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OPDOT: A COMPUTER PROGRAM FOR THE OPTIMUM PRELIMINARY DESIGN OF A TRANSPORT AIRPLANE

Steven M. Sliwa and P. Douglas Arbuckle

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ABSTRACT

A description of a computer program, OPDOT, for the optimal preliminary design of transport aircraft is given. OPDOT utilizes constrained parameter optimization to minimize a performance index (e.g., direct operating cost per block hour) while satisfying operating constraints. The approach in OPDOT uses geometric descriptors as independent design variables. The independent design variables are systematically iterated to find the optimum design. The technical development of the program is provided and a program listing with sample input and output are utilized to illustrate its use in preliminary design. This is not meant to be a user's guide, but rather a description of a useful design tool developed for studying the application of new technologies to transport airplanes.

INTRODUCTION

When new technologies in aircraft design, fabrication and operation are evaluated, current practice requires engineering judgment in making compromises. An engineer utilizes a combination of limited analyses, experience and intuition to combine new technologies (e.g., aerodynamics, controls or structures) to maximize the benefits. This approach is imprecise because it involves extrapolating experience from previous designs and because the improvements are usually made to augment multiple, ill-defined criteria (e.g., weight, cost, or performance). To properly evaluate any changes in design concepts, the airplane configuration should be allowed to evolve to optimize a single, well-defined performance index.

This report describes OPDOT (Optimum Preliminary Design of Transports), a computer program written to perform preliminary design and evaluation of transport aircraft using nonlinear programming techniques. A set of independent design variables is iterated upon until a minimum of a performance index which satisfies a series of constraint functions has been calculated. The design variables usually consist of geometry characteristics and mission parameters, while the constraint functions include, for example, regulatory performance requirements and handling quality design criteria. A slightly modified, constrained sequential optimizer is utilized in the program.

This program, therefore, allows the evaluation of new technologies incorporated into an aircraft design in an optimal fashion. The degree of detail in the analyses when the performance function and the constraint functions are evaluated is at the preliminary design or classical aeronautics level. That is, the precision in some phases of the calculations is expected to be as
poor as 5-10 percent. Hence, whereas the predictive capabilities are expected to be marginal, the accuracy of the relative comparisons of designs is expected to be good.

This report, which includes a program listing, sample input and sample output, is a description of a useful analytical tool for analyzing the effects of new technologies on the preliminary design and sizing of transport airplanes. It describes the methods of calculation, program organization and some of the various options available, but it is not meant to be a comprehensive user's manual. The program code was written to expeditiously obtain answers for a study of the impact of active controls upon transport design. This limited the amount of effort that could be spent on developing user flexibility and on integrating into the program a high degree of self-annotation.

SYMBOLS

- \( A \) wing aspect ratio
- \( A_t \) horizontal tail aspect ratio
- \( b \) span, m
- \( \bar{b} \) ratio of tail span to wing span, \( b_t/b_w \)
- \( B \) Brequet range factor, \( \frac{M L/D}{C} \)
- \( c \) specific fuel consumption
- \( \bar{c} \) mean aerodynamic chord of wing
- \( c_i \) \( i \)th constraint value
- \( C_c \) chordwise force coefficient
- \( C_D \) drag coefficient, drag/\( qS \)
- \( C_L \) lift coefficient, lift/\( qS \)
- \( C_{L_A} \) approach lift coefficient
- \( C_{L_t} \) tail lift coefficient
- \( C_{L_o} \) design lift coefficient for wing airfoil section
$C_{L_{SO}}$  stall lift coefficient with full flaps

$C_{L_{TO}}$  lift coefficient at takeoff

$C_{L_2}$  lift coefficient during second segment climb

$C_m$  pitching moment coefficient, pitching moment/\overline{qS\delta}

$C_N$  normal force coefficient

$C_T$  thrust coefficient

$f$  unaugmented performance index

$F$  augmented performance index

$i$  ith constraint function

$h_t$  vertical tail height, m

$i$  angle of incidence, deg

$K$  penalizing weight

$K_{\delta}$  pitch feedback gain, $\partial\delta/\partial\theta$

$K_{\dot{\delta}}$  pitch rate feedback gain, $\partial\dot{\delta}/\partial\dot{\theta}$

$\lambda_t$  distance from wing aerodynamic center to tail aerodynamic center, m

$L/D$  glide ratio

$m$  mass (slugs)

$M$  Mach number

$M_{q}$  pitching moment derivative due to pitching velocity, sec$^{-1}$

$M_{w}$  pitching moment derivative due to unit vertical velocity, sec$^{-1}$

$M_{\dot{w}}$  pitching moment derivative due to vertical acceleration, sec$^{-1}$

$M_{\sigma}$  pitching moment derivative due to control deflection, sec$^{-1}$
\( n \) number of engines

\( n_{z/a} \) airplane vertical gain, g's/rad

\[ \frac{|S_{l_i}| + |S_{u_i}|}{2} \]

