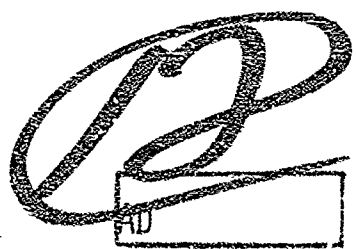


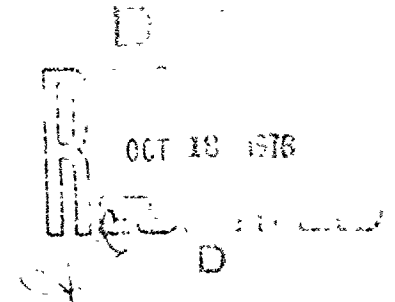
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TECHNICAL REPORT NO. 130

COMPUTER PROGRAMS FOR HELICOPTER AERODYNAMIC
STABILITY EVALUATION

ROBERT R. OEHRLI

AUGUST 1976

OCT 18 1976


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U. S. ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY
Aberdeen Proving Ground, Maryland

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The three equations of motion for helicopters are reviewed for both pitch and roll. These include provisions for a simplified second order stability augmentation system. Two methods of calculating the required stability derivatives and solution of the equations of motion in terms of period and time to damp or time histories for various control motions are shown.		

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1. INTRODUCTION

The feasibility of new helicopter designs depends to a great extent upon an analysis of their flying qualities. Five programs have been developed to carry out feasibility analysis:

These programs evaluate:

1. Helicopter Stability Derivatives
including static stability analysis
2. Solution of Longitudinal Equations of Motion
3. Longitudinal Motion (Time History)
4. Solution of Lateral Equation of Motion
5. Lateral Motion (Time History)

Provisions are included in the programs for investigation of stability augmentation.

A sample calculation is included for a utility helicopter. The helicopter used in the sample calculation was chosen to demonstrate the application of the mathematics only and the type of evaluation that can be made but not to evaluate present capability.

It is recognized that the helicopter chosen is not a current inventory item but was used because the dynamic components are representative of present design and there was extensive flight data available with and without the SAS to compare to calculated results.

In general, the procedures and notation follow those established for fixed wing aircraft. Calculation of the rotor stability derivatives are added and the familiar aircraft elevator, aileron, and rudder deflections δ_c , δ_A , and δ_R are replaced with the longitudinal cyclic,

lateral cyclic and tail rotor collective B_1 , A_1 , and θ_{tR} . Differences in the rotor derivatives between articulated, rigid and teetering rotors may be evaluated with the stability derivative program.

2. GENERAL STABILITY PROBLEM

Normal aircraft have six equations of motion. The general solution of these equations is a breakdown of two sets of three into the longitudinal and lateral modes. Each of these are represented by a determinant, the solution of which is a quartic equation.

There are four possible solutions of the quartic according to the roots λ , being real or complex and having a positive or negative real part.

$$\lambda = a \pm b i \quad \text{etc.}$$

A positive real part indicates an unstable or diverging motion and the complex root an oscillation. A measure of the damping of its oscillation is the time to damp to half or double amplitude.

$$T_{1/2} = \frac{.693}{a}$$

and period

$$p = \frac{2\pi}{b}$$

Another common way to write the stability quartic is to indicate the natural frequency, ω_n and damping ratio, ζ , as

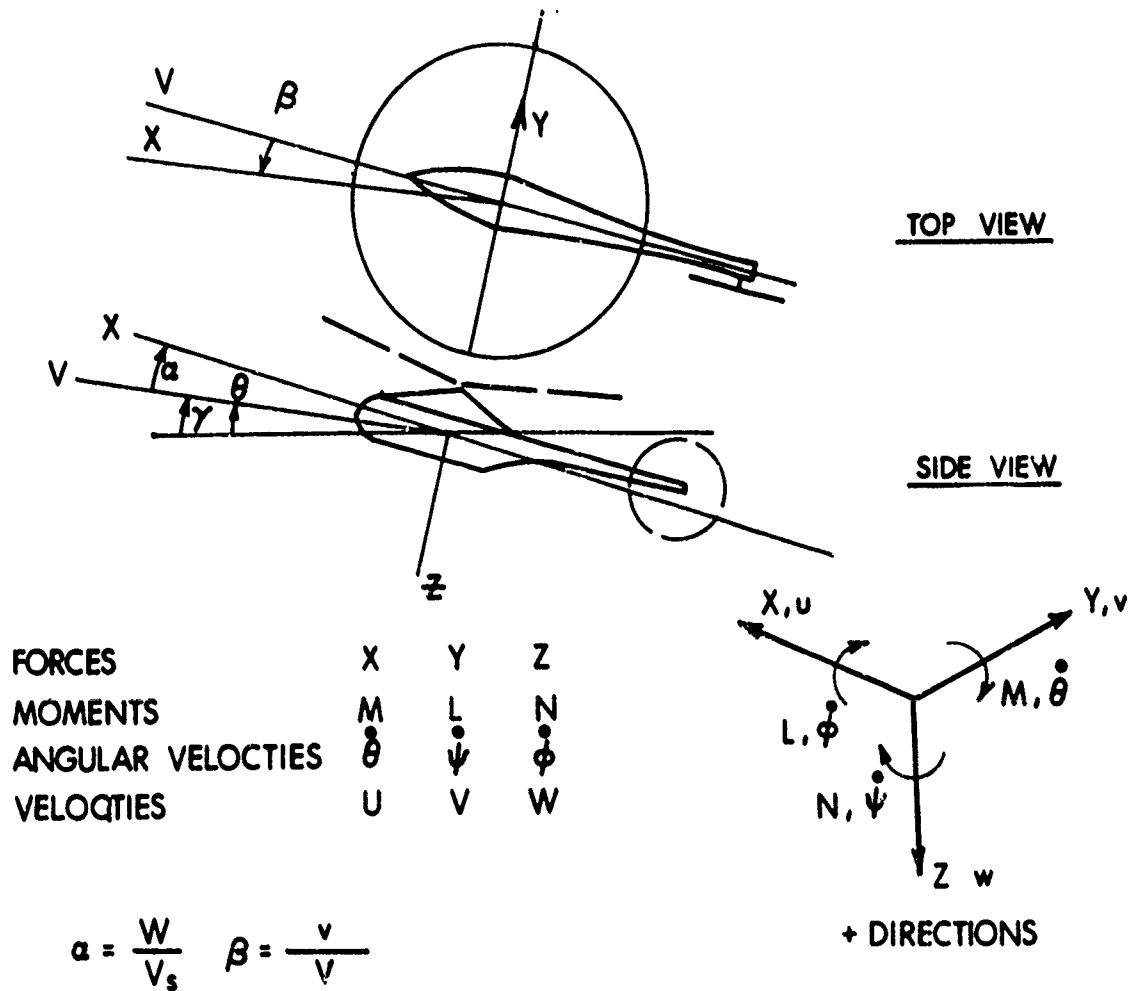
$$(s^2 + 2\zeta_1 \omega_{n1} s + \omega_{n1}^2) (s^2 + 2\zeta_2 \omega_{n2} s + \omega_{n2}^2)$$

The characteristic modes for nearly all aircraft in the longitudinal direction are two oscillations, one the long period or "phugoid" motion with very light damping and the other mode a short period one with

very heavy damping. In the lateral direction there are three normal modes. Two are aperiodic, one a very rapid convergence and the other a slow divergence known as "spiral divergence." The third mode is an oscillatory one, the well known "dutch roll."

In general, for stable oscillations, it is desirable to have damping ratios on the order of 0.6. Specifications for various types of aircraft generally give values of ζ , ω_n or P and $t_{1/2}$ that shall be contractually met, for example see MIL-H-8501A.

3. STABILITY EQUATIONS REVIEW



$$\alpha = \frac{W}{V_s} \quad \beta = \frac{v}{V}$$

THE MOMENTS AND FORCES ACTING ON A VEHICLE ARE WRITTEN AS:

AIRPLANE	HELICOPTER	
$L = C_L \frac{1}{2} \rho V^2 S$	$= C_L \rho V_{TIP}^2 \pi R^2$	LIFT
$D = C_D \frac{1}{2} \rho V^2 S$	$= C_D \rho V_{TIP}^2 \pi R^2$	DRAG
$X = C_X \frac{1}{2} \rho V^2 S$	$= C_X \rho V_{TIP}^2 \pi R^2$	X AXIS FORCE
$Y = C_Y \frac{1}{2} \rho V^2 S$	$= C_Y \rho V_{TIP}^2 \pi R^2$	Y AXIS FORCE
$Z = C_Z \frac{1}{2} \rho V^2 S$	$= C_Z \rho V_{TIP}^2 \pi R^2$	Z AXIS FORCE
$L = C_L \frac{1}{2} \rho V^2 S b$	$= C_L \rho V_{TIP}^2 \pi R^3$	ROLLING MOMENT
$M = C_M \frac{1}{2} \rho V^2 S \bar{c}$	$= C_M \rho V_{TIP}^2 \pi R^3$	PITCHING MOMENT
$N = C_N \frac{1}{2} \rho V^2 S b$	$= C_N \rho V_{TIP}^2 \pi R^3$	YAWING MOMENT

The equations themselves are broken down into two parts, the left and right hand sides. The right hand side represents the inertia forces.

$$\begin{aligned}\Sigma F_x &= m \dot{u} & \Sigma F_y &= m u (\dot{\beta} + \dot{\psi}) \\ \Sigma F_z &= m (\dot{w} - u \dot{\theta}) & \Sigma L &= I_x \ddot{\phi} \\ \Sigma M &= I_y \ddot{\theta} & \Sigma N &= I_z \ddot{\psi}\end{aligned}$$

The left hand forces and moments are series expanded in terms of the changes resulting from the perturbations in the linear and angular velocities and accelerations of the aircraft. These are known as the stability derivatives where

$$\Sigma F_y = \frac{\partial F}{\partial \beta} \beta + \frac{\partial F}{\partial \dot{\beta}} \dot{\beta} + \frac{\partial F}{\partial \dot{\psi}} \dot{\psi} + \text{etc.}$$

It is the purpose of this note to develop a program for estimating the stability derivatives of helicopters and additional programs to utilize these derivatives in solving the resulting equations of motion. A further objective is to develop step by step solutions so that a transient motion of the helicopter after a disturbance can be obtained. Each of the forces varies with the disturbance velocities and their time derivatives:

$$\begin{aligned}X_u &= \frac{\partial X}{\partial u} & \dot{u} &= \frac{\partial u}{\partial t} \\ X_{\dot{u}} &= \frac{\partial X}{\partial \dot{u}} & C X_u &= \frac{\partial C_x}{\partial u} & \text{etc}\end{aligned}$$

The standard aircraft longitudinal equations in terms of the stability derivatives are:(for example see reference 11).

$$X_u u + X_\alpha \alpha - W\dot{\theta} + X_{\delta_e} \delta_e = m \dot{u}$$

$$Z_u u + Z_\alpha \alpha + Z_{\dot{\alpha}} \dot{\alpha} + Z_{\dot{\theta}} \dot{\theta} + Z_{\delta_e} \delta_e = m (\dot{w} - V\dot{\theta})$$

$$M_u u + M_\alpha \alpha + M_{\dot{\alpha}} \dot{\alpha} + M_{\dot{\theta}} \dot{\theta} + M_{\delta_e} \delta_e = I_y \ddot{\theta}$$

$\delta_e = B_1$ = Pitch Cyclic Longitudinal Control Deflection

The lateral equations are:

$$Y_\beta \beta + Y_{\dot{\psi}} \dot{\psi} + W\phi + Y_{\dot{\phi}} \dot{\phi} + Y_{\delta_R} \delta_R + Y_{\delta_a} \delta_a = m (\dot{v} + V\dot{\psi})$$

$$L_\beta \beta + L_{\dot{\psi}} \dot{\psi} + L_{\dot{\phi}} \dot{\phi} + L_{\delta_R} \delta_R + L_{\delta_a} \delta_a = I_x \ddot{\phi}$$

$$N_\beta \beta + N_{\dot{\psi}} \dot{\psi} + N_{\dot{\phi}} \dot{\phi} + N_{\delta_R} \delta_R + N_{\delta_a} \delta_a = I_z \ddot{\psi}$$

$\delta_R = \theta_{tR}$ = Tail Rotor Collective Control Deflection

$\delta_A = A_1$ = Lateral Cyclic Control Deflection

$C_{Y_\beta} = Y_\beta / q\pi R^2$ Typical Derivative Coefficient

Solution of these equations takes many forms.

For static lateral stability the variation of control deflection in steady sideslips based on solution of the determinants become:

$$\frac{d\phi}{d\beta} = \frac{-q \pi R^2}{W} (C_{y_\beta} [C_{\ell_{\theta TR}} C_{n_{A1}} - C_{n_{\theta TR}} C_{\ell_{A1}}] - C_{\ell_\beta} [C_{y_{\theta TR}} C_{n_{A1}} - C_{n_{\theta TR}} C_{y_{A1}}] + C_{n_\beta} [C_{y_{\theta TR}} C_{\ell_{A1}} - C_{\ell_{\theta TR}} C_{y_{A1}}]) / (C_{\ell_{\theta TR}} C_{n_{A1}} - C_{n_{\theta TR}} C_{\ell_{A1}})$$

$$\frac{d\theta_{TR}}{d\phi} = - \frac{(C_{\ell_\beta} C_{n_{A1}} - C_{n_\beta} C_{\ell_{A1}})}{(C_{\ell_{\theta TR}} C_{n_{A1}} - C_{n_{\theta TR}} C_{\ell_{A1}})} \frac{d\beta}{d\phi}$$

$$\frac{dA1}{d\phi} = - \frac{(C_{\ell_\beta} C_{n_{\theta TR}} + C_{n_\beta} C_{\ell_{\theta TR}})}{(C_{\ell_{\theta TR}} C_{n_{A1}} - C_{n_{\theta TR}} C_{\ell_{A1}})} \frac{d\beta}{d\phi}$$

$$C_{y_\beta} = Y_\beta / q \pi R^2 \quad C_{\ell_\beta} = \frac{L_\beta}{q \pi R^3} \quad \text{etc}$$

In a steady state turn $\beta = 0$ and the bank and turn rates become

$$\dot{\phi} = g \frac{\tan \phi}{v}$$

$$\dot{\psi} = g \frac{\tan \phi}{v} \cos \phi$$

which leads to the result

$$\theta_{TR} = \frac{-g \frac{\tan \phi}{v} [\theta (C_{L_{A1}} C_{L_{\dot{\phi}}} - C_{n_{A1}} C_{n_{\dot{\phi}}}) - \cos \phi (C_{L_{A1}} C_{L_{\dot{\psi}}} - C_{n_{A1}} C_{n_{\dot{\psi}}})]}{C_{L_{\theta_{TR}}} C_{n_{A1c}} - C_{n_{\theta_{TR}}} C_{L_{A1c}}}$$

$$A1 = \frac{-g \frac{\tan \phi}{v} [\theta (-C_{L_{\theta_{TR}}} C_{n_{\dot{\phi}}} + C_{n_{\theta_{TR}}} C_{L_{\dot{\phi}}}) - \cos \phi (-C_{L_{\theta_{TR}}} C_{n_{\dot{\psi}}} + C_{n_{\theta_{TR}}} C_{L_{\dot{\psi}}})]}{C_{L_{\theta_{TR}}} C_{n_{A1}} - C_{n_{\theta_{TR}}} C_{L_{A1}}}$$

In pitch the variation of control gradient with speed is

$$\frac{dB_1}{du} = \frac{C_{z_u} C_{m_\alpha} - C_{m_u} C_{z_\alpha}}{-C_{z_{B1c}} C_{m_\alpha} + C_{m_{B1c}} C_{z_\alpha}}$$

The longitudinal cyclic pitch control required in a steady turn is

$$B_1 = \frac{g \frac{\tan \phi \sin \phi}{v} (C_{z_\alpha} C_{m_{\dot{\theta}}} - C_{m_\alpha} C_{z_{\dot{\theta}}}) + (\frac{1}{\cos \phi} - 1) C_{L_o} C_{m_\alpha}}{C_{z_\alpha} C_{m_{B1}} - C_{m_\alpha} C_{z_{B1}}}$$

or

$$B_1 = \frac{\frac{g}{v} (\frac{n^2 - 1}{n}) (C_{z_\alpha} C_{m_{\dot{\theta}}} - C_{m_\alpha} C_{z_{\dot{\theta}}}) + (n - 1) C_{L_o} C_{n_\alpha}}{C_{z_\alpha} C_{m_{B1}} - C_{m_\alpha} C_{z_{B1}}}$$

$$C_{L_o} = W/q\pi R^2, \quad n = \text{Load Factor}$$

For pitch trim in stabilized level flight the load factor, n , is 1. Moments about the C.G. as shown in Figure 1 give:

$$B_1 = \frac{\frac{X}{R} + \frac{H}{R} \frac{C_H}{C_T} + \frac{\mu^2}{2C_T} \frac{\lambda}{\mu} (2K_f V_f - C_{L_{\alpha_t}} \overline{TV}) - (2KV_f \alpha_{OL\beta} - C_{L_{\alpha_t}} \overline{TV} I_{t_t}) \frac{u^2}{2C_T}}{\frac{h}{R} - \frac{u^2}{2C_T} (2K_f V_f - C_{L_{\alpha_t}} \overline{TV})}$$

For steady pull ups the pitch damping term, $C_{m_{\dot{\theta}}}$, may be added as indicated in figure 1.

Solution of the static stability equilibrium equations has been added to the stability determinant program, Appendix "A".

Dynamic stability analysis is considered in separate programs as discussed in the following section.

4. LONGITUDINAL ROOTS

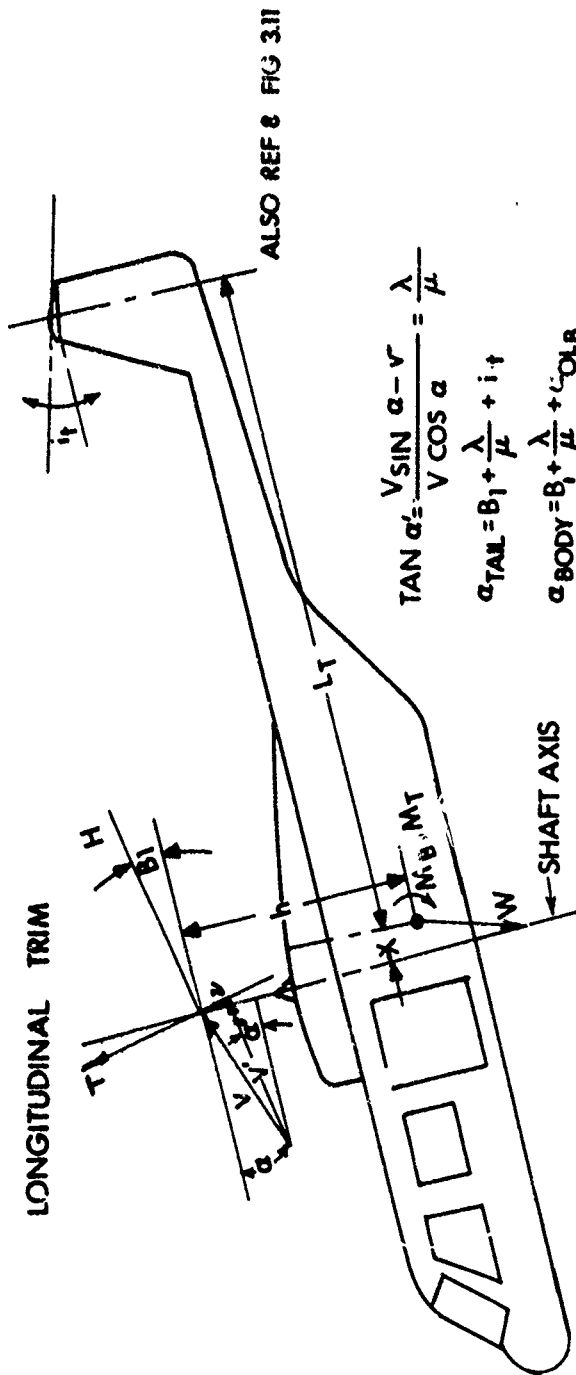
The longitudinal determinant is

$$\begin{array}{ccc} \frac{\mu}{C_{x_{\mu}} - \frac{m'}{V} s} & \frac{\alpha}{C_{x_{\alpha}}} & \frac{\theta}{-C_L} \\ C_{z_{\mu}} & C_{z_{\alpha}} + (C_{z_{\dot{\alpha}}} - m')s & (C_{z_{\dot{\theta}}} + m')s \\ C_{m_{\mu}} & C_{m_{\alpha}} + C_{m_{\dot{\alpha}}} s & C_{m_{\dot{\theta}}} s - I_y' s^2 \end{array}$$

where

$$m' = \frac{mV}{qA_b}, \quad I_y' = I_{yy}/qA_D \text{ ROTR}$$

FIGURE 1



$$\tan \alpha = \frac{V \sin \alpha - v}{V \cos \alpha} = \frac{\lambda}{\mu}$$

$$\alpha_{TAIL} = B_1 + \frac{\lambda}{\mu} + i_t$$

$$\alpha_{BODY} = B_1 + \frac{\lambda}{\mu} + \alpha_{OLB}$$

$$\frac{\partial C_m}{\partial B_1_{ROTOR}} = \frac{\partial C_H}{\partial B_1_{ROTOR}} \quad \frac{h}{R} = -C_T \frac{h}{R}$$

$$\frac{2}{\mu^2} C_m \alpha_B = 2K_f \bar{V}_f = \frac{2K_f VOLF}{\pi R^3}$$

$$\frac{2}{\mu^2} C_m \alpha_t = -C_L \alpha_t \times \frac{S_t \bar{V}_t}{\pi R^3} = -C_L \alpha_t \frac{TV}{TV}$$

$$\frac{g(n-1)}{\theta} \frac{V}{V}$$

$$\cos B_1 = 1, \sin B_1 \approx 0$$

$$\Sigma M_{CG} = T_x + H_h + M \alpha_B \alpha_B + M \alpha_{TAIL} \alpha_{TAIL} + M B_1_{ROTOR} B_1 + M \theta \frac{g(n-1)}{V}$$

$$= C_T \frac{X}{R} + C_H \frac{h}{R} + C_m \alpha_B \alpha_B + C_m \alpha_t \alpha_t + C_m B_1 B_1 + M \frac{g(n-1)}{\theta} \frac{V}{V}$$

$$\frac{h}{R} \frac{X}{R} = \frac{X}{R} + \frac{C_H}{C_T} \times \frac{h}{R} + \frac{\mu^2}{2C_T} 2K_f \bar{V}_f (B_1 + \frac{\lambda}{\mu} - \alpha_{OB}) - \frac{\mu^2}{2C_T} C_L \alpha_t (B_1 + \frac{\lambda}{\mu} + i_t) + \frac{C_m \theta}{C_T} \frac{g(n-1)}{V}$$

$$B_1 = \frac{\frac{X}{R} + \frac{C_H}{C_T} \frac{h}{R} + \frac{\mu}{2C_T} \frac{\lambda}{\mu} (2K_f \bar{V}_f - C_L \alpha_t \frac{TV}{TV}) - \frac{\mu^2}{2C_T} (2K_f \bar{V}_f \alpha_{OLB} - C_L \alpha_t \frac{TV}{TV}) + \frac{C_m \theta}{C_T} \frac{g(n-1)}{V}}{\frac{h}{R} - \frac{\mu^2}{2C_T} (2K_f \bar{V}_f - C_L \alpha_t \frac{TV}{TV})}$$

This gives the stability quartic $A's^4 + B's^3 + C's^2 + D's + E'$.

Let $A = C_{x_\mu}$, $B = C_{z_\mu}$, $C = C_{x_\alpha}$, $E = C_{z_\alpha}$, $D = C_{z_\alpha} m'$, $F = C_{z_\sigma} + m'$

Then:

A'	B'	C'	D'	E'
$\frac{m'}{v} DIy'$	$-ADIy'$	$-AEIy'$	$AECm_\theta$	$-BC_L C_{m_\alpha}$
	$\frac{m'}{v} EIy'$	$+ADCm_\theta$	$-AFC_{m_\alpha}$	$EC_L C_{mu}$
	$-\frac{m'}{v} DC_{m_\theta}$	$-AFCm_\alpha$	$-BCC_{m_\theta}$	
	$+\frac{m'}{v} FC_{m_\alpha}$	$-\frac{m'}{v} EC_{m_\theta}$	$-BC_L C_{m_\alpha}$	
		$+\frac{m'}{v} FC_{m_\alpha}$	CFC_{mu}	
		$+BCIy'$	$DC_L C_{mu}$	

These are solved in the program of Appendix "B". For hover the Z equation $V\dot{\gamma}$ term becomes $\dot{\omega}$. This is accomplished by setting $v = 1$ in the input of the program.

It is easy to introduce various autopilot gains into the quartic. For example, $C_{52} = B_1/\theta$ adds these terms to the quartic coefficients (Table B.1).

$\Delta C'$	$\Delta D'$	$\Delta E'$
$\frac{m'}{v} DC_{52} C_{m_{B1}}$	$ADC_{52} C_{m_{B1}}$	$AEC_{52} C_{m_{B1}}$
$\frac{m'}{v} C_{52} C_{m_\alpha} C_{z_{B1}}$	$-AC_{52} C_{m_\alpha} C_{z_{B1}}$	$-AC_{52} C_{m_\alpha} C_{z_{B1}}$
	$-\frac{m'}{v} EC_{52} C_{m_{B1}}$	$-BCC_{52} C_{m_{B1}}$

$\Delta C'$	$\Delta D'$	$\Delta E'$
—	$+\frac{m'}{v} C_{52} C_{m\alpha} C_{Z_{B1}}$	$+C C_{m\mu} C_{52} C_{Z_{B1}}$
—	$-C_{Z_{\mu}} C_{m\alpha} C_{52} C_{x_{B1}}$	$-C_{Z_{\mu}} C_{m\alpha} C_{52} C_{x_{B1}}$
—	$+C_{m\mu}^D C_{52} C_{x_{B1}}$	$+C_{m\mu} C_{Z_{\alpha}} C_{52} C_{x_{B1}}$

If for a given aircraft and flight condition a set of desired longitudinal phugoid - short period characteristics are required, a desired quartic is known:

$$\begin{array}{rcl}
 A's^4 + B's^3 + C's^2 + D's + E' & \text{Desired} \\
 A's^4 + B's^3 + C's^2 + D's + E' & \text{Aircraft Base} \\
 \hline
 \Delta A's^4 + \Delta B's^3 + \Delta C's^2 + \Delta D's + \Delta E' & \text{Increment}
 \end{array}$$

For each flight condition it is possible to solve for a set of feedback gains to satisfy this condition. Five sets would be required.

For example with:

$$\begin{array}{ll}
 C'_{52} = B1/\theta & C'_{15} = B1/\alpha \\
 C'_{51} = B1/\dot{\theta} & C'_{16} = B1/\dot{\alpha} \\
 C'_{50} = B1/\ddot{\theta} & C'_{17} = B1/\ddot{\alpha}
 \end{array}$$

From the expansion of the stability quartic, obtain the coefficient increments due to each, see Table B.1.

$$A_{15} = \Delta A \text{ due to } C'_{15} \text{ etc.}$$

which gives for each flight condition the set:

$$A15 \cdot C'15 + A16 \cdot C'16 + A50 \cdot C'50 + A51 \cdot C'51 + A52 \cdot C'52 = \Delta A_R$$

$$B15 \cdot C'15 + B16 \cdot C'16 + B50 \cdot C'50 + B51 \cdot C'51 + B52 \cdot C'52 = \Delta B_R$$

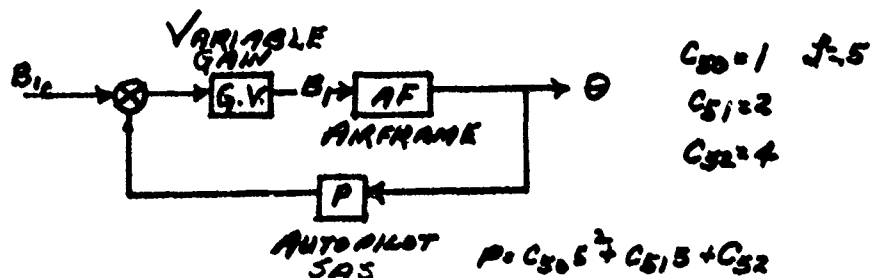
$$C15 \cdot C'15 + C16 \cdot C'16 + C50 \cdot C'50 + C51 \cdot C'51 + C52 \cdot C'52 = \Delta C_R$$

$$D15 \cdot C'15 + D16 \cdot C'16 + D50 \cdot C'50 + D51 \cdot C'51 + D52 \cdot C'52 = \Delta D_R$$

$$E15 \cdot C'15 + E16 \cdot C'16 + E50 \cdot C'50 + E51 \cdot C'51 + E52 \cdot C'52 = \Delta E_R$$

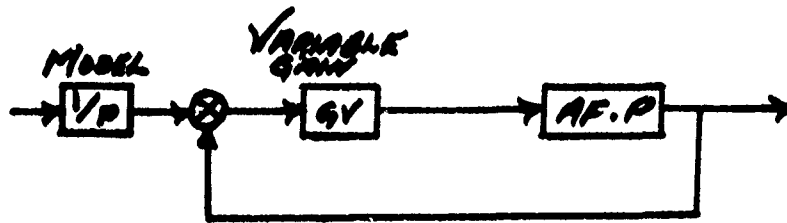
Solution of this set will give the desired stability.

Scheduling of 5 multiple gains through the entire flight regime becomes quite cumbersome. Usually, a hunt and trial method using only one or two gains to obtain an approximate solution is used. To avoid this problem the idea of the high gain-model following autopilot has been used.



In this figure, if the autopilot gains are adjusted so that a desired damping ratio of .5 or .6 is obtained, and if the variable gain is made large enough, the airframe dynamics will tend to be masked and the damping ratio set in to the autopilot will be obtained.

This arrangement is similar to the adaptive autopilot scheme (references 6, 10, and 12), except that the aircraft function is multiplied by the autopilot function in the equivalent circuit.



