IF(IDCN .EQ. 9)
```

```
             +WRITE(6,1055)XNU(IVECT),TIME
         1055 FORMAT(1X,33HVECTORED THRUST ANGLE REDUCED TO ,F4.1,9H DEG. IN ,
             9F4.1,5H SEC.)
2363       55 ANGLE = ANGLE - DTVECT*S(3)
2366          IF(ANGLE .GT. XNU(IVECT))GO TO 56
2372          ANGLE = XNU(IVECT)
2374          MVECT = 1
2374          IVECT = IVECT + 1
2376          HVECT = XHVECT(IVECT)
2400          VVECT = XVVECT(IVECT)
        C
        C      THROTTLE SETTING MANAGEMENT (56-39)
        C
2403       56 CONTINUE
2403          GO TO(31,32,33),IPOWER
2412       31 IF((S(7) - HAPT) .LT. HPOWER .OR. S(4)*SQRT(ANS(7))* VELFTR .LT.
             9 VPOWER)GO TO 39
        C
        C      DETERMINE POWER INCREASE OR DECREASE
        C
2434          IF(PWRSET - XPOWER(MPOWER))34,39,35
        C
        C      ADVANCE THROTTLE SETTING LOOP (34-35)
        C
2441       34 IPOWER = 2
2441          TIME = 100.*(XPOWER(MPOWER) - PWRSET)/DTPUP
2445          SET = XPOWER(MPOWER)*100.
2446          IF(IDCN .EQ. 9)
             +WRITE(6,1050)SET,TIME
         1050 FORMAT(1X,28HADVANCE THROTTLE SETTING TO ,F6.1,12H PERCENT IN ,
             9F4.1,5H SEC.)
2464       32 PWRSET = PWRSET + (DTPUP/100.)*S(3)
2470          IF(PWRSET .LT. XPOWER(MPOWER))GO TO 39
2473          PWRSET = XPOWER(MPOWER)
2475          MPOWER = MPOWER + 1
2477          HPOWER = XHPWR(MPOWER)
2501          VPOWER = XVPWR(MPOWER)
2503          IPOWER = 1
2504          GO TO 39
        C
        C      RETARD THROTTLE SETTING LOOP (35-39)
        C
2507       35 IPOWER = 3
2507          TIME = 100.*(PWRSET - XPOWER(MPOWER))/DTPDWN
2513          SET = XPOWER(MPOWER)*100.
2514          IF(IDCN .EQ. 9)
             +WRITE(6,1051)SET,TIME
         1051 FORMAT(1X,27HRETARD THROTTLE SETTING TO ,F5.1,12H PERCENT IN ,F4.1
             9,5H SEC.)
2532       33 PWRSET = PWRSET - (DTPDWN/100.)*S(3)
2536          IF(PWRSET .GT. XPOWER(MPOWER))GO TO 39
2542          PWRSET = XPOWER(MPOWER)
2544          MPOWER = MPOWER + 1
2545          HPOWER = XHPWR(MPOWER)
2547          VPOWER = XVPWR(MPOWER)
2552          IPOWER = 1
```

```
TAKOFF
  2553      39 CONTINUE
        C
        C    HEADING CONTROL (39-69)
        C
  2553         TRACK = SQRT(S(8)*S(8) + S(9)*S(9))
  2557         IF((S(7)- HAPT) .GE. HHEAD .OR. TRACK .GE. RANGE)GO TO 61
  2576         GO TO 69
  2576      61 MROLL = 1
  2577         IROLL = 1
  2600         HEADF = XHEAD(IHEAD)
  2602         IF(IDCN .EQ. 9)WRITE(6,66)HEADF
            66 FORMAT(1X,22HBEGIN TURN TO HEADING ,F5.1,5H DEG.)
  2616         IHEAD = IHEAD + 1
  2620         RANGE = XRANGE(IHEAD)*RNGFTR
  2622         HHEAD = XHHEAD(IHEAD)
  2625         HEAD = S(6)*57.3
  2627         ITURN = 1
  2630         IF(HEADF .LT. HEAD)ITURN = -1
  2634         DPHIDT = FLOAT(ITURN)*ROLRAT/57.3
  2637      69 CONTINUE
  2637         IF(NCOUNT .LT.10)GO TO 2
  2642         NCOUNT = 0
  2642         XDADT = (ALPHA - ALPHAJ)/S(3)
  2645         DTHTDT = (THETAF - THETAJ)/S(3)
  2647         TA = ENP * THRUST
  2651         VKTS = S(4)*VELFTR
  2654         EAS = VKTS*SQRT(ANS(7))
  2660         GAMMA = S(5)*57.295
  2662         ROC = S(4)*SIN(S(5))*60.
  2671         ROLL = PHI*57.3
  2672         HEAD = S(6)*57.3
  2674         IF(IDCN .EQ. 9)
              +WRITE(6,1002)S(2),S(8),S(9),S(7),VKTS,EAS,EM,S(10),CL,CD,ALPHA,
              9GAMMA,ROC,XLF,TA,THETAF,ROLL,HEAD
  2762         IPAGE = IPAGE +1
  2764         IF(IPAGE .LT. NPAGE)GO TO 2
  2766         IPAGE = 0
  2766         IF(IDCN .EQ. 9)
              +WRITE(6,998)
  2777         IF(IDCN .EQ. 9 .AND. IUNIT .EQ. 1)WRITE(6,1000)
  3015         IF(IDCN .EQ. 9 .AND. IUNIT .EQ. 2)WRITE(6,2000)
        C
        C     END OF MAIN AIRBORNE INTEGRATION LOOP.
        C
  3033         GO TO 2
        C
        C     CONVERSIONS AND PRINT OUT.
        C
  3034       8 TA = ENP * THRUST
  3036         VKTS = S(4)*VELFTR
  3040         EAS = VKTS*SQRT(ANS(7))
  3044         IF(KODE .NE. 3)EAS = VEND
  3054         GAMMA = S(5)*57.295
  3056         ROC = S(4)*SIN(S(5))*60.
  3064         ROLL = PHI*57.3
  3065         HEAD = S(6)*57.3
```