\( N_i \) ith constraint normalizing factor

\( p \) design parameter (constant for optimization)

\( q \) dynamic pressure

\( R \) airplane range, kilometers

\( S_{l_i}, S_{u_i} \) lower and upper boundaries of ith constraint

\( S_t \) tail area, m²

\( S_w \) wing area, m²

\( T \) thrust at altitude, N

\( T_I \) installed thrust at sea level, N

\( \text{TOP} \) Take-off parameter

\( U_0 \) reference velocity, m/sec

\( V_{cr} \) cruise velocity, m/sec

\( V_{l_i}, V_{u_i} \) lower and upper boundaries of ith independent design variable

\( W \) aircraft weight at altitude, N

\( W_{TO} \) maximum aircraft weight at take-off, N

\( W_1 \) initial aircraft weight during cruise segment, N

\( W_2 \) final aircraft weight after cruise segment, N

\( X_i \) ith independent design variable

\( X_{ac} \) % MAC from datum to c.g. in x-direction
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Z_i )</td>
<td>independent design variable transformed</td>
</tr>
<tr>
<td>( Z_6 )</td>
<td>dimensional vertical force derivative due to elevator deflection, sec (^{-1} )</td>
</tr>
<tr>
<td>( Z_{ac} )</td>
<td>( % ) MAC from datum to c.g. in z-direction</td>
</tr>
<tr>
<td>( Z_t )</td>
<td>height of thrust vector from c.g. (( % ) MAC)</td>
</tr>
<tr>
<td>( \varepsilon_1 )</td>
<td>Oswald's efficiency factor for ( 0 \leq C_L \leq C_{L_0} )</td>
</tr>
<tr>
<td>( \varepsilon_2 )</td>
<td>Oswald's efficiency factor for ( C_L &gt; C_{L_0} )</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>flight path angle, rad</td>
</tr>
<tr>
<td>( \omega_{sp} )</td>
<td>short period frequency, sec (^{-1} )</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>Munk's interference factor</td>
</tr>
<tr>
<td>( t )</td>
<td>tail efficiency, ( \bar{q}_t )</td>
</tr>
</tbody>
</table>

**Superscript**

* optimum

**Subscripts**

- \( ac \): aerodynamic center
- \( cr \): cruise
- \( q \): pitch rate
- \( t \): tail
- \( u \): velocity
- \( w \): wing
- \( \alpha \): angle of attack
- \( \dot{\alpha} \): rate of change in angle of attack
PROGRAM DESCRIPTION

General

The overall flow of the program is depicted in figure 1. A set of starting values for the selected independent design variables and design constants is input and used to initialize the optimizer and the data base. Initially, the program was written with seven independent variables (wing area, wing aspect ratio, fuselage length, horizontal tail area, horizontal tail aspect ratio, aft-most center-of-gravity position, and installed thrust), but it has the inherent capability to handle more and has successfully converged with thirteen. Typical design constants include nonvarying geometries, mission parameters, economic constants, nonlinear aerodynamics data and some levels of technology. An extensive list of design constants that were used in one study is shown in Appendix VII.

Design constants are prime candidates for being changed to independent design variables. Both design constants and independent design variables are held constant for each call to the performance function evaluation routines. Independent design variables are typically altered each function call by the optimizer, while design constants are not allowed to vary for the entire optimization. A method for augmenting the set of independent design variables with design constants will be described in a later section.

The inputs (the current value of independent design variables and the design constants) are utilized by a sequence of subroutines that calculate a performance index which is selected by the user. Typically, minimum direct operating cost per block hour is chosen, but minimum direct operating cost per flight, maximum return-on-investment per year, minimum income required for a 15 percent return on investment, maximum L/D and minimum take-off gross weight are also available as criteria to be optimized. During the series of subroutine calls, data is exchanged with and stored in the data base for future use. The program has been constructed in a modular fashion to allow users to replace routines with preferred versions to allow significant configuration changes or to improve the level of accuracy.

Next a series of subroutines is called to calculate the constraint functions. Those that are calculated for cruising flight utilize data stored in the data base during the performance function evaluations. Many subroutines were written in such a fashion as to provide data in slow flight configurations as well as in cruising flight. These are called to yield take-off and landing performance data. As a byproduct, the longitudinal stability derivatives are generated. These nondimensional derivatives, for both approach and cruise, are converted to dimensional derivatives and are then used to determine the roots of a fourth order linear model of the longitudinal dynamics. These roots are used to calculate the damping and frequency in the short period and phugoid modes.
The program determines which constraint functions are violated and adds a penalty term for each violation to the performance index to create an augmented performance index. The optimizer then iterates upon the design variables to minimize the augmented function. If the weights on the penalty terms are sufficiently large, the violations will be driven to zero. A convergence of the optimizer results in the minimum unaugmented performance index that satisfies the constraint functions.