With this simplified arrangement an insight into the dynamic stability problem can be obtained by using the standard quartic root procedure as used for the airframe alone, see Table B.1. The required inputs have been set into Appendix B. A corresponding transient analysis is set up with provision for a variable gain in Appendix C.

Inspection of the $\ddot{\theta}$ equation shows in another way the influence of the autopilot terms

$$\ddot{\theta} = \frac{C_{m\mu} \mu + C_{m\alpha} \alpha + C_{m\dot{\alpha}} \dot{\alpha} + GVC52C_{mB1} \ddot{\theta} + (GVC51C_{mB1} + C_{m\dot{\theta}}) \dot{\theta}}{I_{y'} - GV + C50 C_{mB1}}$$

Thus it can be seen in the denominator an increase in GV or C50 is equivalent to a change in the moment of inertia.

5. Lateral Roots

The lateral determinant is

β	ψ	ϕ
$-m's + C_{Y\beta}$	$(C_{Y\psi} - m')s$	$C_L + (C_{Y\phi} + m'\alpha)s$
$C_{L\beta}$	$C_{L\psi}s$	$-I_X s^2 + C_{L\phi}s$
$C_{n\beta}$	$-I_Z s^2 + C_{n\psi}s$	$+C_{n\phi}s$

where

$$m' = \frac{mV}{q\pi R^2}, \quad I'_X = \frac{I_{XX}}{q\pi R^3}, \quad I'_Y = \frac{I_{YY}}{q\pi R^3}$$

which gives the stability quartic $A's^4 + B's^3 + C's^2 + D's + E'$

A'	B'	C'	D'	E'
$m'I'_X I'_Z$	$-C_{Y\beta} I'_Z I'_X$	$C_{Y\beta} I'_Z C_{L\phi}$	$-C_{L\beta} C_{Y\psi} C_{n\phi}$	$C_{L\beta} C_{n\psi} C_L$
	$-m'I'_Z C_{L\phi}$	$C_{Y\beta} C_{n\psi} I'_X$	$C_{L\beta} m' C_{n\phi}$	$-C_{n\beta} C_{L\psi} C_L$
	$-m'I'_X C_{n\psi}$	$-m' C_{L\psi} C_{n\phi}$	$-C_{L\beta} I'_Z C_L$	
		$m' C_{n\psi} C_{L\phi}$	$C_{L\beta} C_{n\psi} C_{Y\phi}$	
		$-C_{L\beta} I'_Z C_{Y\phi}$	$C_{n\beta} C_{Y\psi} C_{L\phi}$	
		$-C_{n\beta} I'_X C_{Y\psi}$	$-C_{n\beta} m' C_{L\phi}$	
		$C_{n\beta} m' I'_X$	$-C_{n\beta} C_{L\psi} C_{Y\phi}$	
			$C_{Y\beta} C_{L\psi} C_{n\phi}$	
			$-C_{Y\beta} C_{n\psi} C_{L\phi}$	

These determinants are solved in the program of Appendix D. For hover, the side force equation term $V\ddot{\psi}$ disappears. This is accomplished by setting $V=1$ in the input of Appendix D. As for the longitudinal case, a simplified autopilot study is included. Autopilot gain coefficients are shown in Table D.1.

The corresponding transient analysis is included in the calculation of Appendix E.

6. STABILITY DERIVATIVES

Helicopter stability derivatives are influenced by the type of rotor. In general three types of rotor are commonly used.

1. articulated rotor
2. rigid rotor
3. teetering rotor

The first two transfer cyclic control moments directly to the rotor shaft. The cyclic lift couple for the first has an arm equal to the radius of the flapping hinge and the second equal to the radius of the blade spanwise center of lift. The teetering rotor develops its moment by tilting the lift vector about the C.G. No moment is developed at zero lift.

Two programs have been developed for estimating stability derivatives. The first program was based on combining the equations and data of reference 1 and 2. In general, this work was based on the articulated rotor only. In addition contributions of the rotor to some of the small damping turns were neglected.

For this reason a second program based on a rotor strip analysis was developed to calculate complete sets of stability derivatives including a complete model build up. The first program is shown in table A1 and the second table A2 of appendix A. The method of A1 being a closed solution is much cheaper to operate than program A2 which requires a great deal of machine iteration and thus machine time.

In general values obtained from these methods may be used where wind tunnel or other test data are not available. Some useage of

these methods and results obtained are presented in the following examples.

7. EXAMPLE CALCULATION

Several initial studies have been completed using the methods of this report. These are shown in appendix F.

The first study was completed using the abbreviated derivative calculation of table A1. The purpose of this study was to illustrate the influence of variations of the stability derivatives in the dynamic stability of a marginally stable basic helicopter examples I and II. In addition, the static stability relations of a utility helicopter was investigated in example III.

Stability derivatives are shown in Table F.1, Appendix F for typical study helicopters whose characteristics are:

			I	II	III
W	Weight	lbs.	11867	11867	14800
CDA	Helicopter drag area	sq. ft.	36.5	36.5	21
V	Velocity	ft/sec	100	0	169

			I	II	III
TIPMS	Main Rotor Tip Mach No.		.6	.6	.65
SIGMA	Main Rotor Solidity	$B^*C/$ (3.14*R)	.062	.062	.09
ROTR	Main Rotor Radius	ft.	28	28	28
CI	Speed of Sound	ft/sec	1115	1115	1115
RHO	Density	slugs/ ft ³	.0024	.0024	.0024
XR	Distance Rotor to CG Horiz.	ft-CG fwd	-.1	-.1	.5
HR	Distance Rotor to CG Vert.	ft+CG below	8.0	8.0	6.25
HF	Munks KF for Fuselages		.8	.8	.7
VOLF	Munks Fuselage Volume	cu. ft.	1000	1000	1500
ST	Area Horiz. Tail	sq. ft.	12.4	12.4	30
SVT	Area Vert. Tail	sq. ft.	20	20	25
LT	Tail Length	ft.	28	28	33.3
TI	Horiz. Tail Incidence	rad.	0	0	0
SIGMAT	Tail Rotor Solidity		.167	.167	.167
TRR	Tail Rotor Radius	ft.	4.7	4.7	5.0
DS	Angle Shaft to Body Axis (+δ AHD Z)	Rad.	.174	.174	.087
SG	1 for $DP=RHO*VTIP*VTIP$, 0 for $DP=RHO*V*V/2$		0	1	1.0
BMF	Blade Mass Factor = $C*RHO*5.73$ (ROTOR**2)/I		10	10	10
ETA	Load Factor		1.0	1.0	1.0

From the stability derivatives of Table F.1, dynamic flight characteristics have been calculated for examples I and II. These are shown in Appendix F, Tables F.2 through F.4. The effects of changes in stability derivatives and autopilot gains are shown. Figures F.1 to F.3 show typical motions of the aircraft with and without typical autopilot data.

Finally, static stability data are tabulated in Table F.4 for example III. The data include pitch, equilibrium sideslip trim and steady turn data. These data are also plotted in Figures F.4 to F.8.

Figure F.6 indicates that the utility helicopter of example III should have adequate longitudinal control for a CG range of 16.0 inches. This range could be extended to 27.0 inches by coupling the horizontal tail to the longitudinal cyclic control. However, this would be the maximum amount possible since the gradient of control position versus speeds becomes critical at the aft CG, see Figure F.5.

Some recent flight data is available on a series of Bell Helicopters with stability augmentation off. These helicopters use a 44 foot diameter rotor with 27 inch chord operating at tip speed of 745 feet per second. Aircraft using this rotor include the UH-1C and AH-1 series. Tests of the AH-1 series found the airplane with stability augmentation off to be dynamically unstable although not uncontrollable for several flight conditions.

Stability derivatives were estimated for these aircraft at hover at 7100 lbs and level flight at 40 and 140 knots forward speed. All derivatives were estimated by the rotor strip analysis of table A-2. In addition for the hover condition derivatives were estimated by the method of both tables A1 and A2. These are tabulated in Table F.6. The estimated differences between using an equivalent teetering, articulated or rigid rotor at hover are also shown in Table F.6.

Calculated values of the period, P , and time to damp, t , using these derivatives are compared with flight values as follows:

where P/t	+t time to double
	-t time to half

LONGITUDINAL (NO SAS)

	<u>Calculated</u>	<u>Flight</u>	<u>AH-1 ()</u> <u>Model</u>
Hover	16/Divergent		
40 kts	5.5/+63	16/+4 5/Neutral	(R) (Q)
140 kts	DEAD BEAT	DEAD BEAT	(Q)

LATERAL (NO SAS)

Hover	5./Divergent		
40 kts	Divergent	Divergent 5./-5	(R) (Q)
140 kts	2.8/'100	4.5/Neutral	(Q)

In summary the methods of computing stability derivatives shown in table A-1 and A-2 both need continual correlation and updating. The methods may be used as a basis of correlation or for use in preliminary estimates where wind tunnels or other test data is not available.

REFERENCES

1. Seckel, Edward, "Stability and Control of Airplanes and Helicopters," Academic Press, 1964.
2. Tanner, Watson, "Charts for Estimating Rotary Wing Performance in Hover and at High Forward Speeds," NASA CR-114, 1964.
3. Kisielowski, E., "Generalized Rotor Performance," AD 648874, 1967.
4. Rickano, R. R., Gentry, J. R., "Development Testing of High Gain Adaptive Control Augmentation," AD 877025, 1970.
5. Aerodynamic Design Manual, Glenn L. Martin, Co., 1950.
6. Blakelock, John, "Automatic Control of Aircraft and Missiles," Wiley, 1965.
7. Gessow, A., Meyers, G. C., "Aerodynamics of the Helicopter," Ungar, 1967.
8. Nikolsky, A. A., "Helicopter Analysis," Wiley, 1951.
9. Etkin, B., "Dynamics of Flight," Wiley, 1959.
10. Gibson, J. E., "Nonlinear Automatic Control," McGraw Hill, 1963.
11. Ashkenas, I., Bates, C., McRuer, D., "Dynamics of the Airframe, Vol. II," BuAer Report AE 61-4, 1953.

APPENDIX A
HELICOPTER STABILITY DERIVATIVE PROGRAM


```

WRITE(6,2)
2 FORMAT(10X,10HINPUT DATA)
WRITE(6,1)W,CDA,V,TIPMS,SIGMA,ROTR,C1
WRITE(6,1)RHO,XR,HR,HF,VOLF,ST,SVT
WRITE(6,1)TL,TI,SIGMAR,TRR,DS
WRITE(6,1)SG,RMF,ETA,BTI
IF(ETA-1.)13,13,12
12 ETB=32.2*(ETA-1.)/V
GOTO14
13 ETB=0.
14 CONTINUE
51 FORMAT(1H1)
VTIP=TIPMS*C1
DP=RHO*V*V/2.
OMUHS=V/VTIP
AS4=SIGMA*5.73/4.
AD=3.141*ROTR*ROTR
CT=W/(AD*VTIP*VTIP*RHO)
ELO=-1./((2./CT)**.5)
CLOS=CT/SIGMA
CTAS=2.*CT/(5.73*SIGMA)
CDOS=(CDA*DP)*CT/S/W
IF(OMUHS)60,61,60
60 CALL TANNES(TIPMS,OMUHS,CLOS,CDOS,CQOS,CQDOS,1,ACS2)
GOTO 62
61 CALL TANNRH(TIPMH,SIGMA,CLOS,CQOS,CTSTH,1)
DP=RHO*VTIP*VTIP
DP1=DP
WRITE(6,95)
62 CONTINUE
C XU=(DX/DU)/M=(G/CT)*(BR) SECKEL SYSTEM
C CXU NATURAL AIRCRAFT SYSTEM=(M/Q*AD)*XU ALPHA=W/V
C CXU NATURAL HELICOPTER SYSTEM = USE QH=RHO*VTIP*VTIP V=1. THEN AL=W
C THEREFORE SET SG=1 FOR HELICOPTER SYSTEM, SG=0 FOR AIRCRAFT SYSTEM
C NOTE FOR CT PM IN DYNAMIC PROGRAMS TO MATCH
IF(SG)91,91,90
90 DP=RHO*VTIP*VTIP
WRITE(6,93)
GOTO92
91 WRITE(6,94)
92 CONTINUE
DPF=RHO*V*V/(2.*DP)
CQAS=2.*CQOS/5.73
Q1=(4.2+38.*CTAS+2.*OMUHS)/10000.
Q3=(-1.8-2.86*OMUHS**2.5)/10000.
Q2=(CQAS-Q1)/(CTAS**2)
ELS=-3.*MUHS-(.92-.5*OMUHS)*Q2
Q2=Q2+Q3*ELS/CTAS
ELH=ELS*CTAS
TSRP=OMUHS*(2./CT)**.5
IF(TSRP-1.)20,20,21
20 DLDW=.5+.25*TSRP
DLDCT=(.25+.03*TSRP)/ELO
DLDU=.35*TSRP
EL1=.4*TSRP
GOTO 28
21 IF(TSRP-2.)22,22,23
22 DLDW=.75+.2*(TSRP-1.)
DLDCT=(.28-(.06*(TSRP-1.)))/ELO
DLDU=.35-(.14*(TSRP-1.))

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```

      EL1=.4-(.08*(TSRP-1.))
      GOTO 28
23 IF(TSRP-3.)24,24,25
24 DLDW=.95+(.25*(TSRP-2.))
      DLDOCT=(.22-(.04*(TSRP-2.)))/ELO
      DLDU=.21-(.1*(TSRP-2.))
      EL1=.32-(.04*(TSRP-2.))
      GOTO 28
25 IF(TSRP-6.)26,26,27
26 DLDW=1.
      DLDOCT=(.18-(.0333*(TSRP-3.)))/ELO
      DLDU=.11-(.0333*(TSRP-3.))
      EL1=.28-(.04*(TSRP-3.))
      GOTO 28
27 DLDW=1.
      DLDOCT=.08/ELO
      DLDU=.01
      EL1=.16
28 DLDU=DLDU+.005*ACS2
      DCTDT=(1.+1.5*OMUHS*OMUHS)/13.*(1.-AS4*DLDOCT)
      DCTDW=.5*DLDW/(1.-AS4*DLDOCT)
      DCTDU=(3.*OMUHS/(1.+1.5*OMUHS*OMUHS))*(CTAS-ELW/2.)
      DCTDU=(DCTDU+.5*DLDU)/(1.-AS4*DLDOCT)
      R=ROTR
31 UP=((XR/R)+(OMUHS*2.*ELS*(HF*VOLF-1.43*TL*ST)/(5.73*SIGMA*AD*ROTR)
      1-OMUHS*OMUHS*(HF*VOLF*0.+1.43*TL*ST*TI)/(CT*AD*ROTR)))
      DN=(HR/R)-OMUHS*OMUHS*(HF*VOLF-1.43*(BTI+1.)*ST*TL)/(CT*AD*ROTR)
      H4=(6.95*OMUHS**.92)-1.1*OMUHS*ELS
      UP=UP+(.125*OMUHS/(11.4*CTAS)+H4*CTAS-16.*ETB*R*(1.+ELS/4.))/(BMF*
      1VTIP))*HX/R
      R1C=UP/DN
      T1C=(CTAS-ELW/2.)*3.*57.3/(1.+1.5*OMUHS*OMUHS)
      H4P=1.+(10.*(1.-OMUHS)**2.95)*ELS
      H1P=15.7*OMUHS-.685*ELS*OMUHS**.605
      H2P=-.9*OMUHS+.003*ELS
      H3P=8.-5.*OMUHS-(1.5-2.25*OMUHS)*ELS
      H5P=1.0+3.1*OMUHS**2.04+(.25-.07*OMUHS)*ELS
      DCHDT=(-R1C+CTAS*(H1P+2.*AS4*H2P*DLDOCT))*DCTDT
      DCHDW=(-R1C+CTAS*(H1P+2.*H2P))*DCTDW
      DCHDU=(-R1C+CTAS*(H1P+2.*AS4*H2P*DLDOCT))*DCTDU+H2P*CTAS*DLDU+H3P*CT
      1AS*CTAS+.0125/11.46
      DCHDQ=-16.*CTAS*H5P/BMF
      DCHDB1=-OMUHS*DCHDW-CTAS
      DCTDB1=-DCTDW*OMUHS
      DCTDP=(OMUHS/4.)/(1.-AS4*DLDOCT)
      AS5=AS4*SIGMAR/SIGMA
      C01=W/(VTIP*CTAS*DP*AD)
      CXUR=C01*(-DCHDU+DS*(DCHDW+DCTDU)-DS*DS*DCTDW)
      CXU=CXUR-2.*RHO*V*CDN/(DP*AD)
      CXW=C01*(-DCHDW+DS*DCTDW)
      CXA=CXW*V
      C02=W/(CTAS*DP*AD)
      CXTC=C02*(DCTDT*DS-DCHDT)
      CXB1=C02*(DCTDB1*DS-DCHDB1)
      CZU=C01*(DCTDU-DS*DCTDW)
      CZW=-C01*DCTDW
      CZA=CZW*V
      CZTC=-C02*DCTDT
      CZB1=-C02*DCTDB1
      C03=C01/ROTR

```

```

CMUR=C03*(XR*(DCTDU-DS*DCTDW)+HR*(DCHDU-DS*DCHDW))
IF(V)70,70,71
70 C04=0.
C05=0.
CYBR=-.005*(VOLF**.67)/AD
ENVF=0.
C20=0.
CMUF=0.
CMUT=0.
GOTO 73
71 C04=HF*VOLF*RHO*V/(DP*AD*ROTR)
ENVF=-C01*HF*VOLF*2.*OMUHS/(AD*5.73*SIGMA*2.*ROTR)
CYBR=((-.20*CDA/(AD*.6))-2.86*SVT*RHO*V*V/(2.*DP*AD))
CYVR=CYBR/V
C05=-ST*TL*2.86*RHO*V/(DP*AD*ROTR)
C20=-2.86*SVT*V*V/(2.*VTIP*VTIP*AD)
CMUF=C04*((ELW/OMUHS)+2.*(BIC-0.0+DCTDU-3.*OMUHS*(CTAS-ELW/2.)))
CMUT=C05*((ELW/OMUHS)+2.*(BIC+TI+DCTDU-3.*OMUHS*(CTAS-ELW/2.)))
73 CONTINUE
C CMU FOR V GT 20.
CMU=CMUR+CMUF+CMUT
C06=-W*2.86*ST*TL*TL/(VTIP*VTIP*CTAS*5.73*SIGMA*AD*DP*AD*ROTR)
CMWD=C06*(1.-2.*DCTDW)
CMWR=C03*(XR*DCTDW+HR*DCHDW)
CMWT=C03*((OMUHS/(AS4*AD))*(VOLF*HF-(4.30*ST*TL/2.)))*DCTDW
CMW=CMWR+CMWT
CMAD=C06*V*(1.-2.*DCTDW)
CMAR=C03*V*(XR*DCTDW+HR*DCHDW)
CMAT=C03*V*((OMUHS/(AS4*AD))*(VOLF*HF-(4.30*ST*TL/2.)))*DCTDW
CMA=CMAR+CMAT
CMTD=-C03*TL*2.86*OMUHS*ST*TL*DPF/(2.*AS4*AD)+C01*DCHDQ*HR/ROTR
CMIT=-ST*TL*2.86/(AD*ROTR)
CMIT=CMIT*RHC*V*V/(2.*DP)
C06=W/(CTAS*DP*AD*ROTR)
CMTD=C06*(DCTDT*XR+HR*DCHDT)
CMB1=C06*(XR*DCTDB1+HR*DCHDB1)
C END LONGITUDINAL DERIVATIVES START LATERAL
Y01=1.55*OMUHS**.81
Y0P=Y01-(10.+ELS)*(Y01+.82*OMUHS**1.82)/12.
Y02=-1.5+2.*OMUHS
Y0DP=Y02-(10.+ELS)*(Y02-1.5-.05*OMUHS)/12.
Y02=.90*OMUHS**.68
Y1P=Y02-(10.+ELS)*(Y02+(1.85*OMUHS**2.7))/12.
Y2P=-.238*OMUHS-(10.+ELS)+(.108*OMUHS)/12.
Y02=-1.5+.5*OMUHS
Y3P=Y02-(10.+ELS)*(Y02-1.+3.38*OMUHS**1.93)/12.
Y02=22.5-13.*OMUHS
Y4P=Y02-(10.+ELS)*(Y02-5.)/12.
AIC=BIC
DCYDT=DCTDT*(AIC+EL1*(1.+AS4*DLDCT/2.))
DCYDV=-.0125/11.46-Y4P*CTAS*CTAS-DCTDW*AIC*(AIC+1.5*EL1)
DCYDT=DCYDT+DCTDT*BMF*CTAS*Y0P*(Y1P+2.*AS4*Y2P*DLDCT)
DCYDP=.0625*OMUHS*EL1+DCTDP*(AIC+EL1*(1.+AS4*DLDCT/2.))
DCYDP=DCYDP-16.*CTAS*Y3P/BMF+DCTDP*BMF*(Y1P+2.*AS4*Y2P*DLDCT)*CTAS
DCYDV=DCYDV-DCTDW*AIC*BMF*CTAS*(Y1P+2.*Y2P)
CYVR=C01*DCYDV
CTWTR=.25/(1.-AS5*.25)
CYVTR=C01*CTWTR*SIGMA*TRR*TRR/(SIGMA*ROTR*ROTR)
CYVTR=-CYVTR
CYB=V*(CYVR+CYVTR)+CYRB

```

```

CYA1C=W/(DP*AD)
CLB=C03*V*HR*DCYDV
CLTD=C01*HR*DCYDP
CLA1=W*HR/(DP*AD*ROTR)
ENVTR=C03*TL*CTWTR*SIGMAR*TRR*TRR/(SIGMA*ROTR*ROTR)
ENVT=ENVF*1.43*SVT*TL/(-HF*VOLF)
ENVR=C03*DS*HR*DCYDV
CNB=V*(ENVF+ENVT+ENVTR+ENVR)
ENRTR=-TL*ENVTR
ENRT=-TL*ENVT
ENRRR=ROTR*DS*DS*HR*DCYDP*C03
CNSD=ENRT+ENRTR+ENRRR
CNTD=ENRRR/DS
CNA1=CLA1*DS
CTTTR=1./(3.*(1.-AS5*.25))
CNTTR=-W*TRR*TRR*TL*CTTTR/(CTAS*ROTR*ROTR*DP*AD*ROTR)
1 FORMAT(7F10.4)
CYV=(CYVR+CYVTR)+CYVB
CLV=C03*HR*DCYDV
CNV=ENVF+ENVT+ENVTR+ENVR
CYSD=-CYVTR*TL+C20
WRITE(6,3)
3 FORMAT(10X,11HOUTPUT DATA)
CLSD=0.
CYTD=0.
WRITE(6,4)
4 FORMAT(10X,71HLONGITUDINAL DERIVATIVES ARE IN ORDER CXU,CXA,CZU,CZ
1A,CMU,CMA,CMAD,CMTD)
WRITE(6,5)CXU,CXA,CZU,CZA,CMU,CMA,CMAD,CMTD
5 FORMAT(9E14.7)
WRITE(6,6)CZH1,CMB1,CXR1
6 FORMAT(10X,19HCYCLIC CONTROL CZB1=,E15.8,1X,5HCMB1=,E15.8,1X,5HCXB1
1=,E15.8)
WRITE(6,7)CZTC,CMTC,CXTC
7 FORMAT(10X,23HCOLLECTIVE CONTROL CZTC=,E15.8,1X,5HCMTC=,E15.8,1X,5H
1CXTC=,E15.8)
WRITE(6,8)CMIT
8 FORMAT(10X,25HHORIZ. TAIL CONTROL CMIT=,E15.8)
WRITE(6,9)
9 FORMAT(10X,84HLATERAL STABILITY DERIVATIVES IN ORDER ARE CYB,CLB,C
1NB,CYSD,CLSD,CNSD,CYTD,CLTD,CNTD)
WRITE(6,5)CYB,CLB,CNB,CYSD,CLSD,CNSD,CYTD,CLTD,CNTD
WRITE(6,10)CYA1C,CLA1,CNA1
10 FORMAT(10X,20HCYCLIC CONTROL CYA1=,E15.8,1X,5HCLA1=,E15.8,1X,5HCNA
11=,E15.8)
WRITE(6,11)CNTTR
11 FORMAT(10X,28HTAIL ROTOR COLLECTIVE CNTTR=,E15.8)
WRITE(6,80)
WRITE(6,5)DLDU,DLDW,DLDCT,DCTDT,DCTDW,DCTDU,DCTDB1,DCTDP
WRITE(6,81)
WRITE(6,5)DCHDT,DCHDW,DCHDU,DCHDB1
WRITE(6,82)
B1C=B1C*.7.3
WRITE(6,5)B1C,CTAS,CT,ELO,EL1,ELS,CQOS,T1C
80 FORMAT(1X,68HAUXILIARY DERIVATIVES DLDU,DLDW,DLDCT,DCTDT,DCTDW,DCT
1DU,DCTDB1,DCTDP)
81 FORMAT(1X,25H DCHDT,DCHDW,DCHDU,DCHDB1)
82 FORMAT(1X,33H B1C,CTAS,CT,ELO,EL1,ELS,CQOS,T1C)
WRITE(6,96)
WRITE(6,5)CXW,CZW,CMW,CMWD,CYV,CLV,CNV

```

```

96 FORMAT(10X,64H THE VELOCITY DERIVATES ARE IN ORDER CXW,CZW,CMW,CMWD
1,CYV,CLV,CNV)
93 FORMAT(20X,18H HELICOPTER SYSTEM)
94 FORMAT(20X,16H AIRCRAFT SYSTEM)
95 FORMAT(25X,5H HOVER)
50 FORMAT(1HC)
WRITE(6,5)CMUR,CMAR,CMWR,CZW,CZA
WRITE(6,50)
IF(V)19,15,10
19 CONTINUE
CLTTR=0.
CYTTR=-R*CNTTR/TL
C STATIC STABILITY
C STEADY SIDESLIPS
DTDB=-(DP*AD/W)*(CYB*(CLTTR*CNA1-CNTTR*CLA1)-CLB*(CYTTR*CNA1-CNTTR
1*CYA1C)+CNR*(CYTTR*CLA1-CLTTR*CYA1C))
DTRDT=-(CLB*CNA1-CNR*CLA1)/DTDB
DAIDT=-(CLB*CNTTR+CNR*CLTTR)/DTDB
DN2=CLTTR*CNA1-CNTTR*CLA1
DTDR=DTDB/DN2
WRITE(6,18)DTDB,DTRDT,DAIDT
C STEADY TURN
PHI=0.
DPHI=10./57.3
DO 15 K=1,5
PHI=PHI+DPHI
SN=32.2*SIN(PHI)/(COS(PHI)*V)
THT=-30./57.3
DTHT=15./57.3
DO 15 KK=1,3
THT=THT+DTHT
TTR=-SN*(THT*(CLA1*CLTD-CNA1*CNTD)-COS(PHI)*(CLA1*CLSD-CNA1*CNSD))
TTR=TTR/DN2
A1=-SN*(THT*(-CLTTR*CNTD+CNTTR*CLTD)-COS(PHI)*(CLTTR*CNSD+CNTTR*CL
1SD))/DN2
PF=1./COS(PHI)
B1=SN*SIN(PHI)+(((1./COS(PHI))-1.)*CMA*W/(DP*AD))/(CZA*CMTD-CMA*CZ
1TD)
THP=THT*57.3
16 FORMAT(1X,12H STEADY TURN,12H BANK ANGLE=,F5.0,13H CLIMB ANGLE=,F5
1.0,13H L AD FACTOR=,F6.2)
PHP=PHI*57.3
WRITE(6,16)PHP,THP,PF
TTRP=57.3*TTR
A1P=A1*57.3
B1P=B1*57.3
WRITE(6,17)TTRP,A1P,B1P
17 FORMAT(1X,38H CONTROL ANGLES TAIL ROTOR COLLECTIVE=,F6.2,16H LATER
1AL CYCLIC=,F6.2,14H PITCH CYCLIC=,F6.2)
18 FORMAT(1X,33H STEADY SIDESLIP RATIOS PHI/BETA=,F9.5,27H TAIL ROTOR
1 COLLECTIVE/PHI=,F9.5,20H LATERAL CYCLIC/PHI=,F9.5)
15 CONTINUE
GOTO77
END
SUBROUTINE TANNRH(TIPMH,SIGMA,CTOSH,CQOSH,CTSTH,IREAD)
DIMENSION SIG(7),CTH(9,5,3),CQH(9,5,3),CQX(3),CQXX(3)
EQUIVALENCE(IN,INPUT)
150 FORMAT(13F6.4)
IN=5
MADLY=6