```
TAKOFF
   3067          IF(IDCN .EQ. 9)
                +WRITE(6,1002)S(2),S(8),S(9),S(7),VKTS,EAS,EM,S(10),CL,CD,ALPHA,
                9GAMMA,ROC,XLF,TA,THETAF,ROLL,HEAD
   3155          WRITE(6,1052)
   3161          IF(KODE .EQ. 2)WRITE(6,1053)
   3176          IF(KODE .EQ. 3)WRITE(6,1054)
            1052 FORMAT(/,1X,14HEND OF TAKEOFF)
            1053 FORMAT(1X,46HTHROTTLING REQUIRED TO MAINTIAN CONSTANT SPEED)
            1054 FORMAT(1X,59HDESIRED END SPEED NOT ATTAINABLE AT SPECIFIED POWER S
                9ETTING)
   3210          RETURN
   3211        9 CONTINUE
   3211          IF(RTCL .GT. ROC)WRITE(6,996)
             996 FORMAT(/,2X,66HCANNOT ACCEL. AT INPUT R/C (RTCL), TRY VALUE .LT. L
                9AST R/C PRINTED)
   3225          WRITE(6,997)
             997 FORMAT(/,1X,38H*** ABNORMAL TERMINATION OF TAKOFF ***)
   3233          RETURN
   3233          END


SUBPROGRAM LENGTH

04564

FUNCTION ASSIGNMENTS
YYY     - 000020

STATEMENT ASSIGNMENTS
1       - 000770   2       - 001425   3       - 002045   4       - 001704   5       - 000037   6       - 000127
7       - 000150   8       - 003035   9       - 003212   10      - 002223   15      - 002270   16      - 002310
21      - 002101   22      - 002152   23      - 002202   25      - 002212   26      - 001720   27      - 001600
28      - 001547   29      - 001575   31      - 002413   32      - 002465   33      - 002533   34      - 002440
35      - 002506   39      - 002554   41      - 001635   42      - 001644   43      - 001665   44      - 001701
45      - 001776   46      - 002005   47      - 002006   48      - 002040   49      - 002045   50      - 002317
55      - 002364   56      - 002404   61      - 002577   66      - 004210   69      - 002640   101     - 001013
102     - 001057   103     - 001050   106     - 001000   110     - 001061   113     - 001134   120     - 001312
201     - 003454   202     - 003466   203     - 003504   204     - 003513   205     - 003531   206     - 003557
207     - 003600   208     - 003607   209     - 003616   210     - 003622   211     - 003626   212     - 003635
213     - 003644   214     - 003656   215     - 003663   216     - 003667   217     - 003673   299     - 000560
300     - 001455   500     - 003434   501     - 000102   996     - 004244   997     - 004255   998     - 003733
999     - 003677   1000    - 003753   1002    - 004045   1009    - 003710   1010    - 003740   1015    - 004117
1025    - 004130   1030    - 004143   1040    - 004066   1050    - 004164   1051    - 004176   1052    - 004221
1053    - 004225   1054    - 004234   1055    - 004152   1056    - 004102   1057    - 003725   2000    - 004010

BLOCK NAMES AND LENGTHS
UNIV    - 000030/01  AERO    - 000020/02  ROLL    - 000002/03  FXCHNG - 000004/04  XROLL   - 000041/05  XFLATE - 000121/06
UNIT    - 000002/07

VARIABLE ASSIGNMENTS
ALPHA  - 000010/02  ALPHAJ - 004522     ANGLE  - 000005/02  ANS    - 004323     CD     - 000014/02  CDGEAR - 004427
CDGFTR - 004462     CL     - 000013/02  CY     - 000012/02  DADT   - 004454     DELFD  - 000006/02  DELPSI - 004546
DFLPOT - 004430     DPHIDT - 004547     DSTOP  - 004461     DTABS  - 004431     DTGR   - 004432     DTHTDT - 004527
DTPDWN - 004433     DTPUP  - 004434     DTVECT - 004435     EAS    - 004525     EASTO  - 004531     EM     - 000010/01
ENP    - 000021/01  ENPOUT - 004532     EYEW   - 000020/01  EYEWNG - 004436     G      - 000001/07  GAMMA  - 004562
```

```
TAKOFF
GRCD   - 000016/02 HABS   - 000002/02 HAPT   - 004437    HOT    - 004452    HEAD   - 004545    HEADF  - 004550
HFLAP  - 004534    HGR    - 004440    HHEAD  - 004543    HJ     - 004554    HMAN   - 004441    HMAX   - 004455
HPOWER - 004536    HVECT  - 004540    I      - 004464    IDOWN  - 004472    IFAST  - 000017/02 IFLAP  - 004474
IFLY   - 004473    IG     - 004504    IHEAD  - 004507    IOUT   - 004442    IPAGE  - 004465    IPOWER - 004477
IROLI  - 004505    ITURN  - 004551    IUNIT  - 000000/07 IUP    - 004471    IVECT  - 004502    I35    - 004503
JJ1    - 004467    JJ2    - 004470    JROUTE - 004476    K      - 000120/06 KENG   - 004466    KODE   - 004544
METRIC - 004453    MFLAP  - 004475    MPOWER - 004500    MROLL  - 004506    MU     - 000037/05 MVECT  - 004501
NCOUNT - 004521    NEQ    - 000036/05 NPAGE  - 004456    PHI    - 000000/03 PHIMAX - 004510    PMARG  - 004444
PWRSET - 004515    QS     - 000001/02 RANGE  - 004542    RHO    - 000015/02 RNGFTR - 004460    ROC    - 000113/06
ROCMIN - 000001/03 ROLL   - 004563    ROLLMX - 004450    ROLRAT - 004451    RTCL   - 004445    S      - 000000/06
SA     - 004520    SET    - 004560    SROLL  - 000000/04 SH     - 000015/01 S35    - 000001/04 T      - 000000/05
TA     - 000022/01 TEMP   - 004512    TG     - 004555    TGU    - 004556    THEMAX - 000114/06 THETAF - 000115/06
THETAJ - 004523    THRUST - 000003/02 THTFLY - 004446    THTSCP - 004447    TIME   - 004557    TINT   - 004511
TJ5    - 004553    TOW    - 004514    TRACK  - 004561    UM     - 004443    UNITS  - 004463    VEL    - 000000/02
VELFTR - 004457    VEND   - 000060    VFLAP  - 004535    VJ     - 004552    VKTO   - 004530    VKTS   - 004524
VMARG  - 004533    VPOWER - 004537    VVECT  - 004541    V35    - 000002/04 W      - 000006/01 WF     - 000007/01
WG     - 000023/01 WOS    - 004513    XDAOT  - 004526    XDELFD - 004333    XHEAD  - 004422    XHFLAP - 004340
XHHEAD - 004415    XHPWR  - 004352    XHVECT - 004376    XLF    - 000116/06 XLFMAX - 000117/06 XNU    - 004371
XPOWER - 004364    XRANGE - 004410    XVFLAP - 004345    XVPWR  - 004357    XVVECT - 004403    Z      - 004517
ZERO   - 004516