```

```

      IF(IREAD)153,153,154
153 READ(INPUT,150)((CTH(K,J,I),K=1,9),J=1,5),I=1,3)
      READ(INPUT,150)((CQH(K,J,I),K=1,9),J=1,5),I=1,3)
      SIG(1)=.05
      DO 151 I=2,6
151 SIG(I)=SIG(I-1)+.025
149 FORMAT(1H ,38HTANNER DATA FOR HOVER HAS BEEN READ IN)
      WRITE(MADLY,149)
      GO TO 50
154 DO 155 J=1,4
      IF(SIG(J)-SIGMA)155,156,156
155 CONTINUE
156 CALL ZINDEX(J,JA,JB,JC)
      DO 157 K=1,8
      IF(CTH(K,1,1)-CTOSH)157,158,158
157 CONTINUE
158 CALL ZINDEX(K,KA,KB,KC)
      DO 160 I=1,3
      DO 159 J=JC,JA
      CALL CURVEB(CTH(KA,J,I),CTH(KB,J,I),CTH(KC,J,I),CQH(KA,J,I),
      ICQH(KB,J,I),CQH(KC,J,I),CTOSH,CQX(J))
159 CONTINUE
      CALL CURVEB(SIG(JC),SIG(JB),SIG(JA),CQX(JC),CQX(JB),CQX(JA),SIGMA,
      ICQXX(I))
160 CONTINUE
      CALL CURVEB(0.5,0.6,0.7,CQXX(1),CQXX(2),CQXX(3),TIPMH,CQOSH)
      CALL CURVEB(SIG(JC),SIG(JB),SIG(JA),CTH(9,JC,1),CTH(9,JB,1),
      ICTH(9,JA,1),SIGMA,CTHX)
      CALL CURVEB(SIG(JC),SIG(JB),SIG(JA),CTH(8,JC,2),CTH(8,JB,2),
      ICTH(8,JA,2),SIGMA,CTHY)
      CALL CURVEB(SIG(JC),SIG(JB),SIG(JA),CTH(7,JC,3),CTH(7,JB,3),
      ICTH(7,JA,3),SIGMA,CTHZ)
      CALL CURVEB(0.5,0.6,0.7,CTHX,CTHY,CTHZ,TIPMH,CTSTH)
      CQOSH=1.1*CQOSH
50 RETURN
      END
      SUBROUTINE CURVEB(X1,X2,X3,Y1,Y2,Y3,X,Y)
      IF(X1-X2)111,110,111
110 X1=X1+.0001
      WRITE(6,120)X1,X2,X3,Y1,Y2,Y3
111 IF(X1-X3)113,112,113
112 X1=X1+.0001
      WRITE(6,120)X1,X2,X3,Y1,Y2,Y3
113 IF(X2-X3)115,114,115
114 X2=X2+.0001
      WRITE(6,120)X1,X2,X3,Y1,Y2,Y3
115 CONTINUE
120 FORMAT(6F15.8)
      B1=Y1/((X1-X2)*(X1-X3))
      B2=Y2/((X2-X1)*(X2-X3))
      B3=Y3/((X3-X1)*(X3-X2))
      A1=(B1*X2*X3)+(B2*X1*X3)+(B3*X1*X2)
      A2=-B1*(X2+X3)-B2*(X1+X3)-B3*(X1+X2)
      A3=B1+B2+B3
      Y=A1+(A2*X)+(A3*(X**2))
      RETURN
      END
      SUBROUTINE CURVEC(X1,X2,X3,Y1,Y2,Y3,X,Y)
      ZD=((Y2-Y1)/(X1-X2))-((Y3-Y1)/(X1-X3))
      IF(ABS(ZD)-.000001)1,2,2

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1 ZD=.00000001
2 ZA=((((Y1*X1)-(Y3*X3))/(X1-X3))-(((Y1*X1)-(Y2*X2))/(X1-X2)))/ZD
ZC=((Y1*X1)-(Y1*ZA)-(Y3*X3)+(Y3*ZA))/(X1-X3)
Y=ZC+(((X1-ZA)*(Y1-ZC))/(X-ZA))
RETURN
END
SUBROUTINE ZINDEX(IT,ITA,ITB,ITC)
ITA=IT
ITB=IT-1
ITC=IT-2
IF(ITC)1,1,2
1 ITA=3
ITB=2
ITC=1
2 CONTINUE
RETURN
END
SUBROUTINE TANNES(TIPM,OMU,CL,CD,CQ,CDM7,IREAD,AC)
DIMENSION CDS(4,6,25),CQS(4,6,25),EAC(4,6,25),J1(4),PU(4)
DIMENSION CLA(4,6,5),CDM(4,6,5),K1(5),CD7(5),CQ7(5),EA7(5),PCC(5)
C BOE ROTOR PERF. CHARTS STRAIGHT LINE INTERPOLATION VALUES OF MT/MU
C MT=.68/.2,.5,.8,1.,1.2,1.5 MT=.95/.31,.47,.66
C MT=.77/.33,.52,.79,1.06 MT=.875/.35,.52,.75,1.05 VARIOUS CL
C INTERPOLATE BETWEEN MT IS DM, OMU IS PU, CL IS PCC
C NOTE IF BLADE IS STALLED ALPH 14 OR A1 SIGMA IS INCREASED
C NOTE IF OMU IS HIGH ROTOR THRUST IS LOW PROP THRUST IS ADDED
C IN READ (N1,J,K) N1 IS MT, J IS OMU, K 5 VALUES OF ALPH FOR EACH
C OF 5 GROUPS OF CL CONTROLLED BY JJ
IF(IREAD-1)86,70,70
86 N1=1
N2=6
1 DO2J=1,N2
87 FORMAT(10I5)
IA=1
IB=5
DO2JJ=1,5
READ(5,104)(CDS(N1,J,K),K=IA,IB)
READ(5,104)(CQS(N1,J,K),K=IA,IB)
READ(5,104)(EAC(N1,J,K),K=IA,IB)
READ(5,104)(CLA(N1,J,JJ),CDM(N1,J,JJ))
IA=IA+5
IB=IB+5
2 CONTINUE
N1=N1+1
IF(N1-3)3,3,4
3 N2=4
GOTO1
4 IF(N1-4)5,5,6
5 N2=3
GOTO1
6 WRITE(6,91)
GOTO90
91 FORMAT(1H ,11HBOE DATA :N)
70 N1=1
IF(TIPM-.77)7,7,8
7 I1=1
PM=(TIPM-.675)/.095
GOTO11
8 IF((TIPM/.875)-1.)9,9,10
9 I1=2

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      PM=(TIPM-.77)/.105
      GOT025
10  I1=3
      PM=(TIPM-.875)/.075
      GOT035
11  IF(OMU-.5)12,12,13
12  J1(N1)=1
      PU(N1)=(OMU-.2)/.3
      GOT020
13  IF(OMU-.8)14,14,15
14  J1(N1)=2
      PU(N1)=(OMU-.5)/.3
      GOT020
15  IF(OMU-1.0)16,16,17
16  J1(N1)=3
      PU(N1)=(OMU-.8)/.2
      GOT020
17  IF(OMU-1.2)18,18,19
18  J1(N1)=4
      PU(N1)=(OMU-1.0)/.2
      GOT020
19  J1(N1)=5
      PU(N1)=(OMU-1.2)/.3
20  X2=2
      N1=N1+1
25  IF(OMU-.52)26,26,27
26  J1(N1)=1
      PU(N1)=(OMU-.33)/.19
      GOT030
27  IF(OMU-.79)28,28,29
28  J1(N1)=2
      PU(N1)=(OMU-.52)/.27
      GOT030
29  J1(N1)=3
      PU(N1)=(OMU-.79)/.37
30  IF(N1-2)32,100,100
32  X2=3
      N1=N1+1
35  IF(OMU-.52)36,36,37
36  J1(N1)=1
      PU(N1)=(OMU-.35)/.17
      GOT040
37  IF(OMU-.75)38,38,39
38  J1(N1)=2
      PU(N1)=(OMU-.52)/.23
      GOT040
39  J1(N1)=3
      PU(N1)=(OMU-.75)/.3
40  IF(N1-2)42,100,100
42  X2=4
      N1=N1+1
42  IF(OMU-.47)43,43,44
43  J1(N1)=1
      PU(N1)=(OMU-.32)/.15
      GOT0100
44  J1(N1)=2
      PU(N1)=(OMU-.47)/.19
100 J=J1(I)
      I=I1
      D054KK=1.4

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D045KL=1,5
N=KL
IF(CLA(I,J,KL)-CL)45,45,46
45 CONTINUE
46 IF(N-1)47,47,48
47 N=2
48 DEN=CLA(I,J,N)-CLA(I,J,N-1)
PCC(KK)=(CL-CLA(I,J,(N-1)))/DEN
K1(KK)=1+5*N-5
IF(KK-1)49,49,50
49 J=J1(1)+1
GOTO54
50 IF(KK-2)51,51,52
51 I=I+1
J=J1(2)
GOTO54
52 IF(KK-3)53,53,54
53 J=J1(2)+1
54 CONTINUE
I12=I1+1
D055 KK=1,5
K11=K1(1)+KK-6
K12=K11+5
K13=K1(2)+KK-6
K14=K13+5
K15=K1(3)+KK-6
K16=K15+5
K17=K1(4)+KK-6
K18=K17+5
JX=J1(1)
JY=J1(2)
JW=JX+1
JV=JY+1
CD1=CDS(I1,JX,K11)*(1.-PCC(1))+PCC(1)*CDS(I1,JX,K12)
CD2=CDS(I1,JW,K13)*(1.-PCC(2))+PCC(2)*CDS(I1,JW,K14)
CD3=CDS(I12,JY,K15)*(1.-PCC(3))+PCC(3)*CDS(I12,JY,K16)
CD4=CDS(I12,JV,K17)*(1.-PCC(4))+PCC(4)*CDS(I12,JV,K18)
CD5=CD1+PU(1)*(CD2-CD1)
CD6=CD3+PU(2)*(CD4-CD3)
CD7(KK)=CD5+PM*(CD6-CD5)
CQ1=CQS(I1,JX,K11)*(1.-PCC(1))+PCC(1)*CQS(I1,JX,K12)
CQ2=CQS(I1,JW,K13)*(1.-PCC(2))+PCC(2)*CQS(I1,JW,K14)
CQ3=CQS(I12,JY,K15)*(1.-PCC(3))+PCC(3)*CQS(I12,JY,K16)
CQ4=CQS(I12,JV,K17)*(1.-PCC(4))+PCC(4)*CQS(I12,JV,K18)
CQ5=CQ1+PU(1)*(CQ2-CQ1)
CQ6=CQ3+PU(2)*(CQ4-CQ3)
CQ7(KK)=CQ5+PM*(CQ6-CQ5)
EAC1=EAC(I1,JX,K11)*(1.-PCC(1))+PCC(1)*EAC(I1,JX,K12)
EAC2=EAC(I1,JW,K13)*(1.-PCC(2))+PCC(2)*EAC(I1,JW,K14)
EAC3=EAC(I12,JY,K15)*(1.-PCC(3))+PCC(3)*EAC(I12,JY,K16)
EAC4=EAC(I12,JV,K17)*(1.-PCC(4))+PCC(4)*EAC(I12,JV,K18)
EA5=EAC1+PU(1)*(EAC2-EAC1)
EA6=EAC3+PU(2)*(EAC4-EAC3)
55 EA7(KK)=EA5+PM*(EA6-EA5)
N11=(K1(1)+4)/5
N12=N11-1
N13=(K1(2)+4)/5
N14=N13-1
N15=(K1(3)+4)/5
N16=N15-1

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N17=(K1(4)+4)/5
N18=N17-1
CD1=CDM(I1,JX,N12)*(1.-PCC(1))+PCC(1)*CDM(I1,JX,N11)
CD2=CDM(I1,JW,N14)*(1.-PCC(2))+PCC(2)*CDM(I1,JW,N13)
CD3=CDM(I12,JY,N16)*(1.-PCC(3))+PCC(3)*CDM(I12,JY,N15)
CD4=CDM(I12,JV,N18)*(1.-PCC(4))+PCC(4)*CDM(I12,JV,N17)
CD5=CD1+PU(1)*(CD2-CD1)
CD6=CD3+PU(2)*(CD4-CD3)
CDM7=CD5+PM*(CD6-CD5)
D057KK=1,5
N=KK
DEN=CD-CD7(KK)
IF(CD-CD7(KK))57,157,157
57 CONTINUE
GOTO60
157 IF(N-1)58,58,59
58 N=2
59 P=(CD-CD7(N-1))/(CD7(N)-CD7(N-1))
AC=EA7(N-1)+P*(EA7(N)-EA7(N-1))
CQ=CQ7(N-1)+P*(CQ7(N)-CQ7(N-1))
GOTO89
60 AC=10000.
C AC=10000. FOR ROTOR CONDITION OF INADEQUATE THRUST
89 CONTINUE
88 FORMAT(3X7E15.8)
104 FORMAT(10F17.5)
90 RETURN
END
* LIST(STOP)
LIST
* DATA
0. .02 .04 .06 .08 .10 .12 .14 .163 0. .02 .04 .06
.08 .10 .12 .14 .162 0. .02 .04 .06 .08 .10 .12 .14
.158 0. .02 .04 .06 .08 .10 .12 .14 .154 0. .02 .04
.06 .08 .10 .12 .14 .15 0. .02 .04 .06 .08 .10 .12
.14 .146 0. .02 .04 .06 .08 .10 .12 .14 .144 0. .02
.04 .06 .08 .10 .12 .13 .14 0. .02 .04 .06 .08 .10
.12 .13 .136 0. .02 .04 .06 .08 .10 .12 .13 .133 0.
.02 .04 .06 .07 .08 .09 .1 .124 0. .02 .04 .06 .07
.08 .09 .1 .12 0. .02 .04 .06 .07 .08 .09 .10 .117
0. .02 .04 .06 .07 .08 .09 .1 .114 0. .02 .04 .06
.07 .08 .09 .1 .112
.00055.00162.00275.004 .0053 .007 .00875.0109 .015 .00055.0018 .0032 .0045
.0062 .008 .010 .0126 .0174 .00055.002 .0034 .0051 .0070 .0090 .0116 .015
.0190 .00055.0021 .0037 .0055 .0076 .0104 .0132 .017 .0204 .00055.0022 .014
.006 .0082 .011 .0146 .0189 .0215 .00055.00162.00275.004 .0053 .0071 .0092
.012 .0134 .00055.0018 .0031 .0045 .0064 .0085 .011 .0145 .0155 .00055.0020
.0034 .0051 .0071 .0084 .0125 .0144 .0168 .0055 .0021 .0037 .0055 .0078 .0105
.014 .016 .018 .00055.0022 .004 .006 .0085 .0115 .0154 .018 .01871.0055
.00165.0028 .0042 .0049 .00575.00665.00775.0104 .00055.0018 .0032 .0049 .0058
.00675.0079 .0092 .0131 .00055.00195.0035 .00525.0064 .0076 .0088 .0105 .0140
.00055.0021 .0038 .0057 .0068 .0084 .0098 .0115 .0148 .00055.0022 .0040 .0060
.00725.0088 .0106 .0127 .0154
.00125 .0002 -.001 -.0025 -.0045
.00084 .0019 .00149 .00183 .00233
10. 0. -10. -20. -30.
.01 -80.
.00575 .001 -.003 -.00825 -.0145
.0001 .0019 .00203 .00307 .00441
10. 0. -10. -20. -30.

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1

2

.03	-60.			
.01375	.002	-.006	-.01475	-.02425
-.0003	.00119	.00277	.00455	.00658
10.	0.	-10.	-20.	-30.
.05	-60.			
.01825	.003	-.008	-.01975	-.03325
-.00084	.00139	.00376	.00614	.00921
10.	0.	-10.	-20.	-30.
.07	-50.			
.021	.00575	-.00925	-.024	-.0345
-.00109	.00183	.0047	.00817	.01064
10.	0.	-10.	-20.	-27.
.09	-33.			
.00131	.00082	.00033	0.	-.00131
.00117	.00142	.00176	.00209	.00318
10.	0.	-10.	-20.	-30.
.01	-70.			
.00311	.00147	-.00048	-.00245	-.00523
.0005	.00109	.00209	.00334	.00502
10.	0.	-10.	-20.	-30.
.02	-55.			
.00507	0.00213	-.00098	-.004780	-.00948
-.00042	.00075	.00242	.00451	.00736
10.	0.	-10.	-20.	-30.
.03	-40.			
.00703	.00327	-.00131	-.00638	-.01226
-.00134	.000307	.00268	.00527	.00903
10.	0.	-10.	-20.	-30.
.04	-31.			
.00916	.00409	-.00131	-.00752	-.0104
-.00334	.00008	.00268	.00602	.00752
10.	0.	-10.	-20.	-25.
.05	-25.			
.0032	.00205	.00184	.00184	.00226
.00132	.00148	.00158	.00158	.00158
12.	8.	4.	0.	-4.
.01	-17.5			
.0041	.00262	.00205	.00205	.00238
.00079	.00119	.00142	.00135	.00132
12.	8.	4.	0.	-4.
.02	-15.8			
.00525	.00361	.00262	.00258	.00246
.00132	.00059	.00106	.00106	.00116
12.	8.	4.	0.	-4.
.03	-10.5			
.00701	.00513	.00389	.00348	.00328
-.00106	-.0004	.00023	.00026	.00053
12.	8.	4.	0.	-4.
.04	-11.			
.01189	.00656	.00492	.00438	.00402
-.00201	-.00125	-.00053	-.0003	.00023
12.	8.	4.	0.	-4.
.05	-9.			
.00597	.00343	.00267	.00267	.00337
.00051	.00127	.00140	.00178	.00133
12.	8.	4.	0.	-4.
.01	-14.			
.00698	.00413	.00305	.00305	.00330
-.00127	.00089	.00140	.00127	.00051
12.	8.	4.	0.	-4.

.03	-9.5			
.00921	.00603	.00419	.00413	.00540
-.00171	-.00025	.00006	-.00025	0.
12.	8.	4.	0.	-4.
.05	-6.			
.0127	.00889	.00698	.00698	.0087
-.00381	-.00241	-.00152	-.00127	-.0002
12.	8.	4.	0.	-4.
.07	-3.3			
.01778	.0141	.01111	.0111	.0139
-.00711	-.00521	-.0033	-.00127	.0002
12.	8.	4.	0.	-4.
.09	-5			
.00712	.00398	.00351	.00527	.00925
0.	.00495	.00165	.00088	-.00132
8.	4.	0.	-4.	-8.
.01	-12.			
.01027	.00481	.00370	.00416	.00601
0.	.00132	.00165	0.	-.0022
8.	4.	0.	-4.	-8.
.04	-7.			
.01341	.00666	.00388	.00462	.00555
-.00319	0.	.00132	.00066	-.00055
12.	8.	4.	0.	-2.
.05	-5.5			
.01554	.00897	.00555	.00065	.00786
-.00429	-.00110	.00022	-.0011	-.00165
12.	8.	4.	0.	1.
.07	-3.7			
.01536	.01221	.0086	.00999	.01258
-.0066	-.00341	-.00209	-.00165	-.00143
10.	8.	4.	0.	-1.
.09	-2.			
.0177	.00598	.0057	.00656	.00883
.0002	.00064	.0015	.00086	-.00021
4.	2.	0.	-2.	-4.
.01	-8.			
.00627	.00513	.00542	.00627	.00926
.0002	.0015	.00193	.00064	-.00064
4.	2.	0.	-2.	-4.
.03	-5.3			
.01083	.00593	.00513	.00556	.00812
-.00129	.00073	.00193	.00129	-.000143
8.	4.	2.	0.	-2.
.05	-4.3			
.01111	.01398	.0057	.00684	.001
-.0193	.01064	.00172	0.	-.00172
8.	4.	2.	0.	-2.
.07	-3.7			
.01111	.01613	.00656	.00855	.01126
-.00279	.00064	.00107	-.00172	-.00215
8.	4.	2.	0.	1.
.09	-2.6			
.00173	.00028	-.00035	.00139	.00346
.00091	.00114	.00137	.00182	.00274
10.	0.	-10.	-20.	-30.
.01	-80.			
.00554	.00139	-.00277	-.00693	-.01247
-.00023	.00103	.00239	.00376	.00593
10.	0.	-10.	-20.	-30.

.03	-58.			
.01039	.00278	-.00416	-.01247	-.0201
-.00068	.00068	.00235	.00559	.00866
10.	0.	10.	20.	30.
.05	-45.			
.01594	.00589	-.0045	-.01559	-.02772
-.00174	.00023	.00353	.00752	.01254
10.	0.	-10.	-20.	-30.
.07	-28.			
.01951	.00728	-.0045	-.01745	-.02979
-.00228	-.0004	.00388	.00906	.01444
5.	0.	-10.	-15.	-20.
.08	-20.			
.00177	.00133	.00009	.00018	-.00106
.00117	.0014	.00164	.00206	.00309
10.	0.	-10.	-20.	-30.
.01	-62.			
.00319	.00149	0.	-.00212	-.0046
.0004	.00112	.00187	.00318	.00486
10.	0.	-10.	-20.	-30.
.02	-48.			
.00478	.00195	-.00071	-.00372	-.00743
.00070	.00084	.00224	.0043	.00655
10.	0.	-10.	-20.	-30.
.03	-39.			
.0069	.00301	-.00089	-.00531	-.01062
-.0014	.00037	.00252	.00514	.00832
10.	0.	-10.	-20.	-30.
.04	-31.			
.0089	.00407	-.00106	-.00655	-.01292
-.00182	-.00009	.00262	.00608	.01066
5.	0.	-10.	-20.	-30.
.05	-23.			
.00211	.00179	.00239	.00386	.00478
.00159	.00159	.00147	.00098	.00098
8.	0.	-5.	-10.	-15.
.01	-16.			
.00235	.00223	.00219	.00318	.00386
.00122	.00135	.00153	.00129	.00092
8.	0.	-5.	-10.	-15.
.02	-12.			
.00541	.00287	.00271	.00239	.00316
.00006	.00092	.00101	.00138	.00138
12.	5.	0.	-5.	-10.
.03	-12.			
.00689	.00398	.00342	.0033	.00318
-.00083	.00024	.00043	.00098	.00141
12.	5.	0.	-5.	-10.
.04	-11.			
.00864	.00549	.00438	.00386	.00366
-.00184	-.00061	-.00024	.00061	.00181
12.	5.	0.	-5.	-10.
.05	-9.5			
.00533	.00361	.00344	.00568	.01178
.00105	.00136	.0021	.00084	-.00158
8.	4.	0.	-5.	-10.
.01	-13.			
.00568	.00473	.00344	.00559	.01161
.00084	.00126	.00168	.00084	-.00147
8.	4.	0.	-5.	-10.

.03	-8.			
.00568	.00378	.00499	.00654	.00946
-.00116	.00147	.00042	.0002	.00084
8.	4.	0.	-3.	-6.
.05	-5.7			
.01144	.00602	.007662	.00877	.01238
-.00252	.00021	-.00063	.00021	-.00179
10.	5.	0.	-3.	-6.
.07	-4.			
.01428	.00851	.00791	.00955	.01273
-.00431	-.00168	-.00168	-.00126	.00126
10.	5.	3.	0.	-3.
.09	-2.			
.00198	.00103	.00039	-.00119	-.00356
.00111	.00139	.00167	.00222	.00334
10.	0.	-10.	-20.	-30.
.01	-80.			
.00592	.00198	-.00047	-.00632	-.01146
.0052	.00139	.00278	.00417	.00612
10.	0.	-10.	-20.	-30.
.03	-70.			
.01027	.0034	-.00348	-.01082	-.01935
-.00139	.00106	.00334	.00612	.00973
10.	0.	-10.	-20.	-30.
.05	-55.			
.01303	.00442	-.00395	-.01224	-.02291
-.00195	.00080	.00400	.00723	.01182
10.	0.	-10.	-20.	-30.
.06	-47.			
.01619	.00632	-.00395	-.01422	-.02528
-.00306	.00056	.00403	.00834	.01557
10.	0.	-10.	-20.	-30.
.07	-25.			
.0023	.00159	.00124	.00071	-.00057
.00181	.00199	.00238	.00371	.00541
10.	0.	-10.	-20.	-30.
.01	-57.			
.00372	.00146	.00053	-.00142	-.00407
.00109	.00181	.00238	.00352	.00542
10.	0.	-10.	-20.	-30.
.02	-48.			
.00549	0.00266	0.	-.00319	-.00726
.0002	.00143	.00266	.00475	.00741
10.	0.	-10.	-20.	-30.
.03	-39.			
.00766	.00275	-.00004	-.00478	-.01027
-.00076	.00095	.00285	.00570	.00931
10.	0.	-10.	-20.	-30.
.04	-31.			
0.00991	0.00478	-.00035	-.0062	-.0094
-.00199	.00028	.00314	.00665	.0095
10.	0.	-10.	-20.	-25.
.05	-23.			
.0048	.00333	.00343	.00519	.01
.00413	.00409	.00370	.00335	.00279
12.	6.	0.	-8.	-20.
.01	-19.			
.00568	.00342	.00343	.00392	.00598
.00335	.00337	.00348	.00361	.00370
12.	6.	0.	-8.	-20.

.02	-17.8	.00392	.00392	.00510
.00686	.00451	.00344	.00387	.00434
.00249	.00322	0.	-8.	-16.
12.	6.			
.03	-16.			
.0098	.00666	.00534	.00441	.00466
.00034	.00163	.00224	.00335	.00473
12.	6.	0.	-6.	-12.
.04	-11.			
.01372	.00931	.0076	.00637	.00539
-.00241	-.00043	.00077	.0031	.00464
12.	6.	0.	-6.	-10.
.05	-9.			
.00674	.00483	.00412	.00625	.01022
.00283	.00224	.00305	.00231	.00015
10.	6.	0.	-6.	-12.
.01	-12.5			
.00994	.00483	.00454	.00674	.01235
.00052	.00276	.00276	.00209	.00075
12.	6.	0.	-6.	-12.
.03	-8.5			
.01193	.00625	.00554	.00596	.00817
-.00037	.00211	.00224	.00164	.00224
12.	6.	3.	0.	-4.
.05	-5.7			
.01526	.00923	.00795	.0088	.01122
-.00238	.0004	.00224	.00596	.00283
12.	6.	3.	0.	-3.
.07	-1.			
.0186	.01235	.0118	.01257	.01463
-.00447	-.00209	-.00112	.00127	.00343
12.	6.	3.	0.	-3.
.09	-80.			
.00307	.00192	.00004	-.00109	-.00307
.00223	.00244	.00325	.00294	.00355
10.	0.	-10.	-20.	-30.
.01	-70.			
.00685	.00307	-.0016	-.0064	-.01152
.00091	.00213	.00345	.00487	.0065
10.	0.	-10.	-20.	-30.
.03	-45.			
.00112	-.00397	-.00307	-.0112	-.01984
-.00041	.00173	.00416	.007	.01035
10.	0.	-10.	-20.	-30.
.05	-28.			
.01664	.0064	-.00397	-.01472	-.02637
-.00162	.00142	.00518	.00954	.01563
10.	0.	-10.	-20.	-30.
.07	-19.			
.01971	.00794	-.00384	-.0096	-.016
-.00223	.00158	.00599	.00832	.01157
10.	0.	-10.	-20.	-30.
.08	-68.			
-.00335	-.00251	-.00181	-.00098	.00056
.00262	.00275	.00294	.00334	.00438
10.	0.	-10.	-20.	-30.
.01	-46.			
.0067	.00349	.0007	-.00377	-.00809
.00098	.00229	.00379	.00549	.00798
10.	0.	-10.	-20.	-30.

.03	-36.					
.00893	.00413	-.00042	-.0053	-.01116		
.0004	.00196	.00405	.00719	.01033		
10.	0.	-10.	-20.	-30.		
.04	-28.					
.01144	.00558	-.00042	-.00684	-.01395		
-.00078	-.00144	.00432	.00778	.01243		
10.	0.	-10.	-20.	-30.		
.05	-20.					
.01381	.00698	-.00014	-.00405	-.00767		
.00196	.00098	.00445	.00654	.00883		
10.	0.	-10.	-20.	-25.		
.06	-52.					
.0053	.00394	.00316	.00394	.00438		
.0042	.0051	.0066	.00495	.0044		
20.	10.	0.	-10.	-20.		
.01	-53.					
.00393	.00349	.00238	.00127	-.00055		
.00348	.00379	.00512	.00659	.00997		
0.	-10.	-20.	-30.	-40.		
.02	-45.					
.00465	.00316	.00122	-.00105	-.00377		
.00275	.00384	.00604	.00878	.01363		
0.	-10.	-20.	-30.	-40.		
.03	-38.					
.00543	.00366	.00022	-.00111	-.00249		
.00229	.00412	.00714	.00906	.01153		
0.	-10.	-20.	-25.	-30.		
.04	-29.					
.015	.00638	.00332	.00166	-.00014		
-.00037	-.0023	.0042	.0062	.0090		
10.	0.	-10.	-15.	-20.		
.05	-15.					
7100.	24.	0.	.645	.0651	22.	1155.
.00222	-.5	6.	.8	600.	10.9	18.5
27.	0.	.15	4.3	-.0525		
1.	10.	1.	0.			

TABLE A-2

C		STRIP ROTOR THEORY STABILITY DERIVATIVES			
C		LIST OF INPUT CARDS (AFTER 130 AIRFOIL SECTION DATA CARDS)			
C	CD	COL	SYMBOL		
C	1	0-8	TC	COLLECTIVE PITCH	DEG.
C	1	9-16	OMU	TIP SPEED RATIO	
C	1	17-24	VT	TIP SPEED	F.P.S.
C	1	25-32	SIG	ROTOR SOLIDITY	
C	1	33-40	AK	ROTOR ANGLE OF ATTACK	DEG.
C	1	41-48	D3	DELTA 3	DEG.
C	1	49-56	B	NUMBER OF BLADES	
C	1	57-64	R	ROTOR RADIUS	FT.
C	1	65-72	RHO	DENSITY	
C	2	0-8	DS	SHAFT ANGLE	DEG.
C	2	9-16	XR	HORIZONTAL ARM C.G. TO SHAFT	FT. + UP
C	2	17-24	HR	VERTICAL ARM C.G. TO SHAFT	FT. - FWD
C	2	25-32	ET	TAIL LENGTH	FT.
C	2	33-40	VTT	TAIL ROTOR TIP SPEED	F.P.S.
C	2	41-48	SIGT	TAIL ROTOR SOLIDITY	
C	2	49-56	RT	TAIL ROTOR RADIUS	FT.
C	2	57-64	SVT	AREA VERTICAL TAIL	SQ.FT.
C	2	65-72	SHT	AREA HORIZONTAL TAIL	SQ.FT.
C	3	0-8	VOLF	FUSELAGE VOLUME	CU.FT.
C	3	9-16	CDA	FUSELAGE DRAG AREA	SQ.FT.
C	3	17-24	EC	ROTOR BLADE HINGE ECCENTRICITY	EC/R
C		TYPE OF ROTOR	EC=0. FOR TEETERING		
C			EC=GT. 0. LT 1. FOR ARTICULATED		
C			EC=2. FOR RIGID		
C			EC=3.0 FOR RESTRICTED TEETERING		
C	4	25-32	TORSION SPRING RATE FOR EC=3.0		
C		D3 IS DELTA 3 FUTURE USE NOW 0			
		DIMENSION CDR(18,5),CDT(18,5)			
		DIMENSION CL1(91,5),CD1(91,5)			
		DIMENSION C1(2),C2(2),E3(2)			
		DIMENSION E8(10),E9(10),C20(3)			
		DIMENSION CC(12,7),UX(12,7),CB(12,7),CVT(12,7),CHT(12,7),CTR(12,7)			
		DIMENSION C10(2),C11(2),C12(2),C13(2),C14(2),C15(2),C16(2),C17(2)			
		DD13J=1,5			
		READ(5,1)(CL1(I,J),I=1,91)			
		READ(5,1)(CD1(I,J),I=1,91)			
		READ(5,1)(CDT(I,J),I=1,18)			
		READ(5,1)(CDR(I,J),I=1,18)			
		WRITE(6,1)(CL1(I,J),I=1,91)			
		WRITE(6,1)(CD1(I,J),I=1,91)			
		WRITE(6,1)(CDT(I,J),I=1,18)			
		WRITE(6,1)(CDR(I,J),I=1,18)			
13		CONTINUE			
		WRITE(6,6)			
6		FORMAT(15X,35HALL COEFFICIENTS BASED ON DISC AREA)			
		WRITE(6,5)			
20		READ(5,2) TC,OMU,VT,SIG,AK,D3,B,R,RHO			
		READ(5,4) DS,XR,HR,ET,VTT,SIGT,RT,SVT,SHT			
		READ(5,7) VOLF,CDA,EC,RK			
4		FORMAT(4F8.2,F8.0,F8.3,3F8.1)			
7		FORMAT(3F8.2,E15.8)			

```

WRITE(6,5)
WRITE(6,2)TC,DMU,VT,SIG,AK,D3,B,R,RHD
WRITE(6,4)DS,XR,HR,ET,VTI,SIGT,RT,SVT,SHT
WRITE(6,7)VOLF,CDA,EC,RK
WRITE(6,152)
DS=DS/57.3
V=DMU*VT
AS=-12. $DAS=4. $SK=SK/57.3
SY=-15. $DSY=15. $TB=TC/57.3
J3=7
1 FORMAT(9F8.5)
2 FORMAT(2F8.5,F8.0,2F8.5,2F8.1,F8.2,F8.5)
3 FORMAT(3F8.3,5F10.5)
5 FORMAT(/)
RC=SIG*3.141*R*R/B
BIN=0.
WB=2.28*RC*1.164
G=BIN/(RHD*3.141*2.7*VT**2*R**3)
G1=WB*B/(RHD*32.2*.50*3.141*R**3)
CRK=RK/(RHD*3.141*R**3*VT**2)
G2=CRK
IF(AK)30,31,30
30 AS=AK-DAS $J3=1
31 CONTINUE
C ALPHA LOOP
DO102 JN=1,J3
AS=AS+DAS $AA=AS/57.3
CR=0. $CP=0. $CW=0. $CU=0 $CV=0.
A1=-1. $B1=-1.
SK=0.
DO 32 I=1,12
DO 32 J=1,7
CTR(I,J)=0.
VT(I,J)=0.
CHT(I,J)=0.
CB(I,J)=0.
32 CC(I,J)=0.
DO 107 L1=1,2
A1=A1+1.
SM=A1/57.3
CALL ND(TB,DMU,VT,SIG,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CTSS,
1CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,R,G2,HR)
E9(L1)=SV
C20(L1)=CMYSS $C11(L1)=CMXSS $C12(L1)=CYSS
C16(L1)=CDSS
C13(L1)=CTSS $C14(L1)=CHSS $C15(L1)=CQSS $C17(L1)=CLSS
107 CONTINUE
CMYDA=C20(2)-C20(1) $CTDA=C13(2)-C13(1)
CXDA=-(C16(2)-C16(1))
CMXDA=C11(2)-C11(1) $CHDA=C14(2)-C14(1)
CYDA=(C12(2)-C12(1)) $CQDA=C15(2)-C15(1)
SM=0.
IF(CMXDA.NE.0.) SM=-C11(1)/(57.3*CMXDA)
DO 108 L1=1,2
A1=A1+1.
SK=61/57.2
CALL ND(TB,DMU,VT,SIG,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CTSS,
1CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,R,G2,HR)
C20(L1)=CMYSS $C11(L1)=CMXSS $C12(L1)=CYSS $C16(L1)=CDSS
C13(L1)=CTSS $C14(L1)=CHSS $C15(L1)=CQSS $C17(L1)=CLSS

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108 CONTINUE
  CMYDB=C20(2)-C20(1)  $CTDB=C13(2)-C13(1)
  CXDB=-(C16(2)-C16(1))
  CMXDB=C11(2)-C11(1)  $CHDB=C14(2)-C14(1)
  CYDB=C12(2)-C12(1)  $CQDB=C15(2)-C15(1)
  SK=0.
  IF(CMYDB.NE.0.) SK=-C20(1)/(57.3*CMYDB)
  CALL ND(TB,DMU,VT,SIG,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CTSS,
1CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,R,G2,HR)
  C10(1)=CMYSS  $C11(1)=CMXSS  $C12(1)=CYSS  $C16(1)=CDSS
  C13(1)=CTSS  $C14(1)=CHSS  $C15(1)=CQSS  $C17(1)=CLSS
  B1=SK*57.3  $A1=SM*57.3
  WRITE(6,166)
166 FORMAT(5X,29HFINAL VALUES IN PREVIOUS LINE)
  WRITE(6,152)
  WRITE(6,150)
150 FORMAT(1X,5HSHAFT,4X,4HCOLL,6X,3HLAT,5X,5HPITCH,4X,3HTIP,4X,5HSPEE
1D)
  WRITE(6,151)
151 FORMAT(1X,5HANGLE,4X,5HPITCH,5X,4HTRIM,4X,4HTRIM,4X,5HSPEED,4X,5HR
1ATIO)
  WRITE(6,10)AS,TC,A1,B1,VT,DMU
10 FORMAT(4F8.2,F8.0,F8.3)
11 FORMAT(15X,7E5.8)
  WRITE(6,152)
152 FORMAT(/)
15 FORMAT(10X,13HIN ROTOR AXIS)
  WRITE(6,15)  $WRITE(6,152)
  WRITE(6,153)
153 FORMAT(5X,7HYAW MOM,6X,9HPITCH MOM,6X,8HROLL MOM,6X,10H Y
1BX,6H Z ,8X,5H X ,10X,6HTORQUE)
  WRITE(6,154)
154 FORMAT(5X,24HLAT CYCLIC EFFECTIVENESS)
  WRITE(6,11)CMYDA,CMXDA,CYDA,CTDA,CHDA,CQDA
  WRITE(6,155)
155 FORMAT(5X,26HPITCH CYCLIC EFFECTIVENESS)
  WRITE(6,11)CMYDB,CMXDB,CYDB,CTDB,CHDB,CQDB
  CC(1,1)=CMYDA  $CC(1,2)=CMXDA  $CC(1,3)=CYDA
  CC(1,4)=CTDA  $CC(1,5)=CHDA  $CC(1,6)=CQDA
  CC(2,1)=CMYDB  $CC(2,2)=CMXDB  $CC(2,3)=CYDB
  CC(2,4)=CTDB  $CC(2,5)=CHDB  $CC(2,6)=CQDB
  J1=2.
  TB1=TB+1./57.3
  DD99JJ=1,6
  J1=J1+1
  CR=0.  $CP=0.  $CW=0.  $CU=0.  $CV=0.
  IF(JJ.EQ.1) CR=1./57.3
  IF(JJ.EQ.2) CP=-1./57.3
  IF(JJ.EQ.3) CU=-1.
  IF(JJ.EQ.4) CW=1.
  IF(JJ.EQ.5) CV=+1.
  IF(JJ.EQ.6) TB=TB1
  CALL ND(TB,DMU,VT,SIG,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CTSS,
1CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,R,G2,HR)
  EB(JJ)=SV
  C10(2)=CMYSS  $C11(2)=CMXSS  $C12(2)=CYSS
  C16(2)=CDSS
  C13(2)=CTSS  $C14(2)=CHSS  $C15(2)=CQSS
  CMYD=C10(2)-C10(1)  $CTD=C13(2)-C13(1)
  CXD=-(C16(2)-C16(1))

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CMXD=C11(2)-C11(1)  $CHD=C14(2)-C14(1)
CYD=C12(2)-C12(1)  $CQD=C15(2)-C15(1)
WRITE(6,152)
WRITE(6,153)
IF(JJ.EQ.1) WRITE(6,157)
IF(JJ.EQ.2) WRITE(6,158)
IF(JJ.EQ.3) WRITE(6,160)
IF(JJ.EQ.4) WRITE(6,159)
IF(JJ.EQ.5) WRITE(6,161)
IF(JJ.EQ.6) WRITE(6,163)
IF(JJ.EQ.6) TB=TB1-1./57.3
WRITE(6,11) CMYD, CMXD, CYD, CXD, CQD
CC(J1,1)=CMYD  $CC(J1,2)=CMXD  $CC(J1,3)=CYD
CC(J1,4)=CTD  $CC(J1,5)=CHD  $CC(J1,6)=CQD
IF(JJ.EQ.6) GOTD99
IF(JJ-4) 99,162,162
162 CMYD=CMYD*V  $CMXD=CMXD*V  $CYD=CYD*V  $CTD=CTD*V
CHD=CHD*V  $CQD=CQD*V
CXD=CXD*V
IF(JJ.EQ.4) WRITE(6,164)
IF(JJ.EQ.5) WRITE(6,165)
WRITE(6,11) CMYD, CMXD, CYD, CTD, CXD, CQD
J1=J1+1
CC(J1,1)=CMYD  $CC(J1,2)=CMXD  $CC(J1,3)=CYD
CC(J1,4)=CTD  $CC(J1,5)=CXD  $CC(J1,6)=CQD
99 CONTINUE
163 FORMAT(5X,10HCOLLECTIVE)
164 FORMAT(5X,15HANGLE OF ATTACK)
165 FORMAT(5X,8HSIDESLIP)
157 FORMAT(5X,12HROLL DAMPING)
158 FORMAT(5X,13HPITCH DAMPING)
159 FORMAT(5X,17HVERTICAL VELOCITY)
160 FORMAT(5X,16HFORWARD VELOCITY)
161 FORMAT(5X,13H SIDE VELOCITY)
WRITE(6,152)  $WRITE(6,40)  $WRITE(6,152)
WRITE(6,150)
WRITE(6,151)
WRITE(6,10) AS, TC, A1, B1, VT, DMU
WRITE(6,152)
WRITE(6,153)
DO41 I=1,4
DO41 J=1,7
41 CC(1,J)=CC(1,J)*57.3
DO42 J=1,7
42 CC(10,J)=CC(10,J)*57.3
CALL PRNT (CC)
40 FORMAT(10X,15HSUMMARY OF DATA)
A54=CC(5,4)  $A64=CC(6,4)  $A55=CC(5,5)  $A65=CC(6,5)
C  CHANGES ROTOR DERIVATIVES TO STABILITY AXIS
CC(5,4)=-(A54-A64*DS)-(A55-A65*DS)*DS
CC(5,5)=-(A54-A64*DS)*DS+(A55-A65*DS)
CC(6,4)=-(A64+A54*DS)-(A65+A55*DS)*DS
CC(6,5)=-(A64+A54*DS)*DS+(A65+A55*DS)
CC(5,1)=-HR*CC(5,5)/R-XR*CC(5,4)/R
CC(6,1)=-HR*CC(6,5)/R-XR*CC(6,4)/R
CC(1,4)=-CC(1,4)
CC(2,4)=-CC(2,4)
CC(3,4)=-CC(3,4)
CC(4,4)=-CC(4,4)
CC(7,4)=-CC(7,4)

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$CC(8,4) = -CC(8,4)$
 $CC(9,4) = -CC(9,4)$
 $CC(10,4) = -CC(10,4)$
 $CC(1,2) = CC(1,2) + CC(1,3) * HR/R$
 $CC(2,2) = CC(2,2) + CC(2,3) * HR/R$
 $CC(3,2) = CC(3,2) + CC(3,3) * HR/R$
 $CC(4,2) = CC(4,2) + CC(4,3) * HR/R$
 $CC(5,2) = CC(5,2) + CC(5,3) * HR/R$
 $CC(6,2) = CC(6,2) + CC(6,3) * HR/R$
 $CC(8,2) = CC(8,2) + CC(8,3) * HR/R$
 $CC(10,2) = CC(10,2) + CC(10,3) * HR/R$
 $CC(11,2) = CC(11,2) + CC(11,3) * HR/R$
 $CC(1,1) = CC(1,1) + CC(1,4) * XR/R - CC(1,5) * HR/R$
 $CC(2,1) = CC(2,1) + CC(2,4) * XR/R - CC(2,5) * HR/R$
 $CC(3,1) = CC(3,1) + CC(3,4) * XR/R - CC(3,5) * HR/R$
 $CC(4,1) = CC(4,1) + CC(4,4) * XR/R - CC(4,5) * HR/R$
 $CC(5,1) = CC(5,1) + CC(5,4) * XR/R - CC(5,5) * HR/R$
 $CC(6,1) = CC(6,1) + CC(6,4) * XR/R - CC(6,5) * HR/R$
 $CC(8,1) = CC(8,1) + CC(8,4) * XR/R - CC(8,5) * HR/R$
 $CC(10,1) = CC(10,1) + CC(10,4) * XR/R - CC(10,5) * HR/R$
 $CC(11,1) = CC(11,1) + CC(11,4) * XR/R - CC(11,5) * HR/R$
DU 14 I=1,10

14 CC(1,7)=0.

$CC(10,7) = -CC(10,3) * XR/R$
 $CC(1,7) = -CC(1,3) * XR/R$
 $CC(2,7) = -CC(2,3) * XR/R$

CHANGES TO COMPLETE MODEL
TAIL ROTOR

DMUT=DMU*VT/VT

$TB=0.$ $\$SK=0.$ $\$SM=0.$ $\$AA=0.$ $\$CR=0.$ $\$CP=0.$ $\$CW=0.$
 $CU=0.$ $\$CV=0.$ $\$D3=0.$ $\$EC=2.$

CALL NO(TB,DMUT,VTT,SIGT,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CT
1SS,CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,RT,G2,HR)
CTB=CTSS

TB=1./57.3

CALL NO(TB,DMUT,VTT,SIGT,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CT
1SS,CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,RT,G2,FR)
CTTB=(CTSS-CTB)*57.3

CW=1.

TB=0.

CALL NO(TB,DMUT,VTT,SIGT,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CT
1SS,CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,RT,G2,FR)
CTH=CTSS-CTB

TRR=(RT*VT/(R*VT))**2.

YVT=-CTW*TRR $\$ZVT = -YVT * ET/R$ $\$YBTT = V * YVT$ $\$ZBTT = ZVT * V$

YTCT=CTTB*TRR $\$ZTCT = -YTCT * ET/R$

YSDT=-ET*YVT $\$ZSDT = -YSDT * ET/R$

HT=5.

YTDI=YVT*HT

ZTDI=-YTDI*ET/R

C VERTICAL TAIL

CLAT=2.0

$\$QC = VT * VT * 3.141 * R * R$

EVT=CLAT*V*V*SVT/2. $\$YBTVT = -EVT/QC$

ZBTVT=0. $\$YVVT = 0.$ $\$ZVVT = 0.$

IF(V.LT.1.) GOTO8

ZETVT=EVT*ET/(QC*R) $\$YVVT = YBTVT/V$ $\$ZVVT = ZBTVT/V$

B CONTINUE

YSDVT=-YVVT*ET $\$ZSDVT = -ZVVT * ET$

C HORIZONTAL TAIL

CLAT=2.6

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EHT=CLAT* V*V*SHT/2.
ZAHT=-EHT*(1.-(E8(4)-E9(1)))/QC
ZWHT=0.
ZTHDT=0.
IF(V.GT.1.) ZWHT=ZAHT/V
IF(V.GT.1.) ZTHDT=-EHT*ET/(QC*V)
CMAHT=ZAHT*ET/R
CMWHT=ZWHT*ET/R
CMTDHT=ZTHDT*ET/R

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C

BUDY

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CXU=-CDA*V/( R*VT*VT)
HF=.8
CMHF=2.*HF*VOLF*(1.-(E8(4)-E9(1)))/(3.141*R**3.)
CNBF=2.*HF*VOLF/(3.141*R**3.)
CMHF=CMHF*V*V/(2.*VT*VT)
CNBF=CNBF*V*V/(2.*VT*VT)
CMWF=0.
CNVF=0.
IF(V.GT.0.) CMWF=CMHF/V
IF(V.GT.0.) CNVF=-CNBF/V
CTR(8,3)=YVT$ CTR(8,7)=ZVT
CTR(9,3)=YBT$ CTR(9,7)=ZBT
CTR(12,3)=YTCT$ CTR(12,7)=ZTCT
CTR(11,3)=YSDT$ CTR(11,7)=ZSDT
CTR(3,7)=YVT*HT
CTR(3,7)=ZTDT
CTR( 5,2)=-CTR( 3,7)*HT/ET
CTR( 8,2)=-CTR( 8,7)*HT/ET
CTR( 9,2)=-CTR( 9,7)*HT/ET
CTR(11,2)=-CTR(11,7)*HT/ET
CTR(12,2)=-CTR(12,7)*HT/ET
CVT(8,3)=YVVT$ CVT(8,7)=ZVVT
CVT(9,3)=YBVT$ CVT(9,7)=ZBVT
CVT(11,3)=YSDVT$ CVT(11,7)=ZSDVT
CHT(7,4)=ZAHT$ CHT(6,4)=ZWHT
CHT(7,1)=CMAHT$ CHT(6,1)=CMWHT
CHT(4,1)=CMTDHT$ CHT(4,4)=ZTHDT
CB(5,5)=CXU
CVT( 8,2)=CVT( 8,7)*HT/(2.*ET)
CVT( 9,2)=-CVT( 9,7)*HT/(2.*ET)
CVT(11,2)=-CVT(11,7)*HT/(2.*ET)
CVT( 3,3)=CVT( 8,3)*HT/2.
CVT( 3,2)=CVT( 3,3)*HT/(2.*R)
CVT( 3,7)=CVT( 3,3)*ET/(2.*R)
CB(7,1)=CMHF$ CB(6,1)=CMWF
CB(9,7)=CNBF$ CB(8,7)=CNVF
WRITE(6,152)$ WRITE(6,154)$ WRITE(6,152)
WRITE(6,153)$ WRITE(6,152)
33 FORMAT(5X,18HMAIN ROTOR PER DEG)
34 FORMAT(5X,4HBDY)
35 FORMAT(5X,13HVERTICAL TAIL)
36 FORMAT(5X,15HHORIZONTAL TAIL)
37 FORMAT(5X,10HTAIL ROTOR)
38 FORMAT(5X,16HTOTAL PER RADIAN)
WRITE(6,33)
CALL PRNT(CC)
WRITE(6,34)
CALL PRNT(C3)
WRITE(6,35)
CALL PRNT(CVT)

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WRITE(6,36)
CALL PRNT(HT)
WRITE(6,37)
CALL PRNT(CTR)
DO 39 J=1,12
DO 39 J=1,7
39 CC(1,J)=CC(1,J)+CB(1,J)+CVT(1,J)+CHT(1,J)+CTR(1,J)
WRITE(6,38)
CALL PRNT(CC)
102 CONTINUE
16 FORMAT(10X,17HIN STABILITY AXIS)
GOTO20 $END
SUBROUTINE NO(TB,DMU,VT,SIG,SK,SM,AA,CL1,CDR,CHYSS,CHXSS,CYSS,CDSS
1,CTSS,CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,R,G2,HR)
DIMENSIONCDR(18,5),CDT(18,5)
DIMENSIONCL1(91,5),CD1(91,5)
DIMENSION C1(2),C2(2),E3(2)
DIMENSION C10(2),C11(2),C12(2),C13(2),C14(2),C15(2),C16(2),C17(2)
DIMENSION B6(24),B7(24),B10(24)
DO 8 J7=1,24
B6(J7)=0.
B10(J7)=0.
8 B7(J7)=0.
CRK=G2
J=1
DT=VT*57.3/(R*15.)
DT=1./DT
152 FORMAT(/)
DSY=15. $SY=-15.
TC=TB*57.3
AS=AA*57.3
C=1120.
SMF=.014
SV=5.
BLAM=0.
SF=DMU*SIN(AA)
S2=SF*SF
D2=DMU*DMU
C INDUCED VELOCITY LOOP
4 FORMAT(3F10.3,4F10.5,F10.3)
DO101JJ=1,5
IF(SV.GT.110.) SV=100.+1*SV
DO991J=1,2
E1=SV/VT
E2=E1*E1
E3(1J)=E1
C2(1J)=SQRT(4.*E2*(D2+S2-2.*SF*E1*E2))
IF(SV.LT.0.) C2(1J)=-C2(1J)
14 FORMAT(4X,2HAS,7X,2HSY,8X,3HAL2,8X,3HCLU,7X,3HCDU,6X,4HSPAN,7X,3H
1TH)
IF(JJ-5)22,21,22
21 WRITE(6,14)
22 CONTINUE
IF(J.EQ.1)GOTO 12
DO 10 J7=1,24
N1=J7-1
IF(N1.EQ.0) N1=24
N2=J7+1
IF(N2.EQ.25)N2=1
BB=(B7(J7)-B7(N1))/DT

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      B9=(B7(N2)-B7(J7))/DT
10  B6(J7)=(B8+B9)/2.
      DO 11 J7=1,24
        N1=J7-1
        IF(N1.EQ.0) N1=24
        N2=J7+1
        IF(N2.EQ.25)N2=1
        B8=(B6(J7)-B6(N1))/DT
        B9=(B6(N2)-B6(J7))/DT
11  B10(J7)=(B8+B9)/8.
12  CONTINUE
      DO107LK=1,2
      C1SS=0.  $C1SS=0.
      SY=-15.
C    AZIMUTH LOOP
      CMXSS=0.  $CMYSS=0.  $CYSS=0.
      CTSS=0.  $CDSS=0.  $CQSS=0.
      DO100KJ=1,24
      SY=SY+DSY  $SA=SY/57.3
      DTH=0.  $B1=0.
      BQ=0.
      AR=EC
      IF(EC.GT.1.) AR=0.
      CTS=0.  $CPS=0.  $CHS=0.
      CMX=0.  $CMY=0.  $CYS=0.
      CRS=0.
C    SPAN LOOP
      DTH=B7(JK)*D3/(57.3*B.)
      BP=57.3*B7(KJ)
      DO103KK=1,8
      DAR=(1.-EC)/8.
      IF(EC.GT.1.) DAR=.125
      IF(KK.EQ.1) DAR=DAR/2.
      AR=AR+DAR
      IF(AR.EQ.0.) AR=.0625
C    FOR THD/OMEGA RATES
      VY=DMU*VT*SIN(AA)-SV+AR*R*(CR*SIN(SA)+CP*COS(SA))+CW
      VY=VY+AR*R*B6(JK)
      VX=VT*(AR+DMU*SIN(SA)*COS(AA))+CU*SIN(SA)+CV*COS(SA)
      STM=ABS(VX)/C  $IM=STM/.2
      IF(IM)28,27,28
27  IM=1  $PM=0.  $IMM=2
      GOTO29
28  IM=IM+1  $AUM=IM  $AJM=AUM*.2  $PM=(STM-AUM)/.2
29  CONTINUE
      GA=ABS(VY/VX)
C    AH LOCAL ANGLE OF ATTACK RELATIVE WIND TO PLANE PERPENDICULAR TO SHAFT
      AH=ATAN(GA)
      IF(VY)41,40,40
40  IF(VX)44,43,43
44  AH=3.141-AH  $GOTO43
41  IF(VX)46,45,45
45  AH=-AH  $GOTO43
46  AH=AH-3.141
43  AH=AH
      TT=-8./AR/57.3  $FN=1.
      SB=SA-D3/57.3
      AL1=TB+6./57.3+TT-SM*SIN(SB)+SK*COS(SB)-CTH+AH
      IF(AL1)47,47,49
47  AL1=-AL1  $FN=-1.

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```

49 AL2=AL1*57.3
   ID=AL2/2.+1.
   AUS=ID*2
   PU=1.-(AUS-AL2)/2.
C   CLU, CDU LOCAL LIFT AND DRAG COEFFICIENTS
   IDD=ID+1
   CL3=(CL1(ID,IM)+PU*(CL1(IDD,IM)-CL1(ID,IM)))*FN
   CD3=(CD1(ID,IM)+PU*(CD1(IDD,IM)-CD1(ID,IM)))
   CL4=FN*(CL1(ID,IMM)+PU*(CL1(IDD,IMM)-CL1(ID,IMM)))
   CD4=CD1(ID,IMM)+PU*(CD1(IDD,IMM)-CD1(ID,IMM))
   IF(ID-17)33,33,37
33 IF(KK-6)34,34,35
34 PTC=1-KK/6
   CD5=CDR(ID,IM)+PU*(CDR(IDD,IM)-CDR(ID,IM))
   CD6=CDR(ID,IMM)+PU*(CDR(IDD,IMM)-CDR(ID,IMM))
   GOTD36
35 PTC=(KK-6)/2
   CD5=CDT(ID,IM)+PU*(CDT(IDD,IM)-CDT(ID,IM))
   CD6=CDT(ID,IMM)+PU*(CDT(IDD,IMM)-CDT(ID,IMM))
36 CD3=CD3+PTC*(CD5-CD3)
   CD4=CD4+PTC*(CD6-CD3)
37 CONTINUE
   CLU=CL3+PM*(CL4-CL3) $CDU=CD3+PM*(CD4-CD3)
C   CX, CZ COEFF PARALLEL AND PERPENDICULAR TO BLADE TWIST AXIS IN PLANE
C   PERPENDICULAR TO SHAFT AXIS
   CX=(-CLU*SIN(AH)+CDU*CDS(AH))*(VX*VX+VY*VY)*SIG/VT**2
   CZ=(CLU*CDS(AH)+CDU*SIN(AH))*(VX*VX+VY*VY)*SIG/VT**2
   EA=EC
   IF(EC.GT.1.) EA=AR
   IF(EC.EQ.0.) EA=HR/R
   DCZ=0.
   DCX=0.
   S9=SB
   CDSY=-CX*COS(SB)-CZ*SIN(B7(KJ))+SIN(S9)+DCX*COS(SB)
   CDSC=(CX*SIN(SB)-CZ*SIN(B7(KJ)))*COS(S9)-DCX*SIN(SB)
   IF(EC.EQ.0.) GOTD23
   GOTD24
23 EA=EA*SIN(B7(KJ))
   IF(KJ.GT.12.) EA=-EA
24 CONTINUE
   CMX=(-CZ*COS(B7(KJ))+EA*SIN(SB)
   IF(EC.EQ.0.) GOTD25
   GOTD26
25 EA=EA*SIN(B7(KJ))
   IF(KJ.GT.7.OR.KJ.LT.19) EA=-EA
26 CONTINUE
   CMY=(-CZ*COS(B7(KJ))+EA*COS(SB)
   CYS=CYS+CDSY
   CMX=CMX+CMXC $CMY=CMY+CMYC
   CZ=CZ-DCZ
   CTS=CTS+CZ $CHS=CHS+CDSC $CPS=CPS+CX*AR
   CRM=-CZ*COS(B7(KJ))*EA
   CRS=CRS+CRM
   IF(KK-8)106,104,106
104 CTS=CTS-CZ/2.
   CYS=CYS-CDSY/2.
   CHS=CHS-CDSC/2. $CPS=CPS-CX/2.
   CMX=CMX-CMXC/2. $CMY=CMY-CMYC/2.
   CRS=CRS-CRM/2.
106 CONTINUE

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```

AS=AA*57.3
AL2=FN*AL2
B1=B1+C7/(G1*AR)-32.2*R/(AR*VT*VT)
IF(EC.EQ.2.) B1=0.
IF(IJJ-5)19.5,19
6 CONTINUE
IF(LK-2)19,20,19
20 CONTINUE
IF(KJ.EQ.1) GOTO17
IF(KJ-7)18,17,18
18 IF(KJ-19)19,17,19
17 WRITE(6,4)AS,SY,AL2,CLU,CDU,AR,STM,BP
19 CONTINUE
103 CONTINUE
CT=CTS/8.          $CH=CHS/8.
C7=(MX/8.          $CB=CMY/8.
CMXDS=C7/2.        $(MYDS=CB/2.
CTDS=CT/2.
CDUS=C4/2.
CYDS=CYS/16.
CRY=CRS/16.
IF(EC.EQ.3.) B1=CRY/CRK
CQDS=CPS/16.
BP=B1*57.3/9.
BQ=B1/8.
B7(KJ)=BQ
B1=0.
SJ=SK*57.3
15 FORMAT(4X,2HAS,8X,2HTC,8X,2HTB,7X,4HCTDS,6X,4HCDUS,6X,4HCQDS,7X,2H
1SV)
105 CTSS=CTSS+CTDS  $CDSS=CDSS+CDDS  $CQSS=CQSS+CQDS
CMXSS=CMXSS+CMXDS
CMYSS=CMYSS+CMYDS
CYSS=CYSS+CYDS
100 CONTINUE
IF(EC.EQ.3.) GOTO7
IF(EC.GT.0.) GOTO5
7 CONTINUE
DO 3 KJ=1,12
KL=KJ+12
AB=1.
B7(KJ)=AB*(B7(KJ)-B7(KL))/2.
3 B7(KL)=-B7(KJ)
5 CONTINUE
107 CONTINUE
CTSS=CTSS/24.  $CDSS=CDSS/24.  $CQSS=CQSS/24.
CMXSS=CMXSS/24.  $CMYSS=CMYSS/24.  $CYSS=CYSS/24.
CLSS=CTSS*CJS(AA)-CDSS*SIN(AA)
CHSS=CTSS*SIN(AA)+CDSS*CJS(AA)
CTC=C2(IJ)
SS=SM*57.3
ENC=DMJ*CLSS/CQSS
WRITE(6,152)
WRITE(6,16)
WRITE(6,2)
WRITE(6,9)AS,TC,SJ,VT,UMU,CTSS,CDSS,CLSS,CHSS,CQSS,SV,CTC,ENC
WRITE(6,1)SS,CMXSS,CMYSS,CYSS,BQ,SB,AH
16 FORMAT(4X,2HAS,5X,2HTC,7X,2HTB,6X,2HVT,4X,3HJMJ,5X,4HCTSS,8X,4HCDS
1S,8X,4HCLSS,7X,4HCHSS,7X,4HCQSS,7X,2HSSV,7X,3HCTC,6X,3HENC)
9 FORMAT(3F8.2,F8.0,F6.3,5F11.6,F11.3,F11.6,F8.3)

```