START OF CONSTANTS-003423      TEMPS--004263    INDIRECTS-004321

7600 COMPILATION -- RUN76 LEVEL 9H      74/07/15.

ROUTINE COMPILES IN 060200
```

DERIV1

```
      SUBROUTINE DERIV1
C
C     SUBROUTINE DERIV1 COMPUTES THE ACCELERATION T(6) FOR THE GROUND ROLL
C
      REAL MU
      COMMON /UNIV/ NPC    ,NSC    ,IDC    ,H      ,ST     ,R      ,W      ,
     1WF     ,EM     ,VMO    ,EMMO   ,ALPHLO,CLALPH,SW     ,AR     ,B      ,
     2EYEW   ,ENP    ,TA     ,WG     ,WGS    ,KWRITE,DLMC4
     3,KSIZE
      COMMON /AERO/ VEL,QS,HABS,THRUST,TVECT, ANGLE,DELFD,DELSPL,ALPHA,
     9CX,CY,CL,CD,RHO,GRCD,IFAST
      COMMON /XROLL/T(30),NEQ,MU,NREV
      COMMON /UNIT/IUNIT,G
      QS = 0.5*RHO*SW*T(4)*T(4)
      IF(QS .EQ. 0.)QS = 0.1
      IFAST = 1
      CALL ARODYN
      T(6) = (G/W)*(-W*MU + QS*(CY*MU - CX))
      T(7) = T(4)
      RETURN
      END
```

SUBPROGRAM LENGTH

00040

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

BLOCK NAMES AND LENGTHS
UNIV - 000030/01 AERO - 000020/02 XROLL - 000041/03 UNIT - 000002/04

VARIABLE ASSIGNMENTS
CX - 000011/02 CY - 000012/02 G - 000001/04 IFAST - 000017/02 MU - 000037/03 QS - 000001/02
RHO - 000015/02 SW - 000015/01 T - 000000/03 W - 000006/01

START OF CONSTANTS-000025 TEMPS--000030 INDIRECTS-000040

7600 COMPILATION -- RUN76 LEVEL 9B 74/07/15.

ROUTINE COMPILES IN 044000

DERIV2

```
             SUBROUTINE DERIV2
       C   SUBROUTINE DERIV2 COMPUTES THE TIME DERIVATIVES FOR THE AIRBORNE
       C   PORTION OF THE TAKEOFF AND MANAGES THE FLIGHT PATH CONTROL,
       C
             COMMON /UNIV/ NPC    ,NSC    ,IDC    ,H      ,ST     ,R      ,W      ,
            1WF     ,EM     ,VMO    ,EMMO   ,ALPHLO,CLALPH,SW     ,AR     ,B      ,
            2EYEW   ,ENP    ,TA     ,WG     ,WGS    ,KWRITE,DLMC4
            3,KSIZE
             COMMON /AERO/ VEL,QS,HABS,THRUST,TVECT, ANGLE,DELFD,DELSPL,ALPHA,
            9CX,CY,CL,CD,RHO,GRCD,IFAST
             COMMON /XFLATE/ S(75),ROC,THEMAX,THETAF,XLF,XLFMAX,K
             COMMON /ROLL/ PHI,ROCMIN
             COMMON /UNIT/IUNIT,G
             NER = 1
   2         QS = 0.5*RHO*SW*S(4)*S(4)
   5         VKTS = S(4)*0.592087
   7         IF(IUNIT .EQ. 2)VKTS = S(4)
       C
       C    CONSTANT RATE OF CLIMB PORTION
       C
  13        1 IF(K .EQ. 9)CALL CLIMB(ROC,S(5),VKTS,NER)
  20          IF(NER .NE. 1)WRITE(6,666)ALPHA,ROC
          666 FORMAT(1X,30H**ERROR IN CLIMB - ALPHA,ROC =,2F10.2)
  32       26 IFAST = 0
  33          CALL ARODYN
       C
       C    CHECK FUSELAGE ANGLE, IF THETAF .GT. THEMAX, REDUCE ALPHA (261-262)
       C
  34      261 THETAF = S(5)*57.295 + ALPHA - EYEW
  40          IF(THETAF .LE. THEMAX)GO TO 262
  42          ALPHA = THEMAX + EYEW - S(5)*57.295
  45          GO TO 26
       C
       C    CHECK LOAD FACTOR, IF XLF .GT. XLFMAX, REDUCE ALPHA (262-263)
       C
  45      262 XLF = (QS*CY)/W
  47          IF(XLF .LE. XLFMAX)GO TO 263
  52          ALPHA = ALPHA - 0.05
  54          GO TO 26
       C
       C    CHECK ACCELERATION, IF S(10).LT. 0.0, REDUCE ALPHA (263-30)
       C    IF IN CONSTANT RATE OF CLIMB, REDUCE ROLL ANGLE (MIN OF 5.0)
       C
  55      263 S(10) = (G/W)*(-CX*QS - W*SIN(S(5)))
  64          IF(S(10).GE. 0.0)GO TO 30
  66          IF(K .EQ. 9)GO TO 264
  70      265 ALPHA = ALPHA - 0.05
  72          IF(ALPHA .LT. -15.)GO TO 99
  74          GO TO 26
  75      264 IF(ABS(PHI) .LT.5.0/57.3)GO TO 265
 101          IF(PHI .GT. 0.)PHI = PHI - 0.1/57.3
 103          IF(PHI .LT. 0.)PHI = PHI + 0.1/57.3
 106          GO TO 1
 107       30 CONTINUE
 107          ARG = W*COS(S(5))/(CY*QS)
 115          IF(ARG .GT. 1.00)ARG = 1.00
```