```

1 FORMAT(F6.3,6F11.6)
2 FORMAT(2X,2HSS,5X,5HCMXSS,7X,5HCMYSS,7X,4HCYSS)
  C1(IJ)=CTSS
  J9=JJ-5
  IF (J9.EQ.0)GOTO102
  SMF=SMF-.001
99 SV=SV+SMF*VT
  SL=(C1(1)-C2(1)-C1(2)+C2(2))/(E3(1)-E3(2))
  E1=(C1(2)-C2(2))/SL
101 SV=(E3(2)-E1)*VT
102 WRITE(6,152)
  RETURN
  END
  SUBROUTINE PRNT(UX)
  DIMENSION UX(12,7)
  WRITE(6,21)
1 FORMAT(5X,24HLAT CYCLIC EFFECTIVENESS)
2 FORMAT(5X,26HPITCH CYCLIC EFFECTIVENESS)
3 FORMAT(5X,12HROLL DAMPING)
4 FORMAT(5X,13HPITCH DAMPING)
5 FORMAT(5X,16HFORWARD VELOCITY)
6 FORMAT(5X,17HVERTICAL VELOCITY)
7 FORMAT(5X,15HANGLE OF ATTACK)
8 FORMAT(5X,13HSIDE VELOCITY)
9 FORMAT(5X,8HSIDESLIP)
10 FORMAT(5X,16HROTOR COLLECTIVE)
11 FORMAT(5X,11HYAW DAMPING)
12 FORMAT(5X,21HTAIL ROTOR COLLECTIVE)
17 FORMAT(8F15.8)
  DO 20 I=1,12
    IF(I.EQ.1) WRITE(6,1)
    IF(I.EQ.2) WRITE(6,2)
    IF(I.EQ.3) WRITE(6,3)
    IF(I.EQ.4) WRITE(6,4)
    IF(I.EQ.5) WRITE(6,5)
    IF(I.EQ.6) WRITE(6,6)
    IF(I.EQ.7) WRITE(6,7)
    IF(I.EQ.8) WRITE(6,8)
    IF(I.EQ.9) WRITE(6,9)
    IF(I.EQ.10)WRITE(6,10)
    IF(I.EQ.11)WRITE(6,11)
    IF(I.EQ.12)WRITE(6,12)
20 WRITE(6,17)(UX(I,7),(UX(I,J),J=1,6))
21 FORMAT(/)
  WRITE(6,21)
  RETURN
  END
  LIST(STOP)
  LIST
  DATA

```

0.	.21	.42	.63	.85	1.06	1.27	1.32	1.02
.9	.91	.3	.82	.88	.95	1.02	1.05	1.08
1.09	1.09	1.09	1.08	1.06	1.03	1.0	.96	.92
.88	.84	.30	.78	.73	.68	.63	.58	.53
.48	.43	.38	.33	.28	.23	.17	.13	.06

0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33	-.37	L6
.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67	-.70	L7
.73	-.75	-.77	-.78	-.79	-.80	-.81	-.82	-.82	L8
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55	-.47	L9
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46	-.21	L10
0.									L11
.008	.008	.0085	.009	.01	.0125	.017	.038	.16	
.22	.28	.33	.4	.45	.52	.54	.56	.58	
.60	.62	.64	.66	.68	.70	.72	.74	.76	
.78	.92	.94	.86	.88	.90	.92	.94	.96	
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2	1.22	D5
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02	1.	D6
.98	.96	.94	.92	.90	.88	.86	.84	.82	D7
.80	.78	.76	.74	.72	.70	.68	.66	.64	D8
.62	.60	.58	.56	.52	.45	.40	.33	.28	D9
.22	.16	.038	.017	.0125	.01	.009	.0085	.008	D10
.008									D11
.008	.006	.0085	.009	.01	.0125	.017	.038	.16	D21
.22	.28	.33	.4	.45	.52	.54	.56	.58	D22
.008	.008	.0085	.009	.01	.0125	.017	.038	.16	D21
.22	.28	.33	.4	.45	.52	.54	.56	.58	D22
0.	.23	.46	.69	.92	1.08	1.12	1.08	.92	L41
.9	.61	.8	.82	.88	.95	1.02	1.05	1.08	L42
1.09	1.09	1.09	1.09	1.06	1.03	1.	.96	.92	L43
.88	.84	.8	.78	.73	.68	.63	.58	.53	L44
.48	.43	.38	.33	.28	.23	.17	.13	.06	L5
0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33	-.37	L6
.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67	-.70	L7
.73	-.75	-.77	-.79	-.79	-.80	-.81	-.82	-.82	L8
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55	-.47	L9
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46	-.21	L10
0.									L11
.008	.008	.0085	.01	.015	.023	.058	.15	.21	D41
.26	.31	.42	.48	.52	.53	.54	.56	.58	D42
.6	.62	.64	.66	.68	.7	.72	.74	.76	D43
.78	.82	.84	.86	.88	.9	.92	.94	.96	D44
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2	1.22	D5
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02	1.	D6
.98	.96	.94	.92	.90	.88	.86	.84	.82	D7
.80	.78	.76	.74	.72	.70	.68	.66	.64	D8
.62	.60	.58	.56	.52	.45	.40	.33	.28	D9
.22	.16	.038	.017	.0125	.01	.009	.0085	.008	D10
.008									D11
.008	.008	.0085	.01	.015	.023	.058	.15	.21	D41
.26	.31	.42	.48	.52	.53	.54	.56	.58	D42
.008	.008	.0085	.01	.015	.023	.058	.15	.21	D41
.26	.31	.42	.48	.52	.53	.54	.56	.58	D42
0.	.27	.54	.75	.86	.91	.93	.96	.98	L61
.22	.85	.86	.95	1.02	1.12	1.14	1.11	1.08	L62
1.09	1.09	1.09	1.08	1.06	1.03	1.	.96	.92	L63
.88	.84	.88	.78	.73	.68	.63	.58	.53	L64
.48	.43	.38	.33	.28	.23	.17	.13	.06	L5
0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33	-.37	L6
.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67	-.70	L7
.73	-.75	-.77	-.78	-.79	-.80	-.81	-.82	-.82	L8
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55	-.47	L9
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46	-.21	L10
0.									L11
.008	.008	.0092	.019	.05	.10	.19	.24	.29	D61
.35	.41	.48	.55	.55	.53	.54	.56	.58	A-30 D62

.78	.82	.84	.86	.88	.9	.92	.94
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02
.98	.96	.94	.92	.90	.88	.86	.84
.80	.78	.76	.74	.72	.70	.68	.66
.62	.60	.58	.56	.52	.45	.40	.33
.22	.16	.038	.017	.0125	.01	.009	.0085
.008							
.008	.008	.0092	.019	.05	.10	.19	.24
5	341	.48	.55	.55	.53	.54	.56
.008	.008	.0092	.019	.05	.10	.19	.24
5	341	.48	.55	.55	.53	.54	.56
0.	.39	.61	.68	.70	.72	.74	.75
.77	.78	.79	.80	.8	.8	.8	.8
.8	.8	.8	.8	.8	.8	.8	.8
.8	.8	.8	.73	.73	.68	.63	.58
.48	.43	.38	.33	.28	.23	.17	.13
0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33
-.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67
-.73	-.75	-.77	-.78	-.79	-.80	-.81	-.82
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46
0.							
.019	.038	.08	.12	.16	.19	.22	.28
.37	.42	.5	.55	.55	.53	.54	.56
6	.62	.64	.66	.68	.7	.72	.74
78	.82	.84	.86	.88	.9	.92	.94
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02
.98	.96	.94	.92	.90	.88	.86	.84
.80	.78	.76	.74	.72	.70	.68	.66
.62	.60	.58	.56	.52	.45	.40	.33
.22	.16	.038	.017	.0125	.01	.009	.0085
.008							
.019	.038	.08	.12	.16	.19	.22	.28
.37	.42	.5	.55	.55	.53	.54	.56
.019	.038	.08	.12	.16	.19	.22	.28
.37	.42	.5	.55	.55	.53	.54	.56
0.	.2	.4	.56	.58	.59	.60	.60
.67	.7	.78	.82	.88	.95	1.02	1.05
1.09	1.09	1.09	1.08	1.06	1.03	1.	.96
.88	.94	.9	.78	.73	.68	.63	.58
.48	.43	.38	.33	.28	.23	.17	.13
0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33
-.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67
-.73	-.75	-.77	-.78	-.79	-.80	-.81	-.82
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46
0.							
.15	.17	.19	.23	.27	.3	.33	.35
.4	.42	.5	.55	.55	.53	.54	.56
5	.62	.64	.66	.68	.7	.72	.74
.78	.82	.84	.86	.88	.9	.92	.94
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02
.98	.96	.94	.92	.90	.88	.85	.84
.80	.78	.76	.74	.72	.70	.68	.66
.62	.60	.58	.56	.52	.45	.40	.33
.22	.16	.038	.017	.0125	.01	.009	.0085

.6	.62	.64	.66	.68	.7	.72	.74	.76	D63
.78	.82	.84	.86	.88	.9	.92	.94	.96	D64
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2	1.22	D5
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02	1.	D6
.98	.96	.94	.92	.90	.88	.86	.84	.82	D7
.80	.78	.76	.74	.72	.70	.68	.66	.64	D8
.62	.60	.58	.56	.52	.45	.40	.33	.28	D9
.22	.16	.038	.017	.0125	.01	.009	.0085	.008	D10
.008									D11
.008	.008	.0092	.019	.05	.10	.19	.24	.29	D61
5	341	.48	.55	.55	.53	.54	.56	.58	D62
.008	.008	.0092	.019	.05	.10	.19	.24	.29	D61
5	341	.48	.55	.55	.53	.54	.56	.58	D62
0.	.39	.61	.68	.70	.72	.74	.75	.76	L81
.77	.78	.79	.80	.8	.8	.8	.8	.8	L82
.8	.8	.8	.8	.8	.8	.8	.8	.8	L83
.8	.8	.8	.73	.73	.68	.63	.58	.53	L84
.48	.43	.38	.33	.28	.23	.17	.13	.06	L5
0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33	-.37	L6
-.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67	-.70	L7
-.73	-.75	-.77	-.78	-.79	-.80	-.81	-.82	-.82	L8
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55	-.47	L9
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46	-.21	L10
0.									L11
.019	.038	.08	.12	.16	.19	.22	.28	.32	D81
.37	.42	.5	.55	.55	.53	.54	.56	.58	D82
6	.62	.64	.66	.68	.7	.72	.74	.76	D83
.78	.82	.84	.86	.88	.9	.92	.94	.96	D84
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2	1.22	D5
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02	1.	D6
.98	.96	.94	.92	.90	.88	.86	.84	.82	D7
.80	.78	.76	.74	.72	.70	.68	.66	.64	D8
.62	.60	.58	.56	.52	.45	.40	.33	.28	D9
.22	.16	.038	.017	.0125	.01	.009	.0085	.008	D10
.008									D11
.019	.038	.08	.12	.16	.19	.22	.28	.32	D81
.37	.42	.5	.55	.55	.53	.54	.56	.58	D82
.019	.038	.08	.12	.16	.19	.22	.28	.32	D81
.37	.42	.5	.55	.55	.53	.54	.56	.58	D82
0.	.2	.4	.56	.58	.59	.60	.60	.62	L101
.67	.7	.78	.82	.88	.95	1.02	1.05	1.08	L102
1.09	1.09	1.09	1.08	1.06	1.03	1.	.96	.92	L103
.88	.84	.8	.78	.73	.68	.63	.58	.53	L104
.48	.43	.38	.33	.28	.23	.17	.13	.06	L5
0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33	-.37	L6
-.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67	-.70	L7
-.73	-.75	-.77	-.78	-.79	-.80	-.81	-.82	-.82	L8
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55	-.47	L9
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46	-.21	L10
0.									L11
.15	.17	.19	.23	.27	.3	.33	.35	.38	D101
.4	.42	.5	.55	.55	.53	.54	.56	.58	D102
5	.62	.64	.66	.68	.7	.72	.74	.76	D103
.78	.82	.84	.86	.88	.9	.92	.94	.96	D104
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2	1.22	D5
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02	1.	D6
.98	.96	.94	.92	.90	.88	.86	.84	.82	D7
.80	.78	.76	.74	.72	.70	.68	.66	.64	D8
.62	.60	.58	.56	.52	.45	.40	.33	.28	D9
.22	.16	.038	.017	.0125	.01	.009	.0085	.008	D10

.008										D11
15	.17	.19	.23	.27	.3	.33	.35	.38		D101
	.42	.5	.55	.55	.53	.54	.56	.58		D102
.15	.17	.19	.23	.27	.3	.33	.35	.38		D101
.4	.42	.5	.55	.55	.53	.54	.56	.58		D102
7.	0.	745.	.0651	-.1	0.	2.	22.	.00222		
-3.	-.5	6.	27.	745.	.105	4.3	18.5	10.9		
600.	24.	0.								
7.	0.	745.	.0651	-.1	0.	2.	22.	.00222		
-3.	0.	6.	27.	745.	.105	4.3	18.5	10.9		
600.	24.	2.								
7.	0.	745.	.0651	-.1	0.	2.	22.	.00222		
-3.	0.	6.	27.	745.	.105	4.3	18.5	10.9		
600.	24.	.15								
PROB										

APPENDIX B
PROGRAM FOR SOLUTION OF
LONGITUDINAL EQUATIONS

TABLE B.1

EXPANSION OF LONGITUDINAL DETERMINANT

$$\begin{array}{ccc}
 \frac{\mu}{C_{x_{\mu}} - \frac{m'}{v} s} & \frac{\alpha}{C_{x_{\alpha}}} & \frac{\theta}{-C_L} \\
 \\
 C_{Z_{\mu}} & C_{Z_{\alpha}} + (C_{Z_{\alpha}} - m)s & + (C_{Z_{\theta}} + m')s \\
 \\
 C_{m_{\mu}} & C_{m_{\alpha}} + C_{m_{\alpha}} s & C_{m_{\theta}} s - I y s^2
 \end{array}$$

	$\Lambda' s^4$	$B' s^3$	$C' s^2$	$D' s$	E'
BASE VALUES	$-\frac{m'^2}{v} I y'$	$-C_{Z_{\alpha}} C_{x_{\mu}} I y'$	$C_{Z_{\mu}} C_{x_{\alpha}} I y'$	$C_{x_{\alpha}} C_{m_{\mu}} C_{Z_{\theta}}$	$-C_{Z_{\mu}} C_L C_{m_{\alpha}}$
	$\frac{m'}{v} C_{Z_{\alpha}} I y'$	$C_{x_{\mu}} m' I y'$	$-C_{x_{\mu}} C_{Z_{\alpha}} I y'$	$C_{x_{\alpha}} C_{m_{\mu}} m'$	$C_{m_{\mu}} C_L C_{Z_{\alpha}}$
		$\frac{m'}{v} C_{m_{\theta}}$	$C_{Z_{\alpha}} C_{x_{\mu}} C_{m_{\theta}}$	$-C_L C_{Z_{\mu}} C_{m_{\alpha}}$	
		$\frac{m'}{v} C_{Z_{\alpha}} I y'$	$-C_{x_{\mu}} C_{m_{\theta}} m'$	$C_{m_{\mu}} C_L C_{Z_{\alpha}}$	
		$-\frac{m'}{v} C_{Z_{\alpha}} C_{m_{\theta}}$	$-\frac{m'}{v} C_{Z_{\alpha}} C_{m_{\theta}}$	$-C_{m_{\mu}} C_L m'$	
		$\frac{m'}{v} C_{m_{\alpha}} C_{Z_{\theta}}$	$-C_{x_{\mu}} C_{m_{\alpha}} C_{Z_{\theta}}$	$-C_{Z_{\mu}} C_{x_{\alpha}} C_{m_{\theta}}$	
		$\frac{m'^2}{v} C_{m_{\alpha}}$	$-C_{x_{\mu}} C_{m_{\alpha}} m'$	$-C_{m_{\alpha}} C_{x_{\mu}} C_{Z_{\theta}}$	
			$\frac{m'}{v} C_{m_{\alpha}} C_{Z_{\theta}}$	$-C_{m_{\alpha}} C_{x_{\mu}} m'$	
			$\frac{m'^2}{v} C_{m_{\alpha}}$		

TABLE B.1 (Continued)
EXPANSION OF LONGITUDINAL DETERMINANT
PITCH CONTROLLER TERMS

	A's ⁴	B's ³	C's ²	D's	E'	
θ SAS CONTRIBUTIONS	Gain C52		$\frac{m'^2}{v} C_{m_{B1}}$	$C_{Z_\alpha} C_{x_\mu} C_{m_{B1}}$	$C_{x_\alpha} C_{m_\mu} C_{Z_{B1}}$	$\frac{dB_1}{d\theta}$
			$\frac{m'}{v} C_{m_\alpha} C_{Z_{B1}}$	$-C_{x_\mu} m' C_{m_{B1}}$	$-C_{Z_\mu} C_{x_\alpha} C_{m_{B1}}$	
			$-\frac{m'}{v} C_{Z_\alpha} C_{m_{B1}}$	$-\frac{m'}{v} C_{Z_\alpha} C_{m_{B1}}$	$C_{Z_\alpha} C_{x_\mu} C_{m_{B1}}$	
				$-C_{x_\mu} C_{m_\alpha} C_{Z_{B1}}$	$-C_{m_\alpha} C_{x_\mu} C_{Z_{B1}}$	
				$\frac{m'}{v} C_{m_\alpha} C_{Z_{B1}}$	$-C_{Z_\mu} C_{m_\alpha} C_{x_{B1}}$	
				$-C_{Z_\mu} C_{m_\alpha} C_{x_{B1}}$	$C_{m_\mu} C_{Z_\alpha} C_{x_{B1}}$	
				$C_{m_\mu} C_{Z_\alpha} C_{x_{B1}}$		
				$-C_{m_\mu} m' C_{x_{B1}}$		
	C_{51}		3*	2	1	$\frac{dB_1}{d\dot{\theta}}$
	C_{50}		3	2	1	$\frac{dB_1}{d\ddot{\theta}}$

* Note triangular relationship between
 θ $\dot{\theta}$ $\ddot{\theta}$ SAS Contribution

TABLE B.1
EXPANSION OF LONGITUDINAL DETERMINANT
(Continued)

		A's ⁴	B's ³	C's ²	D's	E'
α SAS CONTRIBUTIONS	GAINS		$\frac{m'}{v} I y' C_{Z_{B1}}$	$-C_{x_{\mu}} I y' C_{Z_{B1}}$	$C_{x_{\mu}} C_{m_{\theta}} C_{Z_{B1}}$	$-C_{Z_{\mu}} C_L C_{m_{B1}}$
	C ₁₅			$\frac{m^L}{v} C_{m_{\theta}} C_{Z_{B1}}$	$-C_{x_{\mu}} C_{Z_{\theta}} C_{m_{B1}}$	$C_{m_{\mu}} C_L C_{Z_{B1}}$
				$\frac{m'}{v} C_{Z_{\theta}} C_{m_{B1}}$	$-m' C_{x_{\mu}} C_{m_{B1}}$	
				$\frac{m'^2}{v} C_{m_{B1}}$		
			4	3	2	1
	C ₁₆	4	3	2	1	
	C ₁₇	3	2	1		

$$\frac{dB_1}{d\alpha}$$

$$\frac{dB_1}{d\ddot{\alpha}}$$

$$\frac{dB_1}{d\ddot{\alpha}}$$

* Note triangular relationship between
α α̇ α̈⁽¹⁾ SAS Contribution

(1) Quintic

LIST(START)

SOLUTION OF LONGITUDINAL EQUATIONS

THIS PROGRAM EVALUATES THE LONGITUDINAL STABILITY QUARTIC COEFFICIENTS A,B,C,D,E. OBTAINS THE RESULTING ROOTS, PERIOD AND TIME TO DAMP TO HALF AMPLITUDE. TO OBTAIN SATISFACTORY STABILITY AUTOPILOT GAINS $C50=B1/TDD$, $C51=B1/TD$, AND $C52=B1/THETA$ MAY BE USED.

THE REQUIRED INPUT CARDS AND PROPER COLUMNS ALONG WITH THE SYMBOLS AND IDENTIFICATION ARE PRESENTED BELOW.

CARD	COLUMN	SYMBOL	
1	1-15	PM	MASS M*V/G*AD
1	16-30	V	VELOCITY FT/SEC
1	31-45	CL1	LIFT COEFFICIENT W/G*AD AD DISC AREA
1	46-60	ALPH	ANGLE OF ATTACK
1	61-75	YI	MOMENT OF INERTIA IYY/G*AD*ROTR
2	1-15	CXU	STABILITY DERIVATIVE DCX/DU
2	16-30	CXA	DCX/DALPHA
2	31-45	CZU	
2	46-60	CZA	
2	61-75	CZAD	
3	1-15	CZTD	
3	16-30	CMU	FOR STABILITY DERIVATIVES SEE HELIO 4
3	31-45	CMA1	
3	61-75	CMTD1	
4	1-15	CZTC	COLLECTIVE PITCH CONTROL EFFECT
4	16-30	CMTC	COLLECTIVE PITCH
4	31-45	CZR1	CYCLIC PITCH
4	46-60	CMR1	CYCLIC PITCH
4	61-75	CM1	HORIZONTAL TAIL
4A	1-15	CXI	
5	1-15	FM	AUTOPILOT GAIN
5	16-30	GV	AUTOPILOT GAIN
5	31-45	C50	AUTOPILOT COEFFICIENT S2
5	46-60	C51	
5	460-75	C52	
6	1-10		MORE=1 NEW GAINS, -1 NEW SFT, 0 END

TYPICAL INPUTS ARE

C,000194	1.	.0062	0.	.00051
C=.0000042	.0000079	-.000009	-.000043	0.
C0.	.000000078	.000000008	0.	.000000022
C=-.041	.00000336	0.	-.0013	0.
C,0045				
C0.	0.	0.	0.	0.
C1				
C1.	1.	1.	2.	4.
C=1				
C1,26	100.	.405	0.	.033
C,000486	.05207	-.000173	-.793	0.
C0.	.00035	-.0427	-.00088	-.13
C=3.14	.155	.793	-.168	-.0144
C,353				
C0.	0.	0.	0.	0.
C0				

PROB

DIMENSION XCOF(11),COF(11),ROOTR(10),ROOTI(10)

```

COMMONXCOF,COF,M,ROOTR,ROOTI,IER
M=4
98 CONTINUE
  READ(5,6)PM,V,CL1,ALPH,YI
  READ(5,6)CXJ,CXA,CZU,CZA,CZAD
  READ(5,6)CZTD1,CMU,CMA1,CMAD,CMTD1
  READ(5,6)CZTC,CMTC,CZB1,CMB1,CM1
  READ(5,6)CXI
  1 FORMAT(7F10.6)
  WRITE(6,2)
  2 FORMAT(5X,48HAIRCRAFT GA INPUTS IN ORDER ARE PM,V,CL1,ALPH,YI)
  WRITE(6,6)PM,V,CL1,ALPH,YI
  WRITE(6,3)
  3 FORMAT(2X,74HCXU,CXA,CZU,CZA,CZAD,CZTD1,CMU,CMA1,CMAD,CMTD1,CZTC,
1MTC,CZB1,CMB1,CM1,CXI)
  WRITE(6,6)CXU,CXA,CZU,CZA,CZAD
  WRITE(6,6)CZTD1,CMU,CMA1,CMAD,CMTD1
  WRITE(6,6)CZTC,CMTC,CZB1,CMB1,CM1
  WRITE(6,6)CXI
  CM1=CMB1+CM1
  CZI=CZB1
  YI1=YI
97 CONTINUE
  READ(5,1)FM,GV,C50,C51,C52
  WRITE(6,1)FM,GV,C50,C51,C52
  FG=FM*GV
  YI=YI1-FG*CM1*C50
  C12=FG*C52
  C13=FG*C51
  C14=0
  C15=FG*C50
  A=CXU
  B=CZU
  CMTD=CMTD1+C13*CM1
  CZTD=CZTD1+C13*CZI
  C=CXA
C  WHEN V=0 PM=M/Q*AD  Q=RH0*VTIP*VTIP  USE CZW ETC.
  IF(V=1.)9,9,8
  8 F=CZTD+PM
  GOTO10
  9 F=CZTD
10 CONTINUE
  D=CZAD-PM
  E=CZA+C14*CZI
  CMA=CMA1+C14*CM1
  A1=PM*D*YI/V
  B1=-(A*D*YI)-PM*D*CMTD/V*PM*YI*F/V*PM*F*CMAD/V
  C1=A*D*CMTD-A*E*YI-PM*E*CMTD/V*PM*F*CMA/V-A*F*CMAD
  C1=C1+B*C*YI+C12*PM*(CZI*CMAD-CM1*D)/V
  D1=A*E*CMTD-A*F*CMA+C*F*CMU
  D1=D1-B*C*CMTD-B*CL1*CMAD
  D1=D1+D*CL1*CMU
  D1=D1+C12*PM*(CMA*CZI-E*CM1)/V+C12*A*(D*CM1-C*AD*CZI)
  E1=-(B*CMA*CL1)+E*G 1*CMU
  E1=E1+C12*A*(E*CM1-CMA*CZI)+C12*C*(CMU*CZI-B*CM1)
  C90=CZA*CMU-CZY*CMA
  C91=D*CMU-CZU*CMAD
  E1=E1+C12*CXI*C90
  D1=D1+C12*CXI*C91
  C1=C1+C13*CXI*C91

```

```

D1=D1+C13*CXI*C90
A1=A1+C15*CZI*CMAD*PM/V-C15*CM1*D*PM/V
B1=B1+C15*CZI*((PM/V)*CMA-(CXU*CMAN)+C15*CM1*(CXU*D-CZA*PM/V)+C15*C
1XI*C91
C1=C1+C15*CZI*(CMU*CXA-CMA*CXU)+C15*CM1*(CXU*CZA-CZU*CXA)+C15*CXI*
1C90
A2=1,
B2=B1/A1
C2=C1/A1
D2=D1/A1
E2=E1/A1
XCOF(1)=E2
XCOF(2)=D2
XCOF(3)=C2
XCOF(4)=B2
XCOF(5)=A2
5 FORMAT(2X,43HQUARTIC COEFFICIENTS ARE IN ORDER A,B,C,D,E)
WRITE(6,5)
WRITE(6,6)A,B,C,D,E
WRITE(6,6)A1,B1,C1,n1,E1
WRITE(6,6)A2,B2,C2,n2,E2
6 FORMAT(5E15,8)
WRITE(6,1)C12,C13,C14
CALL ROLRT(XCOF,COF,M,ROOTR,ROOTI,IER)
WRITE(6,7)
7 FORMAT(8X,9HREAL ROOT,8X,10HIMAG, ROOT,8X,6HPERIOD,9X,12HTIME TO W
1ALF)
DO20 I=1,4
IF(ROOTI(I))81,80,81
80 P=200000.
GOTO82
81 P=2,*.3,14/ROOTI(I)
82 D=.69/ROOTR(I)
20 WRITE(6,11)ROOTR(I),ROOTI(I),P,n
READ(5,29)MORE
29 FORMAT(15)
IF(MORE)98,30,97
30 IER=2
11 FORMAT(5X,6E17,8)
END
SUBROUTINE ROLRT(XCOF,COF,M,ROOTR,ROOTI,IER)
DIMENSION XCOF(10),COF(10),ROOTR(10),ROOTI(10)
IF I=0
N=M
IER=0
IF(XCOF(N+1),10,25,10
10 IF(N)15,15,32
15 IER=1
20 RETURN
25 IER=4
GOTO20
30 IER=0
GOTO20
32 IF(N-36)35,35,30
35 NX=N
NXX=N+1
N2=1
KJ1=N+1
DO40 L=1,KJ1
MT=KJ1-L+1

```

```

40 COF(MT)=XCOF(L)
45 XO=,00500101
   YO=,01000101
   IN=U
50 X=XO
   XO=-10.*YO
   YO=-10.*X
   X=XO
   Y=YO
   IN=IN+1
   GOT059
55 IFIT=1
   XPR=X
   YPR=Y
59 ICT=0
60 UX=0,
   UY=0,
   V=0,
   YT=0,
   XT=1,
   U=COF(N+1)
   IF(U)65,130,65
65 DO70I=1,N
   L=N-I+1
   XT2=X*XT-Y*YT
   YT2=X*YT+Y*XT
   U=U+COF(L)*XT2
   V=V+COF(L)*YT2
   FI=I
   UY=UY-FI*YT*COF(L)
   UX=UX+FI*XT*COF(L)
   XT=XT2
70 YT=YT2
   SUMSQ=UX*UX+UY*UY
   IF(SUMSQ)75,110,75
75 DX=(V*UY-U*UX)/SUMSQ
   X=X+DX
   DY=-(U*UY+V*UX)/SUMSQ
   Y=Y+DY
78 IF(ABS(DY)+ABS(DX)-.000001)100,80,80
80 ICT=ICT+1
   IF(ICT-500)60,85,85
85 IF(IFIT)100,90,100
90 IF(IN-5)50,95,95
95 IER=3
   GOT020
100 DO105L=1,NXX
   MT=KJ1-L+1
   TEMP=XCOF(MT)
   XCOF(MT)=COF(L)
105 COF(L)=TEMP
   ITEMP=N
   N=NX
   NX=ITEMP
   IF(IFIT)120,55,120
110 IF(IFIT)115,50,115
115 X=XPR
   Y=YPR
120 IFIT=0
122 IF(ABS(Y/X)-0.000001)135,125,125

```

```

125 ALPHA=X*X
    SUMSQ=X*X+Y*Y
    N=N+2
    GOTO140
130 X=0
    NX=NX
    NXX=NXX+1
135 Y=0
    SUMSQ=0,
    ALPHA=X
    N=N+1
140 COF(2)=COF(2)+ALPHA*COF(1)
    IF(N-2)147,146,146
147 NN=2
    GOTO145
146 NN=N
145 DO150L=2,NN
    M11=L+1
150 COF(M11)=COF(M11)+ALPHA*COF(L)-SUMSQ*COF(L-1)
155 ROOT1(N2)=Y
    ROOTR(N2)=X
    N2=N2+1
    IF(SUMSQ)160,165,160
160 Y=-Y
    SUMSQ=0,
    GOTO155
165 IF(N)20,20,45
    RETURN
    END

```

```

* LIST(STOP)
* LIST

```

```

* DATA

```

.000194	1.	.00062	0.	.00051
-.0000042	.0000079	-.000009	-.000043	0.
0.	.000000078	.000000008	0.	.00000022
-.041	.00000336	0.	-.0013	0.
.0045				
0.	0.	0.	0.	
1				
1.	1.	1.	2.	4.
-1				
1.26	100.	.405	0.	.033
.000486	.05207	-.000173	-.793	0.
0.	.00035	-.0427	-.00088	-.13
-3.14	.155	.793	-.168	-.0144
.353				
0.	0.	0.	0.	
0				

```

PROB

```

APPENDIX C
LONGITUDINAL TRANSLATION MOTION PROGRAM

LONGITUDINAL MOTION

1	1-15	PM	MASS M*V/C*AD		
1	16-30	V	VELOCITY	FT/SEC	
1	31-45	CL1	LIFT COEFFICIENT	W/Q*AD	AD DISC AREA
1	46-60	ALPH	ANGLE OF ATTACK		
1	61-75	YI	MOMENT OF INERTIA	IYY/Q*AD*ROTR	
2	1-15	CXU	STABILITY DERIVATIVE	DCX/DU	
2	16-30	CXA		DCX/DALPHA	

3	31-45	CMA1	
3	61-75	CMTD1	
4	1-15	CZTC	COLLECTIVE PITCH CONTROL EFFECT
4	16-30	CMTC	COLLECTIVE PITCH
4	31-45	CZB1	CYCLIC PITCH
4	46-60	CMB1	CYCLIC PITCH
4	61-75	CM1	HORIZONTAL TAIL EFFECTIVENESS

5	01-10	RTU
5	16-30	RTL
3	21-30	GVII
5	31-40	GVL
6	01-10	FM
6	11-20	C50
6	21-30	C51
5	31-40	C52
6	41-50	SG

0 END, -1 NEW PM, 1 NEW GAIN

FWD VEL)	ALPHA	THETA	
XU*U	XAVA	-CL*T	=MU*UD
ZU*U	ZAA+A*ZAD*AD	ZTD*T	=M*(WD-V*TD)
MU*U	MAA+A*MAD*AD	MTD*T	=I*Y*TD

FWD VEL,	ANGLE OF ATTACK	PITCH
CXU-(PM/V)*S	CXA	-CL
CZU	CZA +(CZAD-PM)*S	(CZTD+PM)*S
CMU	CMA +CMAD*S	CMTD*S +YI*S*S

DETERMINANT FÖR HÖVER $V=0$

FWD VEL.	VERTICAL VEL.	PITCH
CXU-PM*S	CXU	CL
CZU	CZW + (CZWD PM)*S	CZTD*S
CMU	CMW + CMWD*S	CMTD*S-YI*S*S

```

97 CONTINUE
   READ(5,7)PM,V,CL1,A_PM,YI
   READ(5,7)CXJ,CXA,CZJ,CZA,CZAD
   READ(5,7)CZTD1,CMU,CMA1,CMAJ,CMTD1

```

```

      READ(5,7)CZTC,CMTC,CZB1,CMB1,CM1
      READ(5,7)CX1
7     FORMAT(5E15.8)
1     FORMAT(7F10.6)
      WRITE(6,100)
100    FORMAT(5X,48HAI RCRAFT GA INPUTS IN ORDER ARE PM,V,CL1,ALPH,YI)
      WRITE(6,7)PM,V,CL1,ALPH,YI
      WRITE(6,101)
101    FORMAT(2X,74HCXU,CXA,CZU,CZA,CZAD,CZTD1,CMU,CMA1,CMAD,CMTD1,CZTC,C
      1MTC,CZB1,CMB1,CM1,CX1)
      WRITE(6,7)CXU,CXA,CZU,CZA,CZAD
      WRITE(6,7)CZTD1,CMU,CMA1,CMAD,CMTD1
      WRITE(6,7)CZTC,CMTC,C7B1,CMR1,CM1
      WRITE(6,7)CX1
      CZTD=CZTD1
      CMA=CMA1
      CMTD=CMTD1
      CMDE=CMB1+CM1
      CZDE=CZB1
      TV=0,
      V9=V
98     READ(5,1)RTJ,RTL,GVJ,GVL
      READ(5,1)FM,C50,C51,C52,SG
      WRITE(6,102)RTU,RTL,GVU,GVL
102    FORMAT(5X,4HRTU=,F9.3,1X,4HRTL=,F9.3,1X,4HGVU=,F9.3,1X,4HGVL=,F9.3
      1)
      WRITE(6,103)FM,C50,C51,C52
103    FORMAT(5X,3HFM=,F9.4,1X,4HC50=,F9.4,1X,4HC51=,F9.4,1X,4HC52=,F9.4)
      V=V9
      DD1=0,
      TDD2=0,
      GV=0,
      DD2=0,
      TH0=0,
      THD=0,
      ALD=0,
      VD=0,
      TM=0,
      DTM=.05
      CD=0,
      DL=DTM/2,
      DEMX=1./57.3
      N=0
      TH=TH0
      AO=TH
      VO=V
      AL=AO
C      WHEN V=0 PM=M/G*AD Q=RHO*VTIP*VTIP USE CZW ETC.
      IF(VO)8,9,8
8      F10=VO/PM
      GOT010
9      F10=1./PM
10     CONTINUE
      F11=PM-CZAD
      DO 80 I=1,800
      CD1=CD
      IF(TM-.5)70,71,72
70     CD=TM/.5
      GOT0 75
71     CD=1,

```

```

72 IF (TM-1, ) 73, 74, 74
73 CD=(1,-TM)/.5
   GOTO 75
74 CD=0,
75 DE=CD1*DEMX
   DA=AL-AO
   DV=V-VO
   DTH=TH-THO
   RT=ABS((DD2-DD1)/DTM)
   IF (RT-RTU) 201, 200, 200
200 GV=GVU
   GOTO 204
201 IF (RT-RTL) 202, 202, 203
202 GV=GVL
   GOTO 204
203 GV=GVL+((RT-RTL)/(RTU-RTL))*(GVU-GVL)
204 CONTINUE
   IF (TM-1, ) 350, 350, 351
350 GV=0,
351 CONTINUE
   FG=FM*GV
   VD1=(CXU*DV+CXA*DA-CL1*DTH+FG*CXI)*(C50*TDD2+C51*THD+
   ALD1=(CZU*DV+CZA*DA+CZTD*PM+C51*FG*CZDF)*THD+C52*F1
   1*(DE+C50*TDD2*FG))/F11
   TDD1=(CMU*DV+CMA*DA+CMAD*ALD1+(CMTD+C51*FG*CMDE)*TH
   1FG*TH)*TV)/(Y1-C50*FG*CMDF)
   DD1=FM*GV*(C50*TDD2+C51*THD+C52*TH)
   DD15=ABS(DD1)
   IF (DD15-.26) 41, 40, 40
40 DD1=.26*DD1/DD15
   VD1=(CXU*DV+CXA*DA-CL1*DTH+CXI*(DD1+DE))*F10
   ALD1=(CZU*DV+CZA*DA+CZTD*THD+CZDE*(DD1+DE))/F11
   TDD1=(CMU*DV+CMA*DA+CMTD*THD+CMDE*(DD1+DE))/Y1
41 CONTINUE
   V1=V+VD1*DL
   AL1=AL+ALD1*DL
   TD1=THD*TDD1*DL
   T1=TH+THD*DL+.5*TDD1*DL*DL
   V2=V1+VD1*DL
   AL2=AL1+ALD1*DL
   TD2=TD1+TDD1*DL
   T2=T1+THD*DL+.5*TDD1*DL*DL
   DA=AL2-AO
   DV=V2-VO
   DTH=T2-THO
   DE=CD*DEMX
   DD1=FM*GV*(C50*TDD1+C51*TD1+.52*T1)
   RT=ABS((DD1-DD2)/DTM)
   IF (RT-RTU) 301, 300, 300
300 GV=GVU
   GOTO 304
301 IF (RT-RTL) 302, 302, 303
302 GV=GVL
   GOTO 304
303 GV=GVL+((RT-RTL)/(RTU-RTL))*(GVU-GVL)
304 CONTINUE
   IF (TM-1, ) 2, 2, 6
2 GV=0,
6 CONTINUE

```

```

GOTO 75
72 IF (TM-1.) 73, 74, 74
73 CD=(1.-TM)/.5
GOTO 75
74 CD=0.
75 DE=CD1*DEMX
DA=AL-A0
DV=V-V0
DTH=TH-TH0
RT=ABS((DD2-DD1)/DTM)
IF (RT-RTU) 201, 200, 200
200 GV=GVU
GOTO 204
201 IF (RT-RTL) 202, 202, 203
202 GV=GVL
GOTO 204
203 GV=GVL+((RT-RTL)/(RTU-RTL))*(GVU-GVL)
204 CONTINUE
IF (TM-1.) 350, 351, 351
350 GV=0.
351 CONTINUE
FG=FM*GV
VD1=(CXU*DV+CXA*DA-CL1*DTH+FG*CXI*(C50*TDD2+C51*THD+C52*TH))*F10
ALD1=(CZU*DV+CZA*DA+CZTD*THD+C51*FG*CZDF)*THD+C52*FG*CZDE*TH+CZDF
1*(DE+C50*TDD2*FG))/F11
TDD1=(CMU*DV+CMA*DA+CMAD*ALD1*(CMTD+C51*FG*CMDE)*THD+CMDE*(DF+C52*
1FG*TH)*TV)/(YI-C50*FG*CMDF)
DD1=FM*GV*(C50*TDD2+C51*THD+C52*TH)
DD15=ABS(DD1)
IF (DD15=.26) 41, 40, 40
40 DD1=.26*DD1/DD15
VD1=(CXU*DV+CXA*DA-CL1*DTH+CXI*(DD1+DE))*F10
ALD1=(CZU*DV+CZA*DA+CZTD*THD+CZDE*(DD1+DE))/F11
TDD1=(CMU*DV+CMA*DA+CMTD*THD+CMDE*(DD1+DE))/YI
41 CONTINUE
V1=V+VD1*DL
AL1=AL+ALD1*DL
TD1=THD*TDD1*DL
T1=TH+THD*DL+.5*TDD1*DL*DL
V2=V1+VD1*DL
AL2=AL1+ALD1*DL
TD2=TD1+TDD1*DL
T2=T1+THD*DL+.5*TDD1*DL*DL
DA=AL2-A0
DV=V2-V0
DTH=T2-TH0
DE=CD*DEMX
DD1=FM*GV*(C50*TDD1+C51*TD1+.52*T1)
RT=ABS((DD1-DD2)/DTM)
IF (RT-RTU) 301, 300, 300
300 GV=GVU
GOTO 304
301 IF (RT-RTL) 302, 302, 303
302 GV=GVL
GOTO 304
303 GV=GVL+((RT-RTL)/(RTU-RTL))*(GVU-GVL)
304 CONTINUE
IF (TM-1.) 2, 2, 6
2 GV=0.
6 CONTINUE

```

```

FG=FM*GV
VD2=(CXU*DV+CXA*DA-CL1*DTH+FG*CXI*(C52*DTH+C51*THD+C50*TDD1))*F10
ALD2=(CZU*DV+CZA*DA+(CZTD+PM+C51*FG*CZDE)*TD2+C52*FG*CZDE*T2+CZDF*
1(DE+C50*TDD1*FG))/F11
TDD2=(CMU*DV+CMA*DA+CMAD*ALD2+(CMTD+C51*FG*CMDE)*TD2*CMDE*(DE+C52*
1FG*T2)+TV)/(YI-C50*FG*CMDE)
DD2=FM*GV*(C50*TDD1+C51*THD+C52*DTH)
DD15=ABS(DD2)
IF(DD15=.26)43,42,42
42 DD2=.26*DD2/DD15
VD2=(CXU*DV+CXA*DA-CL1*DTH+CXI*(DD2+DE))*F10
ALD2=(CZU*DV+CZA*DA+CZTD*TD2+CZDE*(DD2+DE))/F11
TDD2=(CMU*DV+CMA*DA+CMAD*ALD2+CMTD*TD2*CMDE*(DD2+DE))/YI
43 CONTINUE
V=V1+VD2*DL
AL=AL1+ALD2*DL
THD=TD1+TDD2*DL
TH=T1+TD1*DL+.5*TDD2*DL*DL
THP=57.3*TH
IF(V)11,12,11
11 ALP=57.3*AL
GP=THP-ALP
GOTO13
12 ALP=0.
GP=THP-ALP
ALP=AL
13 CONTINUE
GL=ABS(GP)
IF(GL=90.)79,81,81
79 CONTINUE
IF(N=1)20,20,21
20 N=N+1
GOTO 80
21 N=0
DD2=FM*GV*(C50*TDD2+C51*THD+C52*TH)
DX=57.3*DD2
DX1=57.3*DD1
IF(V)606,607,606
606 WRITE(6,104)TM,V,DX1,DX,ALP,THP,GP
GOTO608
607 WRITE(6,605)TM,V,DX1,DX,ALP,THP,GP
608 CONTINUE
104 FORMAT(3X,3HTM=,F6,2,1X,2HV=,F5,1,1X,4HDX1=,F9.5,1X,4H DX=,F9.5,1X
1,4HALP=,F10.6,1X,4HTHP=,F10.6,1X,3HGP=,F10.6)
605 FORMAT(3X,3HTM=,F6,2,1X,2HV=,F5,1,1X,4HDX1=,F9.5,1X,4H DX=,F9.5,1X
1,4H W=,F10.6,1X,4HTHP=,F10.6,1X,3HTM=,F10.6)
80 TM=TM*DTM
81 IF(SG)97,30,98
30 CONTINUE
END
* LIST(STOP)
* LIST
* DATA
,000194      0.      ,0062      0.      ,00051
-,0000042    ,0000079    -,0000009    -,000043    0.
0.          ,000000078    ,000000008    0.      -,0000043
-,041        ,00000336    0.      -,0013      0.
,0045
10.          1.          0.          0.
4.           1.          2.          4.          1.

```

APPENDIX D
PROGRAM FOR SOLUTION OF
LATERAL EQUATIONS

$$\begin{array}{ccc}
 \psi & \phi & \psi \\
 C_{YV} - \frac{m'}{V} s & C_L & (-m + C_{Y\psi}) s \\
 C_{L\psi} & s C_{L\phi} - I'_X s^2 & C_{L\psi} s \\
 C_{\eta\psi} & C_{\eta\phi} s & C_{\eta\psi} s - I'_Z s^2
 \end{array}$$

	A's ²	B's ³	C's ²	D's	E'
BASE VALUES	$-\frac{m'}{V} I'_X I'_Z$	$C_{YV} I'_X I'_Z$ $\frac{m'}{V} (I'_Z C_{L\phi} + I'_X C_{\eta\psi})$	$-C_{YV} (I'_Z C_{L\phi} + I'_X C_{\eta\psi})$ $\frac{m'}{V} (C_{L\phi} C_{\eta\psi} - C_{L\psi} C_{\eta\phi})$ $C_{L\psi} I'_Z C_{Y\phi}$ $C_{\eta\psi} I'_X C_{Y\psi}$ $-m C_{\eta\psi} I'_X$	$C_{YV} (C_{L\phi} C_{\eta\psi} - C_{L\psi} C_{\eta\phi})$ $C_{L\psi} (C_L I'_Z - C_{Y\phi} C_{\eta\psi} + C_{Y\psi} C_{\eta\phi})$ $C_{\eta\psi} (C_{Y\phi} C_{L\psi} - C_{Y\psi} C_{L\phi})$	$C_{\eta\psi} C_L C_L C_{L\psi}$ $-C_{L\psi} C_L C_{\eta\psi}$
SAS CONTRIBUTIONS GAIN C ₆₀			$\frac{m'}{V} I'_Z C_{LA1}$	$-C_{YV} I'_Z C_{LA1}$ $-\frac{m'}{V} C_{\eta\phi} C_{LA1}$ $\frac{m'}{V} C_{L\psi} C_{\eta A1}$ $C_{L\psi} I'_Z C_{YA1}$	$m' C_{\eta\psi} C_{LA1}$ $C_{YV} C_{\eta\psi} C_{LA1}$ $C_{YV} C_{L\psi} C_{\eta A1}$ $C_{L\psi} C_{Y\psi} C_{\eta A1}$ $-m' C_{L\psi} C_{\eta A1}$ $C_{L\psi} C_{\eta\psi} C_{YA1}$ $C_{\eta\psi} C_{L\psi} C_{YA1}$ $C_{\eta\psi} C_{Y\psi} C_{LA1}$
		(1)	(1)	(2)	(3)
	C ₆₁	(1)	(2)	(3)	
	C ₆₂ (1)	(2)	(3)		
SAS CONTRIBUTIONS	C ₇		(5)	(5)	(7)
	C ₈	(5)	(6)	(7)	(8)
		(6)	(7)	(8)	
	$\frac{m'}{V} I'_X C_{\eta\theta TR}$	$-C_{YV} I'_X C_{\eta\theta TR}$ $-\frac{m'}{V} C_{L\phi} C_{\eta\theta TR}$ $-\frac{m'}{V} C_{\eta\phi} C_{L\phi}$ $C_{\eta\psi} I'_X C_{Y\theta TR}$	$C_{YV} C_{L\phi} C_{\eta\theta TR}$ $-C_{YV} C_{\eta\psi} C_{L\theta TR}$ $C_{L\psi} C_{\eta\phi} C_{Y\theta TR}$ $-C_{L\psi} C_{Y\phi} C_{\eta\theta TR}$ $C_{\eta\psi} C_{Y\phi} C_{L\theta TR}$ $-C_{\eta\psi} C_{L\phi} C_{Y\theta TR}$	$C_{YV} C_L C_{L\theta TR}$ $C_{L\psi} C_L C_{\eta\theta TR}$	
C ₉					

*NOTE TRIANGULAR RELATIONSHIP

$$\begin{array}{ccc}
 \phi & \phi & \phi \\
 (1) & \psi & \psi \\
 & \psi & \psi
 \end{array}$$

(1) QUINTIC

TABLE D.1 Expansion of Lateral-Directional Derivatives

LIST(START)

SOLUTION OF LATFRAI' EQUATIONS

	SV	SY	T
	-PM(S)+CYV	(-PM*V+CYSD)(S)	CYTD(S)+CL
	CLV	CLSD(S)	-XI(S**2)+CLTD(S)
	CNV	-ZI(S**2)+CNSD(S)	CNTD(S)

CARD	COLUMN	SYMBOL			
1	01-15	PM			
1	11-20	V	VELOCITY	FT/SEC	
1	21-30	CL1	LIFT COEFFICIENT	W/Q*AD	AD DISC AREA
1	31-40	XI	MOMENT OF INERTIA	IXX/Q*AD*ROTR	
1	41-50	ZI	MOMENT OF INERTIA	IZZ/Q*AD*ROTR	
2	1-10	CYV			
2	11-20	CLV			
2	21-30	CNV			
2	31-40	CYSD			
2	41-50	CLSD			
2	51-60	CNSD			
2	61-70	CYPHD			
3	1-10	CLPHD			
3	11-20	CNPHD			
3	21-30	CYDS			
3	31-40	CLDS			
3	41-50	CNDS			
4	1-10	CYDR			
4	11-20	CLDR			
4	21-30	CNDR			
5	1-10	FM	MODEL GAIN		
5	11-20	GV	GAIN		
5	21-30	C60	AUTOPILOT COEFFICIENT S2		
5	31-40	C61			
5	41-50	C62			

TYPICAL INPUTS

C1.26	100.	.405	.0071	.0278	
C=.00094	-.000072	.0004	-.011	0.	-.193
C0.	-.000085	.000015	-.405	-.116	-.0201
C.114	.025	-.114			
C0.	0.	0.	0.	0.	
C1					
C4.	1.	1.	2.	4.	
C=1					
C.000194	1.	.0062	.00011	.00043	
C=.000061	-.00000076	.0000052	.000148	0.	-.000148
C0.	.0000018	.00000031	-.0045	-.0013	-.00023
C.0012	.0004	-.0018			
C0.	0.	0.	0.	0.	
C1					
C4.	1.	1.	2.	4.	
C0					

PROB

 DIMENSION XCOF(11),COF(11),ROCTR(10),ROOTI(10),Z(4)
 COMMON XCOF,COF,M,ROCTR,ROOTI,IER

11 FORMAT(2X,6E17.8)

12 FORMAT(1X,50H REA_ IMAG PERIOD T 1/2 WN

110H DR /1X,6F10.4)

```

97 CONTINUE
  J=0
  READ(5,1)PM,V,CL,XI,ZI
  READ(5,1)CYV,CLV,CNV,CYSD,CLSD,CNSD
  READ(5,1)CYPHD,CLPHD,CNPHD,CYDS,CLDS,CNDS
  READ(5,1)CYDR,CLDR,CNDR
  WRITE(6,95)PM,V,CL,XI,ZI
  WRITE(6,94)CYV,CLV,CNV,CYSD,CLSD,CNSD
  WRITE(6,93)CYPHD,CLPHD,CNPHD,CYDS,CLDS,CNDS
  WRITE(6,92)CYDR,CLDR,CNDR
92 FORMAT(1X,5HCYDR=,E15.8,1X,5HCLDR=,E15.8,1X,5HCNDR=,E15.8)
93 FORMAT(1X,6HCYPHD=,E15.8,1X,6HCLPHD=,E15.8,1X,6HCNPHD=,E15.8,1X,5H
1CYDS=,E15.8,1X,5HCLDS=,E15.8,1X,5HCNDS=,E15.8)
94 FORMAT(1X,4HCYV=,E15.8,1X,4HCLV=,E15.8,1X,4HCNV=,E15.8,1X,5HCYSD=,
1E15.8,1X,5HCLSD,E15.8,1X,5HCNSD=,E15.8)
95 FORMAT(1X,3HPM=,E15.8,1X,2HVV=,E15.8,1X,3HCL=,E15.8,1X,3HXI=,E15.8,
11X,3HZI=,E15.8)
C   IF INPUTS CYB IF NOT REMOVE NEXT 3 CARDS IE CYV=CYV/V
C   CYV=CYV/V
C   CLV=CLV/V
C   CNV=CNV/V
98 READ(5,1)FM,GV,C60,C61,C62
  WRITE(6,91)FM,GV,C60,C61,C62
91 FORMAT(1X,3HFM=,F6.3,1X,3HGV=,F6.3,1X,4HC60=,F6.3,1X,4HC61=,F6.3,1
1X,4HC62=,F6.3)
  FG=FM*GV
  M=4
  C10S=FG*C60
  C10=FG*C61
  C11=FG*C62
C   FOR HOVER SET V=1 AND PM=M/(Q*An) Q=RHO*VTIP*VTIP
  IF(V-1.)3,3,4
3 F10=0,
  F11=0,
  F12=0,
  WRITE(6,6)
6 FORMAT(5HHOVER)
  GOT05
4 F10=CNV*XI*CYSD
  F11=CNV*CLPHD*PM-CLV*PM*CNPHD
  F12=PM*CNV*CLDS-PM*CLV*CNSD
5 CONTINUE
  A=-PM*XI*ZI/V
  B=CYV*XI*ZI+PM*(CLPHD*ZI+CNSD*XI)/V
  C=-CYV*(CLPHD*ZI+XI*CNSD)-PM*(CLPHD*CNSD-CNPHD*CLSD)/V+CLV*CYPHD*7
1I+F10
  C=C-CNV*XI*PM
  D=CYV*(CLPHD*CNSD-CNPHD*CLSD)+CLV*(ZI*CL-CYPHD*CNSD+CNPHD*CYSD)+CN
1V*(CYPHD*CLSD-CLPHD*CYSD)
  D=D+F11
  E=-CLV*CL*CNSD+CNV*CL*CLSD
  XI=CYV*(CLDS*CNSD-CNDS*CLSD)+CLV*(-CYDS+CNSD+CYSD*CNDS)+CNV*(CYDS*
1CLSD-CYSD*CLDS)
  XI=XI+F12
  X2=-CYV*CLDS*ZI-PM*(CLDS*CNSD-CLSD*CNDS)/V+CLV*CYDS*ZI
  X3=PM*CLDS*ZI/V
  YI=PM*XI*CNDR/V
  Y2=-CYV*XI*CNDR-(PM/V)*(CLPHD*CNDR-CLDR*CNPHD)+CNV*CYDR*XI
  Y3=CYV*(CLPHD*CNDR-CLDR*CNPHD)+CLV*(CYDR*CNPHD-CYPHD*CNDR)+CNV*
1PHD*CLDR-CYDR*CLPHD)

```

```

Y4=CNV*CL*CLDR-CLV*CL*CNDR
E1=C11*X1
D1=C11*X2+C10*X1
C1=C11*X3+C10*X2+C10S*X1
B1=C10*X3+C10S*X2
A1=C10S*X3
A=A+A1
B=B+B1
C=C+C1
D=D+D1
E=E+E1
A1=1,
B1=B/A
C1=C/A
D1=D/A
E1=E/A
XCOF(1)=E1
XCOF(2)=D1
XCOF(3)=C1
XCOF(4)=B1
XCOF(5)=A1
WRITE(6,1)A1,B1,C1,D1,E1
CALLROLRT(XCOF,COF,4,ROOTR,ROOTI,IER)
DO20I=1,4
:F(ROOTI(I))B1,80,B1
80 P=200000,
GOTO82
81 P=2.*3.1417/ROOTI(I)
82 D=.69/ROOTR(I)
WN=(ROOTI(I)**2-ROOTR(I)**2)**.5
DR=-ROOTR(I)/WN
20 WRITE(6,40)ROOTR(I),ROOTI(I),P,D,WN,DR
90 FORMAT(1X,6HROOTR=,E12.5,1X,6HROOTI=,E12.5,1X,7HPERIOD=,E12.5,1X,1
14H TIME TO HALF=,E12.5,1X,3HWN=,E12.5,1X,3HDR=,E12.5)
1 FORMAT(7F10.6)
2 FORMAT(110)
READ(5,2)MORE
IF(MORE)97,30,98
30 CONTINUE
END
SUBROUTINE ROLRT(XCOF,COF,M,ROOTR,ROOTI,IER)
DIMENSION XCOF(10),COF(10),ROOTR(10),ROOTI(10)
IFIT=0
N=M
IER=0
IF(XCOF(N+1))10,25,10
10 IF(N)15,15,32
15 IER=1
20 RETURN
25 IER=4
GOTO20
30 IER=0
GOTO20
32 IF(N=36)35,35,30
35 NX=N
NXX=N+1
N2=1
KJ1=N+1
DO40L=1,KJ1
MT=KJ1-L+1

```

```

40 COF(MT)=XCOF(L)
45 XO=.00500101
   YO=.01000101
   IN=0
50 X=XO
   XO=-10.*YO
   YO=-10.*X
   X=XO
   Y=YO
   IN=IN+1
   GOT 15
55 IF IY=1
   XPR=X
   YPR=Y
59 ICT=0
60 UX=0.
   UY=0.
   V=0.
   YT=0.
   XT=1.
   U=COF(N+1)
   IF(U)65,130,65
65 DO 70 I=1,N
   L=N-I+1
   XT2=X*XT-Y*YT
   YT2=X*YT+Y*XT
   U=U+COF(L)*XT2
   V=V+COF(L)*YT2
   FI=I
   UY=UY-FI*YT*COF(L)
   UX=UX+FI*XT*COF(L)
   XT=XT2
70 YT=YT2
   SUMSQ=UX*UX+UY*UY
   IF(SUMSQ)75,110,75
75 DX=(V*UY-U*VX)/SUMSQ
   X=X+DX
   DY=-(U*UY+V*UX)/SUMSQ
   Y=Y+DY
78 IF(ABS(DY)+ABS(DX)=.000001,100,80,80)
80 ICT=ICT+1
   IF(ICT-500)60,85,85
85 IF(ICT)100,90,100
90 IF(IN-5)50,95,95
95 IER=3
   GOT 020
100 DO 105 L=1,NXX
   MT=KJ1-L+1
   TEMP=XCOF(MT)
   XCOF(MT)=COF(L)
105 COF(L)=TEMP
   ITEMP=N
   N=NX
   NX=ITEMP
   IF(ICT)120,55,120
110 IF(ICT)115,50,115
115 X=XPR
   Y=YPR
120 IF IY=0
122 IF(ABS(Y/X)-0.00001)135,125,125

```