```
DERIV2
    121         IF(ABS(PHI) .GT. 0. .AND. S(4)*SIN(S(5))*60. .LT. ROCMIN)PHI =
               +(PHI/ABS(PHI))*ACOS(ARG)
    142         S(11) = (G/(W*S(4)))*(CY*QS*COS(PHI) - W*COS(S(5)))
    154         IF(S(11)*57.3 .GE. -1.0)GO TO 40
    160         IF(PHI .EQ. 0.)GO TO 40
    161         IF(PHI .LT. 0.)PHI = PHI + 0.1/57.3
    164         IF(PHI .GT. 0.)PHI = PHI - 0.1/57.3
    167         IF(ABS(PHI).LT. 0.15/57.3)PHI = 0.
    173         GO TO 30
    174      40 S(12) = (G/(W*S(4)*COS(S(5))))*(CY*QS*SIN(PHI))
    206         S(13) = S(4)*SIN(S(5))
    211         S(14) = S(4)*COS(S(5))*COS(S(6))
    217         S(15) = S(4)*COS(S(5))*SIN(S(6))
    226         RETURN
    226      99 WRITE(6,66)S(8)
             66 FORMAT(1X,46H*** UNABLE TO MAINTAIN ACCEL. .GE. 0.0. DV/DT=,F9.5)
    235         K = 99
    236         END


SUBPROGRAM LENGTH

00347

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS
1      - 000014     26     - 000033     30     - 000110     40     - 000175     66     - 000270     99     - 000227
261    - 000035     262    - 000046     263    - 000056     264    - 000076     265    - 000071     666    - 000245

BLOCK NAMES AND LENGTHS
UNIV   - 000030/01  AERO   - 000020/02  XFLATE - 000121/03  ROLL   - 000002/04  UNIT   - 000002/05

VARIABLE ASSIGNMENTS
ALPHA  - 000010/02  ARG    - 000346     CX     - 000011/02  CY     - 000012/02  EYEW   - 000020/01  G      - 000001/05
IFAST  - 000017/02  IUNIT  - 000000/05  K      - 000120/03  NER    - 000344     PHI    - 000000/04  QS     - 000001/02
RHO    - 000015/02  ROC    - 000113/03  ROCMIN - 000001/04  S      - 000000/03  SW     - 000015/01  THEMAX - 000114/03
THETAF - 000115/03  VKTS   - 000345     W      - 000006/01  XLF    - 000116/03  XLFMAX - 000117/03

START OF CONSTANTS=000241       TEMPS--000300     INDIRECTS=000336

7600 COMPILATION -- RUN76 LEVEL 98       74/07/15.

ROUTINE COMPILES IN 044300
```

CLIMB

```
               SUBROUTINE CLIMB(ROC,GAMMA,VKTS,NER)
         C
         C     SUBROUTINE CLIMB FINDS THE REQUIRED ALPHA TO FLY AT THE CONSTANT
         C     RATE OF CLIMB RTCL, GIVEN THE THRUST AND VELOCITY.  CHANGES IN FLIGHT
         C     PATH ANGLE ARE FAIRLY INSENSITIVE TO VARIATIONS IN ANGLE OF ATTACK,
         C     AS A RESULT, THE COMPUTED RATE OF CLIMB WILL DIFFER SOME (USUALLY LOWER)
         C     THAN THE DESIRED VALUE RTCL.
         C     SUBROUTINE ZERJVB IS A ZERO-FINDER.
         C
               REAL NU
               COMMON /UNIV/ NPC    ,NSC    ,IDC    ,H      ,ST     ,R      ,W      ,
              1WF    ,EM     ,VMO    ,EMMO   ,ALPHLO,CLALPH,SW     ,AR     ,B      ,
              2EYEW  ,ENP    ,TA     ,WG     ,WGS    ,KWRITE,DLMC4
              3,KSIZE
               COMMON /AERO/ VEL,QS,HABS,THRUST,TVECT, ANGLE,DELFD,DELSPL,ALPHA,
              9CX,CY,CL,CD,RHO,GRCD,IFAST
               COMMON /ROLL/ PHI,ROCHIN
               COMMON /UNIT/IUNIT,G
               NER = 1
      6        TOL = 0.01
      7        STEP = 1.0
     11        JX = 0
     11        JC = 0
     12        FACTOR = 2.8561
     14        IF(IUNIT .EQ. 2)FACTOR = 1.00
     17        QS = 0.5*RHO*VKTS*VKTS*SW*FACTOR
     23        ERROR = 999.
     25     40 IF(JX .EQ. 0)ERRM1 = ERROR
     30        IFAST = 0
     31        CALL ARODYN
     32        ALPHX = ALPHA*.017453
     34        ERROR = QS*(CY*COS(GAMMA)*COS(PHI) - CX*SIN(GAMMA)) - W
     60        IF(ABS(ERROR) .LT. 0.0025)GO TO 60
     66        IF(JX .EQ. 2)GO TO 60
     70        CALL ZERJVB(ERROR,ERRM1,ALPHA,STEP,TOL,JC,JX)
     76        IF(JC .GT. 25)GO TO 65
    104        GO TO 40
    104     60 RETURN
    105     65 NER = 9
    106        RETURN
    107        END
```

SUBPROGRAM LENGTH

00147

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