```

125 ALPHA=X*X
   SUMSQ=X*X+Y*Y
   N=N+2
   GOT0140
130 X=0
   NX=NX
   NXX=NXX-1
135 Y=0
   SUMSQ=0,
   ALPHA=X
   N=N+1
140 COF(2)=COF(2)+ALPHA*COF(1)
   IF(N=2)147,146,146
147 NN=2
   GOT0145
146 NN=N
145 DO1=0L=2,NN
   M11=L+1
150 COF(M11)=COF(M11)+A_PHA*COF(L)-SUMSQ*COF(L-1)
155 ROOT1(N2)=Y
   ROOTR(N2)=X
   N2=N2+1
   IF(SUMSQ)160,165,160
160 Y=-Y
   SUMSQ=0,
   GOT0155
165 IF(N)20,20,45
   RETURN
   END
*   LIST(STOP)
*   LIST
*   DATA
1,26      100,      .405      .0071      .0278
-.000094  -.000072  .0004      -.011      0.      -.193
0,        -.000085  .000015  -.405      -.116      -.0201
.114      .025      -.114
0,        0.        0.        0.        0.
1
4,        1.        1.        2.        4.
-1
.000194   1.        .0062      .00011     .00043
-.000061  -.00000076 .0000052  .000148    0.      -.000148
0,        .0000018  .00000031 -.0045     -.0013     -.00023
.0018     .0004      -.0018
0,        0.        0.        0.        0.
1
4,        1.        1.        2.        4.
0
      PROB

```

APPENDIX E
LATERAL TRANSIENT MOTION PROGRAM

*
\$ MAXO(2400)
* LIST(START)

LATERAL-DIRECTIONAL MOTION
FEEDBACK GAINS C60 C61 C62

CARD	COLUMN	SYMBOL			
1	01-15	PM			
1	11-20	V	VELOCITY	FT/SEC	
1	21-30	CL1	LIFT COEFFICIENT	W/Q*AD	AD DISC AREA
1	31-40	YI	MOMENT OF INERTIA	IXX/Q*AD*ROTR	
1	41-50	XI	MOMENT OF INERTIA	IZZ/Q*AD*ROTR	
2	1-10	CYV			
2	11-20	CLV			
2	21-30	CNV			
2	31-40	CYSD			
2	41-50	CLSD			
2	51-60	CNSD			
2	61-70	CYPHD			
3	1-10	CLPHD			
3	11-20	CNPHD			
3	21-30	CYDS			
3	31-40	CLDS			
3	41-50	CNDS			
4	1-10	CYDR			
4	11-20	CLDR			
4	21-30	CNDR			
5	01-15	RTU			
5	16-30	RTL			
5	31-45	GVU			
5	46-60	GVL			
	01-15	C60			
6	16-31	C61			
6	31-45	C62			
6	46-60	SG			

0 END, -1 NEW PM, 1 NEW GAIN

TYPICAL INPUTS

C1.26	100.	.405	.0071	.0278	
C-.00094	-.000072	.0004	-.011	0.	-.193
C0.	-.000085	.000015	-.405	-.116	-.0201
C.114	.025	-.114			
C10.	.1	4.	.5		
C.25	1.	2.	4.	1.	
C10.	.1	4.	.5		
C1.0	1.	2.	4.	-1.	
C.000194	0.	.0062	.00011	.00043	
C-.000061	-.00000076	.0000052	.000148	0.	-.000148
C0.	.0000018	.00000031	-.0045	-.0013	-.00023
C.0018	.0004	-.0018			
C10.	.1	4.	.5		
C.25	1.	2.	4.	1.	
C10.	.1	4.	.5		
C1.	1.	2.	4.	0.	

C PROB
100 CONTINUE
READ(5,1)PM,V,CL,XI,ZI
READ(5,1)CYV1,CLV1,CNV1,CYSD,CLSD,CNSD
READ(5,1)CYTD,CLTD,CNTD,CYDS,CLDS,CNDS

```

      READ(5,1)CYDR,CLDR,CNDR
1  FORMAT(7F10.6)
      WRITE(6,2)PM,V,CL,XI,7I
      WRITE(6,3)CYV1,CLV1,CNV1,CYSD,CLSD,CNSD
      WRITE(6,4)CYTD,CLTD,CNTD,CYNS,CLDS,CNDS
      WRITE(6,5)CYDR,CLDR,CNDR
2  FORMAT(1X,3HPM=F6.3,1X,2HV=F5.1,1X,3HCL=F6.3,1X,3HXI=F7.4,1X,7
      1HZI=F7.4)
3  FORMAT(1X,5HCYV1=F10.6,1X,5HCLV1=F10.6,1X,5HCNV1=F10.6,1X,5HCYS
      1D=F10.6,1X,5HCLSD=F10.6,1X,5HCNSD=F10.6)
4  FORMAT(1X,5HCYTD=F10.6,1X,5HCLTD=F10.6,1X,5HCNTD=F10.6,1X,5HCYN
      1S=F10.6,1X,5HCLDS=F10.6,1X,5HCNDS=F10.6)
5  FORMAT(1X,5HCYDR=F10.6,1X,5HCLDR=F10.6,1X,5HCNDR=F10.6)
98 READ(5,1)RTU,RTL,GVU,GVL
      READ(5,1)FM,C60,C61,C62,SG
      WRITE(6,9)RTU,RTL,GVU,GVL
      WRITE(6,6)FM,C60,C61,C62
9  FORMAT(1X,4HRTU=F6.3,1X,4HRTL=F6.3,1X,4HGVU=F6.3,1X,4HGVL=F6.3
      1)
6  FORMAT(1X,4H FM=F6.3,1X,4HC60=F6.3,1X,4HC61=F6.3,1X,4HC62=F6.3
      1)
      WRITE(6,87)
87 FORMAT(3X,2HTM,10X,2HSV,10X,2HSY,10X,2HTH,10X,2HDR,9X,3HDXR,9X,3HD
      1XA,9X,4HALAT)
C      IF INPUT CYV REMOVE NEXT 3 CARDS OKE FOR CYB
C      CNV=CNV1/V
C      CLV=CLV1/V
C      CYV=CYV1/V
      CYV=CYV1
      CNV=CNV1
      CLV=CLV1
      SVD2=0.
      DD1=0.
      DD2=0.
      DI2=0.
      DRMX=1./57.3
      TDD2=0.
      SV=0.
      SY=0.
      TH=0.
      TDD=0.
      SVD=0.
      SD=0.
      TD=0.
      NN=0
      TM=0.
      DTM=.05
      CD=0.
      DL=DTM/2.
      DR=0.
C      FOR HOVER WHEN V=0  PM=M/(Q*AD)  Q=RH0*VTIP*VTIP
      IF(V)10,10,11
10  F10=C.
      F11=1./PM
      GOTO12
11  F10=PM
      F11=V/PM
12  CONTINUE
      DO80 JJ=1,800
      CD1=CD

```

```

T=TM
IF(T=.5)70,71,72
70 CD=T/.5
GOTO75
71 CD=1,
GOTO75
72 IF(T=1.)73,74,74
73 CD=(1,-T)/.5
GOTO75
74 CD=0,
75 DR=CD1*DRMX
RT=ABS((DD2-DD1)/DT4)
IF(RT-RTU)201,201,200
200 GV=GVU
GOTO204
201 IF(RT-RTL)202,202,203
202 GV=GVL
GOTO204
203 GV=GVL+((RT-RTL)/(RTU-RTL))*(GVU-GVL)
204 CONTINUE
IF(TM-1.)350,350,351
350 GV=0,
351 CONTINUE
FG=FM*GV
SDD=(CNV*SV+CNDS*SD+(CNTD*FG+C62*CNDS)*TD+CNDS*FG+C62*TH+CNDS*FG*
160*TDD+CND*DR)/Z1
SVD1=(CL*SIN(TH)+CYV*SV+CYSD*SD+(CYTD*FG+C61*CYDS)*TD+C60*FG*CYDS*
170*TDD+C62*FG*CYDS*TH+CYDR*DR-F10*SD)*F11
TDD=(CLV*SV+CLSD*SD+(CLTD*FG+C61*CLDS)*TD+FG*C62*CLDS*TH+CLDR*DR)/
180*1(XI=FG*C60*CLDS)
DD1=FM*GV*(C60*TDD+C61*TD+C62*TH)
DD1=ABS(DD1)
IF(DD15=.26)41,40,40
40 DD1=.26*DD1/DD15
SDD=(CNV*SV+CNDS*SD+CNTH*TD+CNDS*DD1+CND*DR)/Z1
SVD1=(CL*SIN(TH)+CYV*SV+CYSD*SD+CYTD*TD+CYDS*DD1+CYDR*DR-F10*SD)*
190*F11
TDD=(CLV*SV+CLSD*SD+CLTH*TD+CLDS*DD1+CLDR*DR)/X1
41 CONTINUE
SD1=SD+SDD*DL
TD1=TD+TDD*DL
SV1=SV+SVD1*DL+D12
S1=SY+SD1*DL
T1=TH+TD1*DL
TD2=TD1+TDD*DL
SV2=SV+SVD1*DL+D12
T2=T1+TD1*DL
SD2=SD1+SDD*DL
RT=ABS((DD1-DD2)/DT4)
IF(RT-RTU)301,300,300
300 GV=GVU
GOTO304
301 IF(RT-RTL)302,302,303
302 GV=GVL
GOTO304
303 GV=GVL+((RT-RTL)/(RTU-RTL))*(GVU-GVL)
304 CONTINUE
IF(TM-1.)352,352,353
352 GV=0,
353 CONTINUE

```

```

DR=CD*DRMX
FG=FM*GV
SDD2=(CNV*SV2+CNSD*SD2+(CNTD*FG*C61*CNDS)*TD2+CNDS*FG*C62*T2+CNDS*
1FG*C60*TDD+CND*DR)/Z1
SVD2=(CL*SIN(T2)+CYV*SV2+CYSD*SD2+(CYTD*FG*C61*CYDS)*TD2+C60*FG*CY
1DS*TDD+C62*FG*CYDS*TH+CYDR*DR-F10*SD2)*F11
TDD2=(CLV*SV2+CLSD*SD2+(CLTD*FG*C61*CLDS)*TD2+FG*C62*CLDS*T2+CLDR
1*DR)/(X1-FG*C60*CLDS)
DD2=FM*GV*(C60*TDD2+C61*TD2+C62*T2)
DD15=ABS(DD2)
IF(DD15=.26)43,42,42
42 DD2=.26*DD2/DD15
SDD2=(CNV*SV2+CNSD*SD2+CNTD*TD2+CNDS*DD2+CND*DR)/Z1
TDD2=(CLV*SV2+CLSD*SD2+CLTD*TD2+CLDS*DD2+CLDR*DR)/X1
SVD2=(CL*SIN(T2)+CYV*SV2+CYSD*SD2+CYTD*TD2+CYDS*DD2+CYDR*DR-F10*SD
12)*F11
43 CONTINUE
SV=SV1+SVD2*DL+DI2
SD=SD1+SDD2*DL
ALAT=(SVD2+V*SD)/32.2
TD=TD1+TDD2*DL
SY=S1+SD*DL
TH=T1+TD*DL
TDD=TDD2
SYP=SY*57.3
THP=TH*57.3
DRP=DR*57.3
DXR=57.3*DD1
DXA=57.3*DD2
IF(NN=1)20,20,21
20 NN=NN+1
GOTO80
21 NN=N
WRITE(6,13)TM,SV,SYP,THP,DRP,DXR,DXA,ALAT
80 TM=TM+DTM
13 FORMAT(8E12.5)
IF(SG)100,30,98
30 CONTINUE
END
* LIST(STOP)
* LIST
* DATA
1,26      100.      .405      .0071      .0278
-.00094   -.000072  .0004     -.011      0.         -.193
0.        -.000085   .000015   -.405      -.116      -.0201
.114      .025        -.114
10.       .1         4.        .5
.25       1.         2.        4.         1.
10.       .1         4.        .5
1.0       1.         2.        4.        -1.
.000194   0.         .0062     .00011     .00043
-.000061  -.00000076 .0000052  .000148    0.         -.000148
0.        .0000018   .00000031 -.0045     -.0013     -.00023
.0018     .0004      -.0018
10.       .1         4.        .5
.25       1.         2.        4.         1.
10.       .1         4.        .5
1.        1.         2.        4.         0.

```

PROB

APPENDIX F
CALCULATIONS

TABLE F.1
TYPICAL LATERAL STABILITY DERIVATIVES
AND NOTATION USED IN EQUATIONS OF MOTION

SYMBOL	NORMAL	FORTRAN	TYPICAL VALUES	
			AIRCRAFT SYSTEM	HELICOPTER SYSTEM
PM			1.26	.00194
V		Mass Coefficient $M \cdot V / Q \cdot AD$ Velocity	100	0
CL		Lift Coefficient $W / (Q \cdot AD)$	.405	.0062
XI		Moment Coefficient $IXX / (Q \cdot AD \cdot ROTR)$	.0071	.0081
ZI		Moment Coefficient $IZZ / (Q \cdot AD \cdot ROTR)$	.0278	.00011
				.00043
CYV		Side Force Due to Sideslip Velocity	-.00094	-6.1×10^{-5}
CLV		Rolling Moment Due to Sideslip Velocity	-.000072	-7.6×10^{-7}
CNV		Yawing Moment due to Sideslip Velocity	.0004	5.2×10^{-6}
CYSD		Side Force due to Yawing Velocity	-.011	1.48×10^{-4}
CLSD		Rolling Moment Due to Yawing Velocity	0	0
CNSD		Yawing Moment due to Yawing Velocity	-.193	-1.48×10^{-4}
CYPHD		Side Force Damping	0	0
CLPHD		Roll Damping	-.000085	1.8×10^{-6}
CNPHD		Yaw Damping	.000015	3.1×10^{-7}
				-1.43×10^{-6}

TABLE F. 1

TYPICAL LATERAL STABILITY DERIVATIVES
AND NOTATION USED IN EQUATIONS OF MOTION
(Continued)

SYMBOL NORMAL FORTRAN	TYPICAL VALUES			
	AIRCRAFT SYSTEM	HELICOPTER SYSTEM		
$-C_{Y A1}$	CYDS	Side Force due to Lateral Cyclic Control	-.405	-4.5×10^{-3}
$-C_{\ell A1}$	CLDS	Rolling Moment due to Lateral Cyclic	-.116	-1.3×10^{-3}
$-C_{n A1}$	CNDS	Yawing Moment due to Lateral Cyclic	-.0201	-2.3×10^{-4}
$C_{Y TR}$	CYDR	Side Force due to Tail Rotor Pitch	.114	.0018
$C_{\ell TR}$	CLDR	Rolling Moment due to Tail Rotor Pitch	.025	.0004
$C_{n TR}$	CNDR	Yawing Moment due to Tail Rotor Pitch	-.114	-.0018
				-3.5×10^{-3}

θ_c = TIC, Main Rotor Collective Pitch

AD = Disc Area = $\pi * \overline{ROTR}^2$

B_1 = Main Rotor Longitudinal Cyclic Pitch

ROTR = Rotor Radius

A_1 = Main Rotor Lateral Cyclic Pitch

IXX, IYY, IZZ Airplane Moments of Inertia

M = Aircraft Mass

$\dot{\theta}_{tR}$ = Tail Rotor Collective Pitch

W = Aircraft Weight

Q = $RH\emptyset * VTIP * VTIP$ Helicopter System

Q = $RH\emptyset * V * V/2$ Aircraft System

TABLE F.1 (cont'd)
TYPICAL LONGITUDINAL STABILITY DERIVATIVES
AND NOTATION USED IN EQUATIONS OF MOTION

SYMBOL	NORMAL FORTRAN	TYPICAL VALUES		
		AIRCRAFT SYSTEM	HELICOPTER SYSTEM	
		I	II	III
	Mass Coefficient	1.26	.000194	.0425
	Velocity	100	0	169
C_L	CL1	.405	.0062	.0081
α	ALPHA	0	0	0
	YI	.033	.00051	
C_{X_u}	CXU	.0000486	-4.2×10^{-6}	-1.0×10^{-5}
C_{X_α}	CXA	.05207	7.9×10^{-6}	-3.0×10^{-3}
C_{Z_u}	CZU	-.000173	-9×10^{-6}	3.7×10^{-6}
C_{Z_α}	CZA	-.793	-4.3×10^{-5}	-3.15×10^{-2}
$C_{Z_{\dot{\alpha}}}$	CZAD	0	0	0
$C_{Z_{\dot{\theta}}}$	CZTD	0	0	0

F-5

TABLE F.2

EFFECTS OF CHANGES OF LOGARITHMICAL DERIVATIVES
P-133

3-2ND-0000/2. A=3.18-0000 (Z=X/(C+A)) (Y=M/(C+A)) PM=1.26 CL=405 VI=033

	120.	130.	140.	150.	160.	170.	180.	190.	200.	210.	220.	230.	240.	250.	260.	270.	280.	290.	300.	310.	320.	330.	340.	350.	360.	370.	380.	390.	400.	410.	420.	430.	440.	450.	460.	470.	480.	490.	500.	
CU=	30485	30486	30487	30488	30489	30490	30491	30492	30493	30494	30495	30496	30497	30498	30499	30500	30501	30502	30503	30504	30505	30506	30507	30508	30509	30510	30511	30512	30513	30514	30515	30516	30517	30518	30519	30520	30521	30522	30523	
CV=	30524	30525	30526	30527	30528	30529	30530	30531	30532	30533	30534	30535	30536	30537	30538	30539	30540	30541	30542	30543	30544	30545	30546	30547	30548	30549	30550	30551	30552	30553	30554	30555	30556	30557	30558	30559	30560	30561	30562	
CW=	30563	30564	30565	30566	30567	30568	30569	30570	30571	30572	30573	30574	30575	30576	30577	30578	30579	30580	30581	30582	30583	30584	30585	30586	30587	30588	30589	30590	30591	30592	30593	30594	30595	30596	30597	30598	30599	30600	30601	
CX=	30602	30603	30604	30605	30606	30607	30608	30609	30610	30611	30612	30613	30614	30615	30616	30617	30618	30619	30620	30621	30622	30623	30624	30625	30626	30627	30628	30629	30630	30631	30632	30633	30634	30635	30636	30637	30638	30639	30640	
CY=	30641	30642	30643	30644	30645	30646	30647	30648	30649	30650	30651	30652	30653	30654	30655	30656	30657	30658	30659	30660	30661	30662	30663	30664	30665	30666	30667	30668	30669	30670	30671	30672	30673	30674	30675	30676	30677	30678	30679	
CZ=	30680	30681	30682	30683	30684	30685	30686	30687	30688	30689	30690	30691	30692	30693	30694	30695	30696	30697	30698	30699	30700	30701	30702	30703	30704	30705	30706	30707	30708	30709	30710	30711	30712	30713	30714	30715	30716	30717	30718	
CA=	30719	30720	30721	30722	30723	30724	30725	30726	30727	30728	30729	30730	30731	30732	30733	30734	30735	30736	30737	30738	30739	30740	30741	30742	30743	30744	30745	30746	30747	30748	30749	30750	30751	30752	30753	30754	30755	30756	30757	
CB=	30758	30759	30760	30761	30762	30763	30764	30765	30766	30767	30768	30769	30770	30771	30772	30773	30774	30775	30776	30777	30778	30779	30780	30781	30782	30783	30784	30785	30786	30787	30788	30789	30790	30791	30792	30793	30794	30795	30796	30797
CC=	30798	30799	30800	30801	30802	30803	30804	30805	30806	30807	30808	30809	30810	30811	30812	30813	30814	30815	30816	30817	30818	30819	30820	30821	30822	30823	30824	30825	30826	30827	30828	30829	30830	30831	30832	30833	30834	30835	30836	
CD=	30837	30838	30839	30840	30841	30842	30843	30844	30845	30846	30847	30848	30849	30850	30851	30852	30853	30854	30855	30856	30857	30858	30859	30860	30861	30862	30863	30864	30865	30866	30867	30868	30869	30870	30871	30872	30873	30874	30875	
CE=	30876	30877	30878	30879	30880	30881	30882	30883	30884	30885	30886	30887	30888	30889	30890	30891	30892	30893	30894	30895	30896	30897	30898	30899	30900	30901	30902	30903	30904	30905	30906	30907	30908	30909	30910	30911	30912	30913	30914	
CF=	30915	30916	30917	30918	30919	30920	30921	30922	30923	30924	30925	30926	30927	30928	30929	30930	30931	30932	30933	30934	30935	30936	30937	30938	30939	30940	30941	30942	30943	30944	30945	30946	30947	30948	30949	30950	30951	30952	30953	
CG=	30954	30955	30956	30957	30958	30959	30960	30961	30962	30963	30964	30965	30966	30967	30968	30969	30970	30971	30972	30973	30974	30975	30976	30977	30978	30979	30980	30981	30982	30983	30984	30985	30986	30987	30988	30989	30990	30991	30992	
CH=	30993	30994	30995	30996	30997	30998	30999	31000	31001	31002	31003	31004	31005	31006	31007	31008	31009	31010	31011	31012	31013	31014	31015	31016	31017	31018	31019	31020	31021	31022	31023	31024	31025	31026	31027	31028	31029	31030	31031	

FM =	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
GV =	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
CS0 =	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
CS1 =	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
CS2 =	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30

P=	35.03	4.83	7.00	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60
11/2=	7.10	1.30	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50
11/2=	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
12=	2.80	5.70	8.70	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30
12=	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30

TABLE F.3

EFFECT OF AUTOSAS ON LONGITUDINAL STABILITY

	V=100													
FM=	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2	2.0	4.0	10.0	0.0	CMU= 0.48000E-02
GV=	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	CXA= -0.52070E-00
CS0=	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	0.0	CZU= -0.17000E-03
CS1=	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	2.0	2.0	0.0	CZA= -0.79000E-00
CS2=	3.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	4.0	4.0	4.0	4.0	0.0	CZAD= 0.00000E-00
P=	3.0	5.0	3.0	2.0	23.2	24.7	21.3	25.3	6.2	4.9	4.8	4.7	0.0	CZTD= 0.00000E-00
Y1/2=	8.0	0.7	0.7	0.7	0.0	0.0	0.0	0.0	1.2	1.4	1.4	1.4	0.0	CMU = 0.35000E-03
Y1/2=	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CMA = 0.00000E-00
Y2=	3.0	0.0	0.0	0.0	3.7	77.5	0.1	6.1	0.0	0.0	0.0	0.0	0.0	CMAD= -0.88000E-03
Y2=	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CMTD= -0.65400E-01
P=	15.0	0.0	9.5	12.7	0.1	0.0	191.0	0.0	0.0	0.0	0.0	0.0	0.0	CTXC= -0.16100E-00
Y1/2=	3.0	4.5	9.5	12.7	0.1	0.1	0.1	1.8	9.2	43.6	57.8	71.8	0.0	CZTC= -0.31400E-01
Y1/2=	3.0	1.1	1.1	1.1	1.1	1.1	0.0	1.1	1.1	1.1	1.1	1.1	0.0	CMTC= 0.11000E-00
Y2=	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CVBI= 0.35000E-00
Y2=	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CZBI= 0.79000E-00
Y2=	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CMBI= -0.16800E-00
Y2=	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CMI= -0.14400E-01
FM=	3.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2	0.5	1.0	2.0	4.0	10.0	CMU= -0.42000E-05
GV=	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	CXA= 0.79000E-05
CS0=	3.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	CZU= -0.90000E-05
CS1=	3.0	1.0	0.0	0.0	1.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	CZA= -0.43000E-04
CS2=	3.0	1.0	1.0	2.0	0.0	0.0	0.0	4.0	4.0	4.0	4.0	4.0	4.0	CZAD= 0.00000E-00
P=	42.7	10.2	0.0	0.0	0.0	0.0	0.0	6.2	5.4	5.1	4.9	4.8	4.9	CZTD= 0.00000E-00
Y1/2=	3.0	3.3	15.6	20.3	3.2	6.3	7.7	0.2	1.9	1.6	1.5	1.4	1.4	CMU = 0.78000E-07
Y1/2=	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CMA = 0.80000E-08
Y2=	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CMAD= 0.00000E-00
Y2=	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CMTD= 0.43000E-06
P=	747.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CZTC= 0.72000E-01
Y1/2=	3.0	1.6	269.0	227.0	4.3	78.5	96.7	0.0	20.2	20.5	20.7	20.7	20.8	CZTC= -0.41000E-01
Y1/2=	3.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	3.3	3.1	3.1	3.1	3.1	CMTC= 0.43000E-05
Y2=	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CVBI= 0.42000E-02
Y2=	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CZBI= 0.00000E-00
Y2=	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CMBI= -0.13000E-02
Y2=	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CMI= 0.00000E-00

MEACH SAYSOLUN J.F. S-AIRKALHJ 77-3177 J2 555-040 JG 101111

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TABLE F.5
EXAMPLE III - SUMMARY OF STATIC STABILITY
PITCH TRIM AND SIDESLIP

V _{KTS}	V'/sec	x	h	δ_s	n	PITCH TRIM		$\frac{d\phi}{d\beta}$	$\frac{d\theta_{TR}}{d\phi}$	$\frac{dA_1}{d\phi}$	$\frac{d\theta_{TR}}{d\beta}$	$\frac{dA_1}{d\beta}$
						(1)	B_1					
		.5	6.25	087	1	4.6	14.9					
100	0					5.1/9.3	7.42	-.031	-64.2	3.0	1.98	-.093
125	169					/11.1	8.4	-.31	-11.4	.46	3.54	-.143
150	212					5.5/13/6	9.4	-.61	-9.2	.34	5.6	-.207
	254											
	0	0				0	15					
100	169					3.2/5.8	7.4	-.031	-64.2	3.0	1.98	-.093
125	212					3.7/7.9	8.4	-.31	-11.4	.46	3.54	-.143
150	254					4.5/10.85	9.4	-.61	-9.2	.34	5.6	-.207
	0	-1				-9.2	14.9					
100	169					-7.8/-1.4	7.4	-.031	-64.2	3.0	1.98	-.093
125	212					.75/1.6	8.4	-.31	-11.4	.46	3.54	-.143
150	254					2.2/5.2	9.4	-.61	-9.2	.34	5.6	-.207

(1) $\frac{dA_1}{d\beta} = 1$

TABLE F.5

EXAMPLE III - SUMMARY OF STATIC STABILITY (cont'd)

PITCH TRIM AND SIDESLIP

V _{KFS}	V'/sec	x	h	δ _s	PITCH TRIM			dφ/dβ	SIDESLIP				
					(1)	B ₁	θ _c		dθ _{TR} /dφ	dA ₁ /dφ	dθ _{TR} /dβ	dA ₁ /dβ	
		0	6.25	.087	1	3.1/5.7	7.4						
100	169				1.5	3.0/5.5	7.4						
125	212				2.0	2.9/5.25	7.4						
150	254				2.5	2.74/5.0	7.4						
0					1	3.7/8.0	8.4						
100					1.5	3.6/7.8	8.4						
125					2.0	3.5/7.6	8.4						
150					2.5	3.4/7.45	8.4						
0	0		5.25		1	0	15.0						
100	169		5.25			3.0/5.8	7.4	-.031	-64.2	3.0	1.98	-.093	
125	212		5.25			3.4/5.8	8.4	0.30	-11.4	.46	3.54	-.143	
150	254		5.25			4.0/7.9	9.4	-.61	-9.2	.34	5.6	-.207	
0	0		6.25	.174		0	14.9						
100	169					/5.7	7.4	-.031	-64.3	3.0	1.98	-.093	
125	212					3.7/8.0	8.4	-.31	-11.4	.46	3.54	-.143	
150	254					4.4/10.9	9.2	-.61	-9.2	.34	5.6	-.207	

TABLE F.5
EXAMPLE III - STATIC STABILITY (Continued)

STEADY TURNS

V = 100 KTS

FWD C.G.

BANK ANGLE	CLIMB ANGLE	LOAD FACTOR	δ_{tr} TAIL ROTOR COLLECTIVE	A ₁ LATERAL CYCLIC	B ₁ PITCH CYCLIC
0	-15				
	0	1		0	-1.8
	15				
10	-15	1.02	.43	0	.29
	0	1.02	.43	0	.29
	15	1.02	.43	0	.29
20	-15	1.06	.85	-.01	1.18
	0	1.06	.85	0	1.18
	15	1.06	.85	.01	1.18
30	-15	1.15	1.24	-.02	2.73
	0	1.15	1.24	0	2.73
	15	1.15	1.25	.02	2.73
40	-15	1.31	1.59	-.02	5.05
	0	1.31	1.60	0	5.05
	15	1.31	1.61	.02	5.05
50	-15	1.56	1.89	-.03	8.45
	0	1.56	1.90	0	8.45
	15	1.56	1.92	.03	8.45

TABLE F.6

LONGITUDINAL DERIVATIVES

	1	2	3	4	5	6	7
CUU	-0.250E-05	-0.110E-05	-0.110E-05	-0.110E-05	-0.140E-05	-0.110E-03	-0.470E-03
CUV	0.210E-05	-0.440E-05	-0.640E-05	-0.640E-05	-0.510E-05	-0.310E-03	-0.410E-03
CUW	0.600E-06	0.610E-06	0.600E-06	0.600E-06	0.770E-06	0.960E-06	0.200E-05
CXA	0.550E-05	0.420E-05	0.420E-05	0.430E-05	0.490E-05	0.620E-05	0.140E-02
CXB	-0.400E-04	-0.430E-04	-0.430E-04	-0.430E-04	-0.530E-04	-0.470E-02	-0.350E-01
CYA	0.000E-00	0.000E-00	0.000E-00	0.000E-00	-0.210E-05	0.490E-04	-0.410E-02
CYB	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00
CZAD	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00
CZAC	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00
CATD	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00
CZTD	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00
CATD	-0.170E-05	-0.940E-05	-0.940E-05	-0.940E-05	-0.110E-06	-0.620E-04	-0.240E-03
CXB	0.280E-02	0.110E-02	0.110E-02	0.110E-02	0.270E-02	0.900E-04	-0.320E-03
CZB	0.000E-00	0.170E-03	0.170E-03	0.170E-03	0.250E-03	0.170E-02	0.180E-02
CMB	-0.530E-02	-0.320E-03	-0.310E-03	-0.220E-01	-0.650E-02	-0.460E-03	-0.470E-03

LATERAL DERIVATIVES

CVV	-0.610E-06	-0.180E-05	-0.180E-05	-0.180E-05	-0.220E-05	-0.430E-03	-0.370E-02
CLV	-0.600E-06	-0.490E-05	-0.490E-05	-0.490E-05	-0.570E-06	-0.640E-04	-0.550E-03
CNV	0.500E-05	0.650E-06	0.650E-06	0.650E-06	0.450E-06	0.490E-03	0.520E-02
CVSC	0.100E-03	0.140E-04	0.140E-04	0.140E-04	0.140E-04	0.150E-03	0.350E-03
CLSC	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00
CNSC	-0.130E-03	-0.180E-04	-0.180E-04	-0.180E-04	-0.180E-04	-0.170E-03	-0.430E-03
CNTD	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00	0.000E-00
CLTD	0.370E-04	-0.100E-04	-0.100E-04	-0.100E-04	-0.100E-04	-0.100E-04	-0.100E-04
CNTD	-0.200E-03	0.320E-05	0.320E-05	0.320E-05	0.320E-05	0.220E-04	-0.140E-04
CYA	0.370E-02	0.110E-02	0.110E-02	0.110E-02	0.290E-02	0.180E-02	0.210E-02
CLA	0.100E-02	0.240E-02	0.240E-02	0.240E-02	0.450E-02	0.710E-03	0.120E-02
CNA	-0.540E-04	0.260E-04	0.260E-04	0.260E-04	0.350E-04	0.000E-00	0.000E-00
CYDR	0.240E-02	0.460E-03	0.460E-03	0.460E-03	0.590E-03	0.200E-02	0.400E-02
CLDR	0.550E-03	0.130E-03	0.130E-03	0.130E-03	0.130E-03	0.460E-03	0.910E-03
CNDR	-0.300E-04	-0.720E-03	-0.720E-03	-0.720E-03	-0.720E-03	-0.250E-02	-0.490E-02

TABLE A1
 2 TABLE A2 TEETER MR=0.0 V=0
 3 TABLE A2 TEETER MR=0.0 V=0
 4 TABLE A2 RIGID MR=0.0 V=0
 5 TABLE A2 ARTIC MR=0.0 V=0
 6 TABLE A2 ARTIC MR=0.0 V=40
 7 TABLE A2 ARTIC MR=0.0 V=140

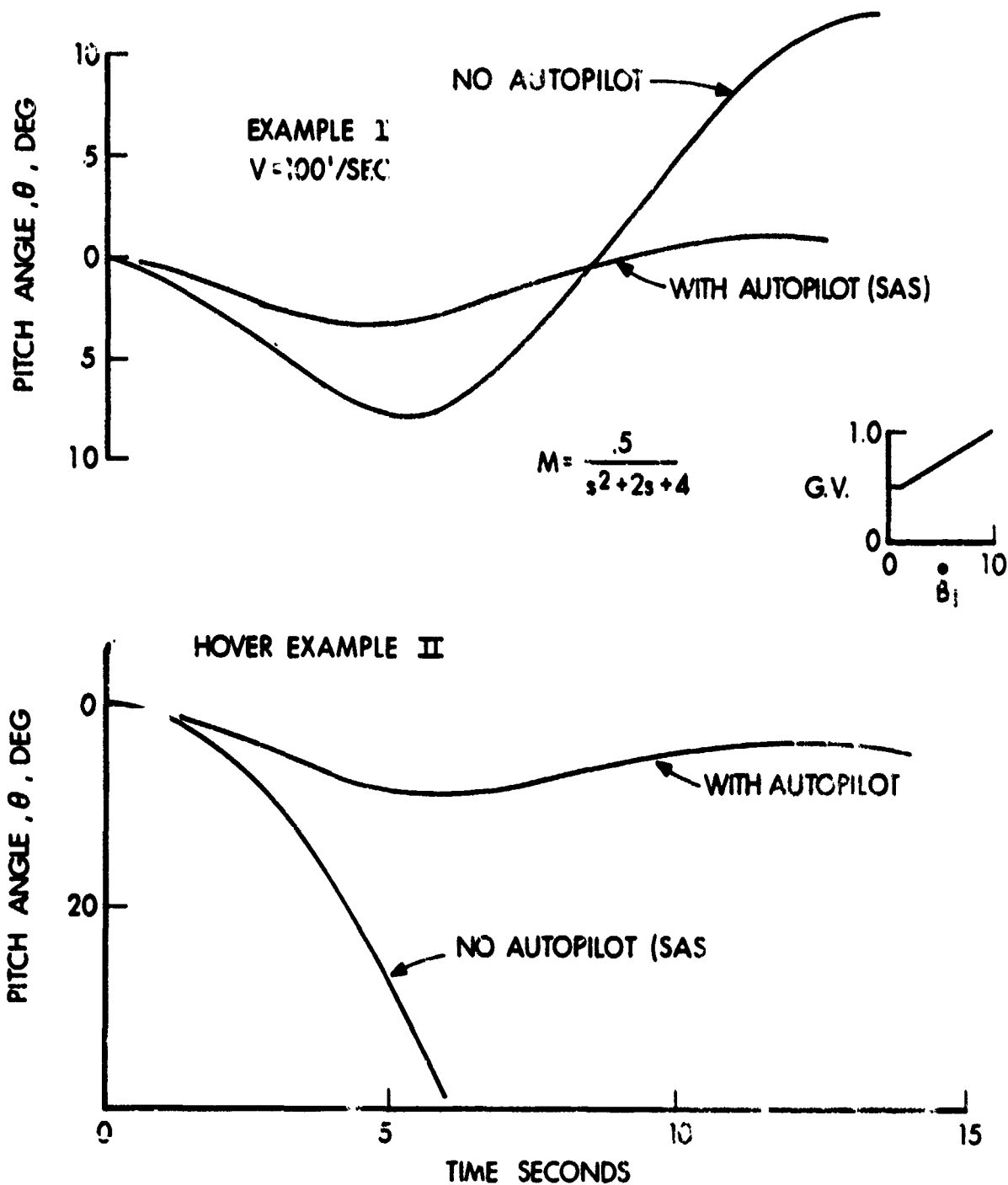


Figure F-1. Effect of Autopilot Dynamics Longitudinal Stability 1° Longitudinal Cyclic Pulse.

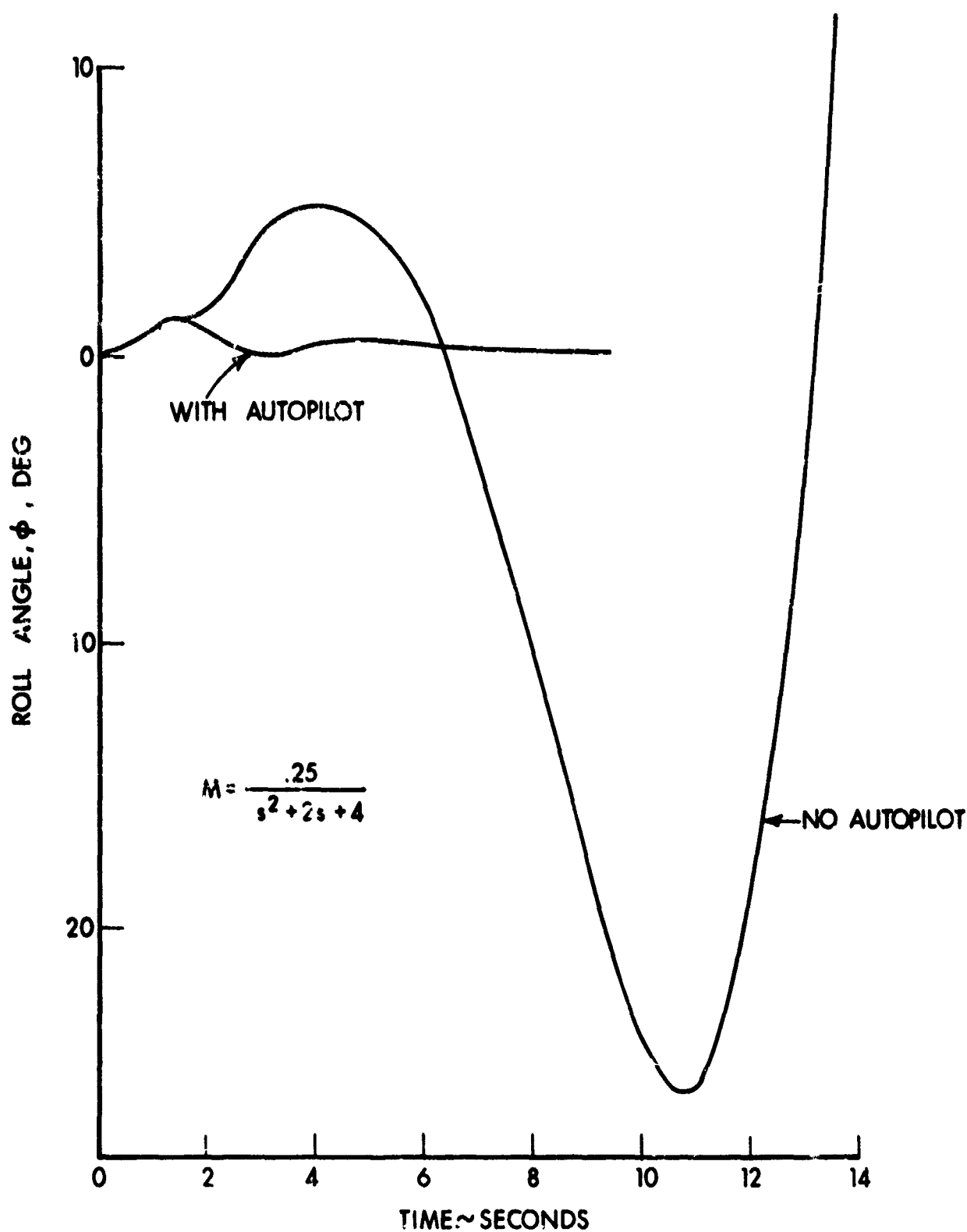


Figure F-2. Effect of Autopilot Dynamic Lateral Stability
Hover 1° Lateral Cyclic Pulse Example II.

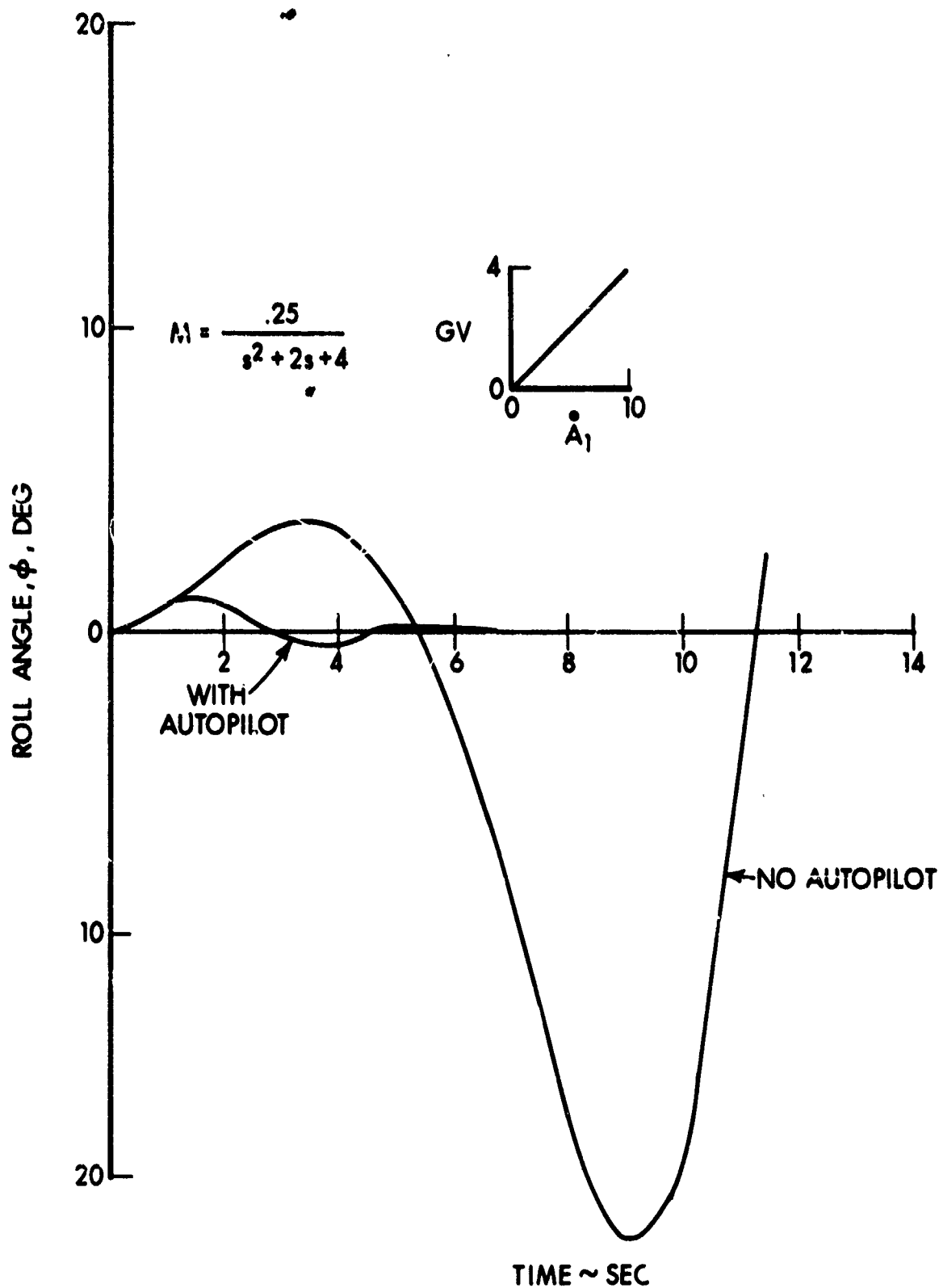


Figure F-3. Effect of Autopilot Dynamic Lateral Stability
Velocity = 100'/sec 1° Lateral Cyclic Pulse
Example I.

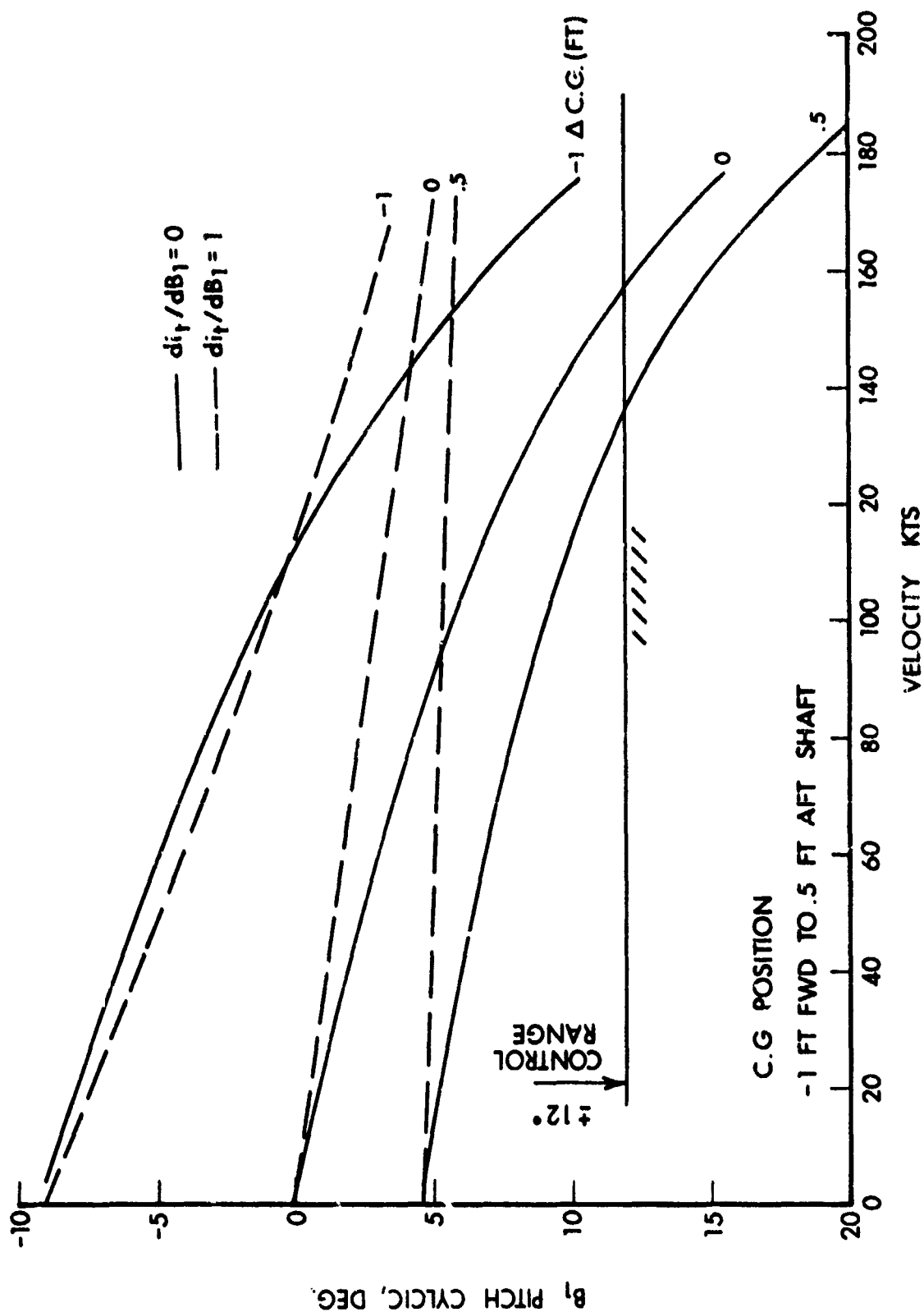


Figure F-4. Example III Level Flight Trim B vs V Effect of Horizontal Tail Coupling.

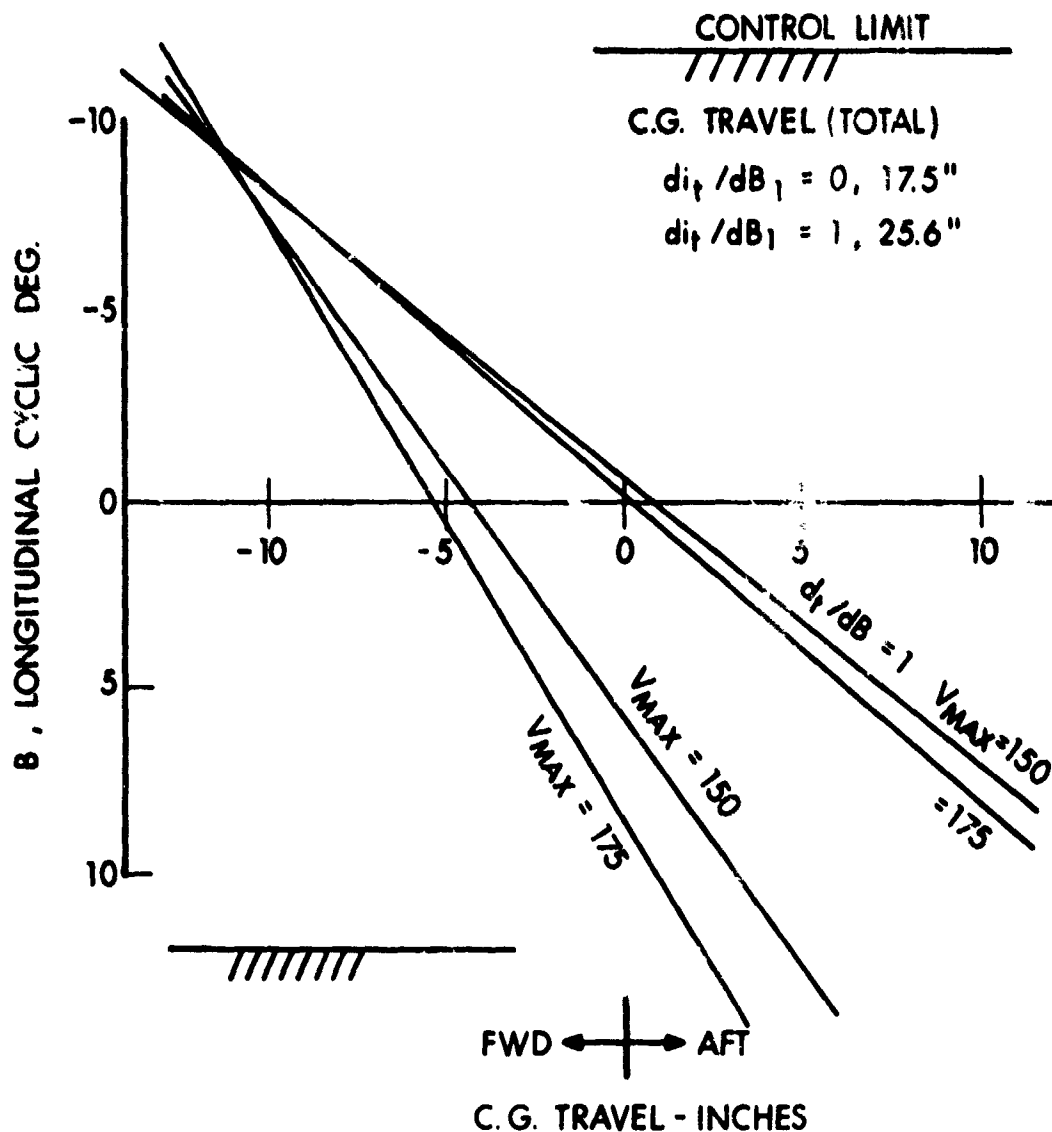


Figure F-5. Example III Estimated C.G. Travel for $\pm 12^\circ$ Longitudinal Cyclic Control Power Trim Limits Between Hover (Fwd C.G.) and High Speed.

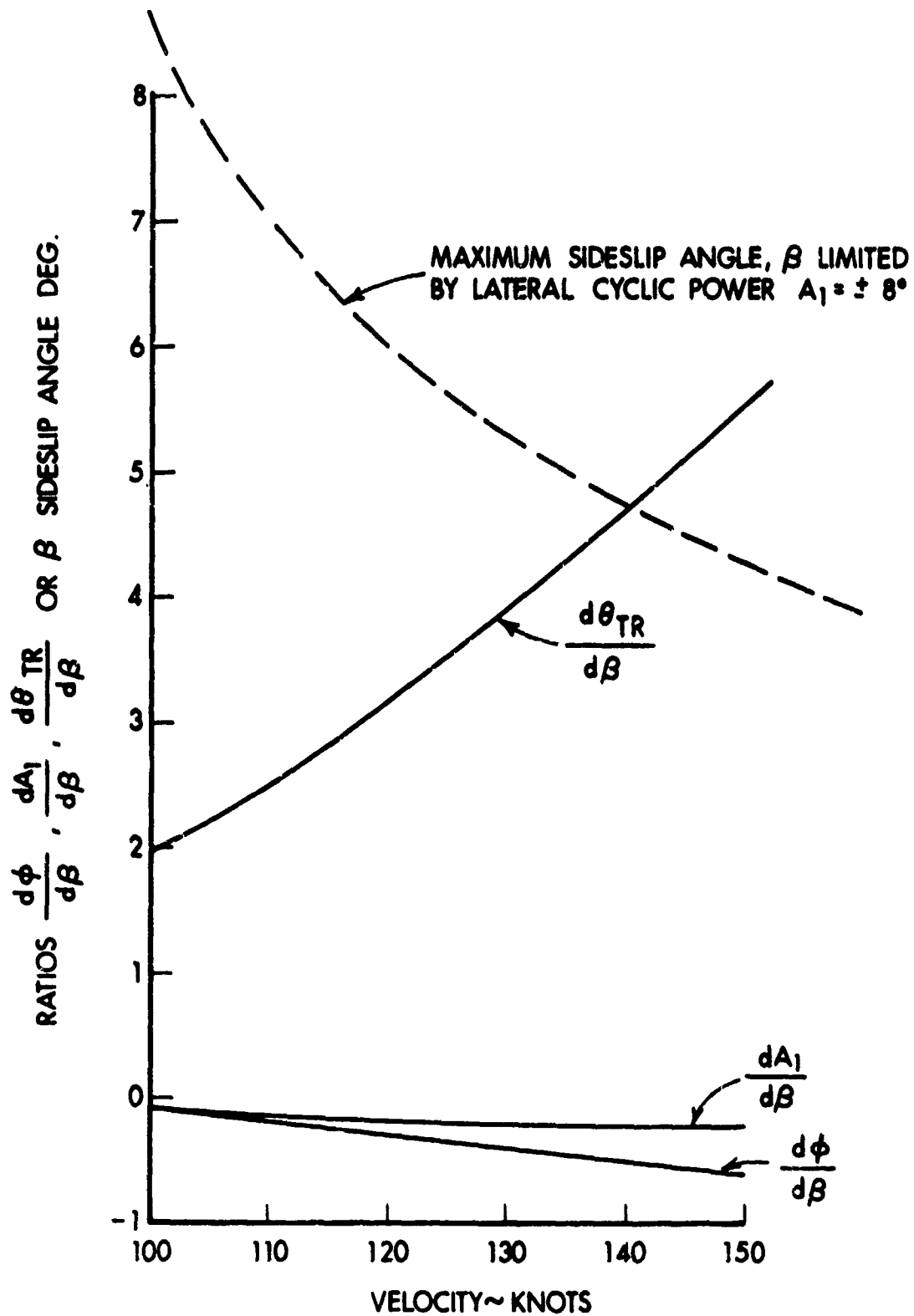


Figure F-6. Example III Steady Sideslips Level Flight Power.

C.G. ON SHAFT AXIS

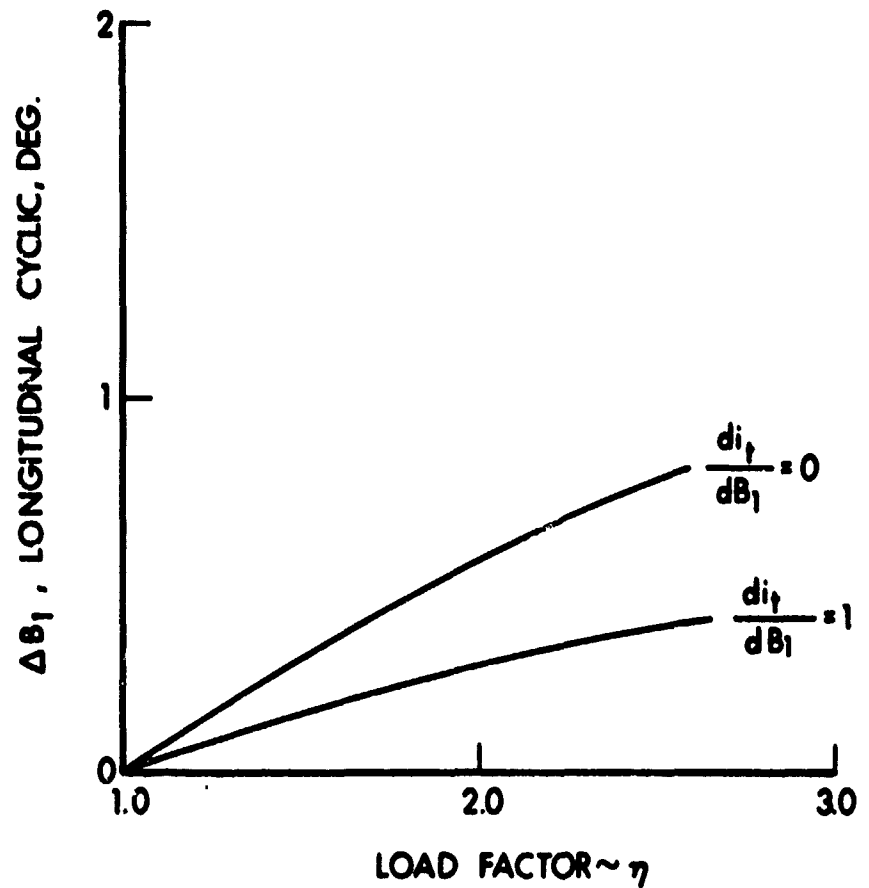


Figure F-7. Example III Pull Up Velocity 100 kts
Control Position vs Load Factor.

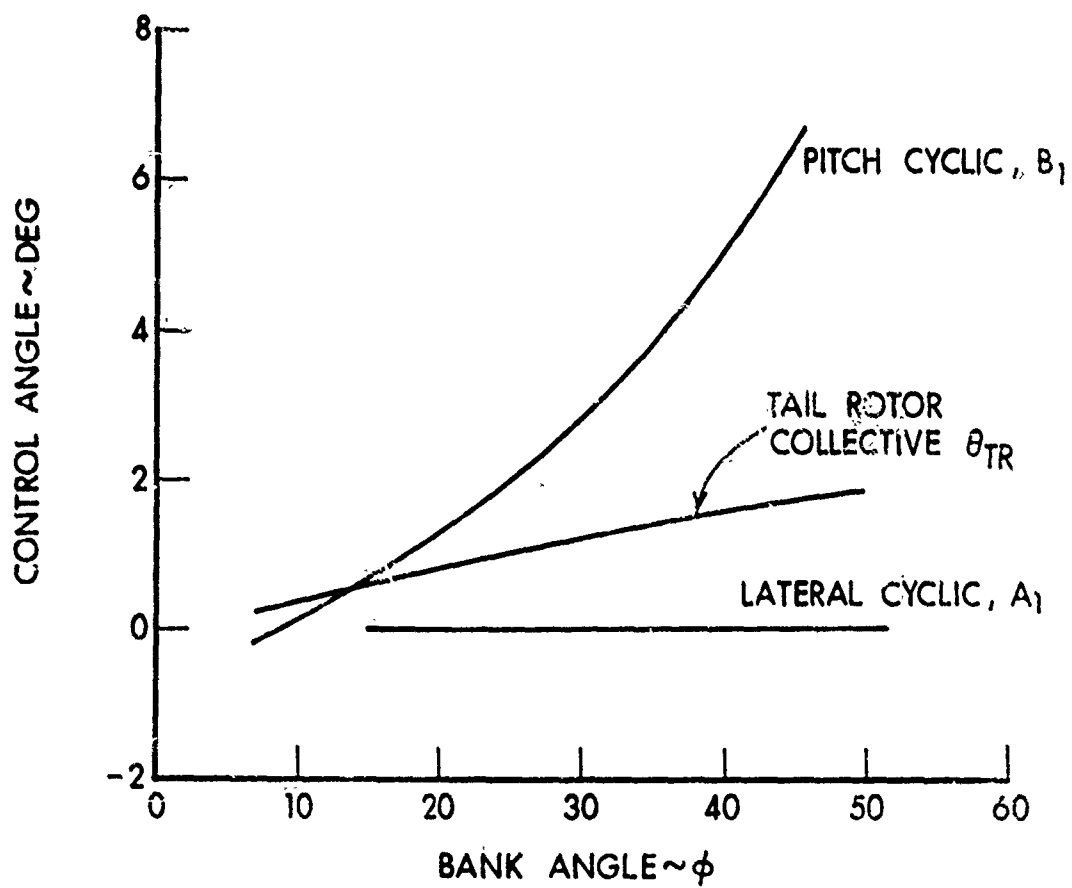


Figure F-8. Example III Control Angle vs Bank Angle
Steady Turn $V = 100$ kts.

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