```
40     - 000026     60     - 000105     65     - 000106
```

BLOCK NAMES AND LENGTHS

```
UNIV   - 000030/01  AERO   - 000020/02  ROLL   - 000002/03  UNIT   - 000002/04
```

```
CLIMB

VARIABLE ASSIGNMENTS
ALPHA  = 000010/02  ALPHX  = 000146     CX     = 000011/02  CY     = 000012/02  ERRM1  = 000145     ERROR  = 000144
FACTOR = 000143     IFAST  = 000017/02  TUNIT  = 000000/04  JC     = 000142     JX     = 000141     NU     = 000136
PHI    = 000000/03  QS     = 000001/02  RHO    = 000015/02  STEP   = 000140     SW     = 000015/01  TOL    = 000137
W      = 000006/01

START OF CONSTANTS=000112       TEMPS==000122    INDIRECTS=000136

7600 COMPILATION -- RUN76 LEVEL 9B       74/07/15.

ROUTINE COMPILES IN 044000
```

PULLUP

```
          SUBROUTINE PULLUP(DADT,KODE,PWRSET,KENG,VEND,HAPT,DTABS)
      C
      C   SUBROUTINE PULLUP DTERMINES THE TIME RATE OF CHANGE OF THE ANGLE OF
      C   ATTACK DADT REQUIRED TO BRING THE AIRCRAFT FROM THE CONSTANT RATE OF
      C   CLIMB TO THE FINAL CLIMB SPEED(I,E, REDUCE ACCELERATION ALONG FLIGHT
      C   PATH TO ZERO AND THUS INCREASING FLIGHT PATH ANGLE),  THE PULLUP
      C   MANEUVER STARTS AT SPEED OF VEND - PHARG*VEND(E,G, VEND=250., PHARG=0.04,
      C   = START OF PULLUP AT 240. KNOTS).  THE SUBROUTINE DOES THE VERY SAME
      C   INTEGRATION LOOP AS TAKOFF, WITHOUT ANY PRINT OUT, AND VARIES THE
      C   VALUE OF DADT UNTIL PROPER VALUE FOUND.  THE SEARCH FOR THE REQUIRED
      C   DADT IS FOUND BY A BISECTION TECHNIQUE.
      C
      C   IF PULLUP FAILS WITH DADT=4.0 (MAX. VALUE ALLOWED), USER SHOULD INPUT
      C   LARGER VALUE FOR PHARG.  THE PROGRAM WILL GENERALLY OVER-SHOOT THE
      C   END SPEED BY A KNOT OR SO.
      C
          EXTERNAL DERIV2
          COMMON /UNIV/ NPC    ,NSC    ,IDC    ,H      ,ST     ,R      ,W      ,
         1WF    ,EM     ,VMO    ,EMMO   ,ALPHLO,CLALPH,SW     ,AR     ,B      ,
         2EYEW  ,ENP    ,TA     ,WG     ,WGS    ,KWRITE,DLMC4
         3,KSIZE
          COMMON /AERO/ VEL,QS,HABS,THRUST,TVECT, ANGLE,DELFD,DELSPL,ALPHA,
         9CX,CY,CL,CD,RHO,GRCD,IFAST
          COMMON /XFLATE/ S(75),ROC,THEMAX,THETAF,XLF,XLFMAX,K
          COMMON /UNIT/IUNIT,G
          DIMENSION ANS(8)
          VELFTR = 0.592087
12        IF(IUNIT .EQ. 2)VELFTR = 1.00
16        S2J = S(2)
17        S4J = S(4)
21        S5J = S(5)
22        S6J = S(6)
24        S7J = S(7)
25        S8J = S(8)
27        S9J = S(9)
30        WJ = W
32        ALPHAJ = ALPHA
33        KODE = 1
34        ILOOP = 0
35        DADT = 4.0
36        DADTLO = 0.0
37        ITIME = 1
40     50 ILOOP = ILOOP + 1
42        IF(ILOOP .GT. 15) GO TO 95
45        ISTART = 1
46     51 S(2) = S2J
47        S(4) = S4J
51        S(5) = S5J
52        S(6) = S6J
54        S(7) = S7J
55        S(8) = S8J
57        S(9) = S9J
60        W = WJ
62        ALPHA = ALPHAJ
64    300 CALL ATMOS(S(7),DTABS,ANS)
75        SA = ANS(4)
```

PULLUP

```
      RHO = ANS(3)
      EM = S(4)/SA
      HABS = S(7) - HAPT
      CALL ENGINE(S(7),DTABS,EM,PWRSET,WF,KENG)
      IF(ISTART .NE. 2)
     9CALL INTS(S,6,2,1.,1.,1.,1.,1.,1., DERIV2)
      IF(ISTART .EQ. 3)RETURN
      ISTART = 2
      W = W - WF*ENP*S(3)/3600.
      K = 1
      ALPHA = ALPHA + DADT*S(3)
      IF(XLF .LT. 0.9)ALPHA = ALPHA + DADT*S(3)
      IF(XLF .LT. 0.8)ALPHA = ALPHA + DADT*S(3)
      CALL INTM(S,6,2,1.,1.,1.,1.,1.,1., DERIV2)
      EAS = S(4)*SQRT(ANS(7))*VELFTR
C
C    TEST FOR VARIOUS END CONDITIONS ( -110)
C
      IF(S(10).LT. 0.02 )GO TO 100
      IF(EAS .GE. VEND + 0.5 .AND. ITIME .EQ. 1)GO TO 100
      GO TO 300
  100 IF(ITIME .EQ. 2)GO TO 101
      IF(S(10).GT. 0.02 .AND.EAS .GE. VEND + 0.5)GO TO 150
      ITIME = 2
  101 IF(DADT .LT. 0.03)GO TO 160
      IF(EAS .GT. VEND .AND. EAS .LT. VEND + 1.0)GO TO 200
      IF(EAS .LT. VEND)GO TO 110
      IF(DADT .EQ. 4.0)GO TO 99
      DADTLO = DADT
      GO TO 115
  110 DADTUP = DADT
  115 DADT = 0.5*(DADTUP + DADTLO)
      GO TO 50
C
C    KODE = 2 END SPEED REACHED, BUT TOO MUCH THRUST AVAILABLE - THROTTLING
C    WILL BE REQUIRED.
C    KODE = 3 - CANNOT REACH DESIRED END SPEED AT SPECIFIED POWER SETTING -
C    PULLUP DONE TO ZERO ACCELERATION
C    KODE = 9 - PROGRAM FAILS
C
  150 KODE = 2
      GO TO 200
  160 KODE = 3
  200 ISTART = 3
      GO TO 51
   99 WRITE(6,98)
   98 FORMAT(1X,44H*** FAILED IN PULLUP - TRY INPUT PHARG = 0.1)
      KODE = 9
      RETURN
   95 WRITE(6,96)
   96 FORMAT(1X,29H*** EXCESSIVE LOOPS IN PULLUP)
      KODE = 9
      RETURN
      END
```

```
PULLUP

SUBPROGRAM LENGTH

00406

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS
50      = 000041   51      = 000047     95      = 000301     96      = 000340     98      = 000331     99      = 000270
100     = 000221   101     = 000237     110     = 000257     115     = 000260     150     = 000263     160     = 000265
200     = 000266   300     = 000065

BLOCK NAMES AND LENGTHS
UNIV    = 000030/01  AERO    = 000020/02  XFLATE = 000121/03  UNIT    = 000002/04

VARIABLE ASSIGNMENTS
ALPHA   = 000010/02  ALPHAJ = 000376     ANS     = 000354     DADTLO = 000400     DADTUP = 000405     DTABS   = 000000
EAS     = 000404     EM     = 000010/01  ENP     = 000021/01  FACTOR = 000365     HABS   = 000002/02  ILOOP   = 000377
ISTART  = 000402     ITIME  = 000401     IUNIT   = 000000/04  K      = 000120/03  RHO    = 000015/02  S       = 000000/03
SA      = 000403     S2J    = 000366     S4J     = 000367     S5J    = 000370     S6J    = 000371     S7J     = 000372
S8J     = 000373     S9J    = 000374     VELFTR  = 000364     W      = 000006/01  WF     = 000007/01  WJ      = 000375
XLF     = 000116/03

START OF CONSTANTS=000314      TEMPS--000345    INDIRECTS=000353

7600 COMPILATION -- RUN76 LEVEL 9B      74/07/15.

ROUTINE COMPILES IN 044600
```

ZERJVB

```
      SUBROUTINE ZERJVB(ERROR,ERRM1,DRIVER,STEP,TOL,JC,JX)
      ERR = ERROR
      IF(JC.GT.0)GO TO 10
      JM=0
      JP=0
      JF=0
      JX=0
      JA=0
   10 JC=JC+1
      IF(JP.GT.0)GO TO 20
   12 JP=JP+1
      DRM1=DRIVER
      DRIVER = DRIVER + STEP
   15 RETURN
   20 CONTINUE
      IF(JF.GT.0)GO TO 45
      IF(ERRM1.LT.0..AND.ERR.GT.0.)GO TO 30
      IF(ERRM1.GT.0..AND.ERR.LT.0.)GO TO 30
      IF(ERR.LT.0.)GO TO 25
      IF(JM.GT.0)GO TO 22
      IF(ERR.GT.ERRM1)GO TO 22
      GO TO 12
   22 BU=DRIVER
      DRM1=DRIVER
      DRIVER = BU - STEP
      JM=JM+1
      GO TO 15
   25 IF(JM.GT.0)GO TO 22
      IF(ERR.LT.ERRM1)GO TO 22
      GO TO 12
   30 IF(DRM1.GT.DRIVER)GO TO 35
      BL=DRM1
      BU=DRIVER
      GO TO 40
   35 BU=DRM1
      BL=DRIVER
      ERRM1 = ERROR
   40 JX = 1
      IF(JF .GT. 0)GO TO 45
      JF = JF + 1
      DRIVER = BL + 0.5 * (BU - BL)
      RETURN
   45 IF(ERROR * ERRM1 .LE. 0.0) GO TO 46
      BL = DRIVER
      ERRM1 = ERROR
      GO TO 47
   46 BU = DRIVER
   47 DRIVER = BL + 0.5 * ( BU -BL)
      IF(ABS(BU - BL) .LT. TOL)JX = 2
      RETURN
      END
```

SUBPROGRAM LENGTH

```
ZERJVB

00153

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS
10     = 000020     12     = 000024     15     = 000030     20     = 000031     22     = 000055     25     = 000062
30     = 000067     35     = 000075     40     = 000101     45     = 000112     46     = 000117     47     = 000120

BLOCK NAMES AND LENGTHS

VARIABLE ASSIGNMENTS
BL     = 000152     BU     = 000151     DRM1   = 000150     ERR    = 000143     JA     = 000147     JF     = 000146
JM     = 000144     JP     = 000145     JX     = 000000

START OF CONSTANTS=000133       TEMPS==000135     INDIRECTS=000143

7600 COMPILATION == RUN76 LEVEL 96       74/07/15.

ROUTINE COMPILES IN 044000
```

ATMOS

```
              SUBROUTINE ATMOS(HH,DTABS,ANS)
              COMMON /UNIT/IUNIT,G
              DIMENSION ANS(8)
          C  HH=ALTITUDE IN FEET
          C  DTABS=TEMPFRATURE INCREMENT FROM STANDARD TEMPERATURE
          C  ANS(1)=TEMPERATURE         (RANKINE)
          C  ANS(2)=PRESSURE (PSF)
          C  ANS(3)=DENSITY (SLUG/FT3)
          C  ANS(4)=SPEED OF SOUND IN FT./SEC.
          C  ANS(5)=KINEMATIC VISCOSITY (FT2/SEC)
          C  ANS(6)=PRESSURE RATIO
          C  ANS(7)=DENSITY RATIO
          C  ANS(8)=TEMPERATURE RATIO
              HJ = HH
      5       IF(IUNIT .EQ. 2)HJ = HJ / 0.3048
     11       DTABJ = DTABS
     12       IF(IUNIT .EQ. 2)DTABJ = DTABJ*(9./5.)
     15       THETA = 1.-.000006875*HJ + DTABJ/518.67
     21       DELTA = (1.-.000006875*HJ)**5.2561
     26       IF (HJ.LE.36089.) GO TO 4
     31       THETA = .7519 + DTABJ/518.67
     33       DELTA = .22336*EXP((36089.-HJ)/20786.)
     43     4 SIGMA = DELTA/THETA
     45       ANS(1) = THETA * 518.67
     46       ANS(2) = DELTA * 2116.22
     50       ANS(3) = SIGMA * .0023769
     52       ANS(4) =1117.061 *SQRT(THETA )
     57       P = ANS(2)/144.
     60       ANS(5) = .270558E-06*ANS(1)*SQRT(ANS(1))/(P*(1.+198.72/ANS(1)))
     74       ANS(6) = DELTA
     75       ANS(7) = SIGMA
     77       ANS(8) = THETA
    100       IF(IUNIT .EQ. 1)RETURN
    103       ANS(3) = ANS(3)*515.38
    105       ANS(4) = ANS(4)*0.3048
    107       RETURN
    110       END
```

```
SUBPROGRAM LENGTH

00172

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS
4        - 000044

BLOCK NAMES AND LENGTHS
UNIT    - 000002/01

VARIABLE ASSIGNMENTS
DELTA   - 000167    DTABJ   - 000165    HJ      - 000164    IUNIT   - 000000/01   P       - 000171    SIGMA   - 000170
THETA   - 000166
```