Optimization Code

The optimization is performed by a sequential simplex method (Ref. 1 and 2) which utilizes a continuous penalty function. This direct search algorithm has the advantage of not using gradient evaluations, and hence does not perform poorly near "ridges" in the performance index. Additionally, the penalty scheme is independent of the number of active constraints. Its chief disadvantage is slow convergence in large regions of small gradients of the augmented performance function with respect to the independent design variables.

The general problem is formulated as follows:

Let the unaugmented performance index, $f$, be a function of the independent design variables, $x$, and design parameters, $p$.

$$f = fcn(x,p) \quad (1)$$

and

$$g_i = \begin{cases} 
0 & \text{if } c_i \geq S_{l_i} \text{ and } c_i \leq S_{u_i} \\
S_{l_i} - c_i & \text{if } c_i < S_{l_i} \\
c_i - S_{u_i} & \text{if } c_i > S_{u_i} 
\end{cases}$$

then

$$F = f + \sum_{i=0}^{m} K(g_i/N_i)^2 \quad (2)$$

The goal is to find the minimum of the augmented function, $F$, with the gains, $K$, large.

A variable transformation (Ref. 3) is used to automatically scale the variables and apply "side" constraints, which are inequality constraints applied
directly on the design variables. This resulted in a reduction in the number of iterations required for convergence.

The form of the transformation is as follows:

\[
X_i = \frac{V_{u_i} - V_{l_i}}{2} \sin \left( \frac{\pi Z_i}{2} \right) + \frac{V_{u_i} + V_{l_i}}{2}
\] (3)

where \(V_{u_i}\) and \(V_{l_i}\) are the \(i\)th upper and lower independent design variable boundaries. So the simplex optimizer iterates on the transformed variable \(Z\), which spans the set of allowable values of the independent design variables with the range in \(Z\) of \(1\) to \(-1\). This allows consistency in step size selection and limits the allowed values of the independent design variables.

A version of the program is listed in Appendix I. The main program SIMPACT, the subroutines NELMIN and SETUP with the function FN are used to perform the optimization. Some key variables and a description of the pertinent labelled common blocks are shown in Appendices V and VI, respectively. Prior to the optimization, a series of inputs to initialize the optimization blocks is read in and XINPUT is used to initialize the aircraft data. NELMIN, the subroutine which returns the constrained minimum, is called several times (usually two) with increasing weights and diminishing convergence criteria and initial step sizes. This is to help in obtaining a satisfactory local minimum with no constraints violated and, ideally, with the active constraints resting against their boundaries.

NELMIN calls FN which returns the augmented performance index. FN calls SETUP which performs the variable transformations, obtains the unaugmented performance index, calls the constraint evaluation routines, determines the penalty terms and then assembles the augmented performance index. The unaugmented performance index is determined by calling DOCOST and the constraint functions are calculated from CNSTRN.

Evaluation of Unaugmented Performance Index

A flow diagram showing the general procedure for evaluating the unaugmented performance index is shown in figure 2. DOCOST (Included in Appendix I) assembles various cost components by first calling GEO to calculate and store some geometry constants and then calling CGCAL to assign the center-of-gravity positions for the various phases of flight and the landing gear position (if variable). Then WEIGHT is called which is used to estimate the airplane's operating weights, the amount of fuel burned during the mission and a variety of other parameters required from the cruise portion of the flight.

In WEIGHT, an initial estimate of take-off weight and fuel fraction is made. The individual weight components are determined using statistical relationships
from references 4 through 6. The primary source was reference 4, but the
critical components for the intended uses of the program (i.e., wing, horizontal
tail and fuselage) were limited to geometric ranges to maintain validity. To
improve the capability of predicting the weights of these components (e.g., at
high aspect ratios) an average of values calculated from references 4 through 6
was made. After the component weights are summed, FUELCAL is used to determine
the weight of the fuel required to fly the passenger mission and the reserve
mission. This fuel weight is used to estimate the weight of the fuel systems.

The sum of the individual estimated weight components is compared with the
initial estimate of take-off weight; and, if the difference is greater than some
convergence criterion (usually about .2 Newtons), a new estimate is made and the
components are summed again. This continues until the weight loop convergence
criterion is satisfied. The new estimate for the gross take-off weight is made
through a weighting scheme based on the number of current iterations. The
total and average number of iterations is displayed to the user to provide
guidance in possible programming changes in the event of slow weight loop conver-
gence. Usually WEIGHT averages between 3 and 5 iterations per function call
during an optimization run.

FUELCAL assumes a flight profile schematically illustrated in Figure 3. A
fixed percentage of the total fuel burnoff is attributed to the following tasks:
taxi, take-off, initial climb, climb to cruise, descent and landing. The
remainder of the flight (the cruise portion) is divided into ten equal segments.
During the first segment the transport is flown at a $C_L$ for maximum range
factor, $B_*$. The initial cruise altitude is 11000 m (36000 ft), and CRUALT is
called to find the desired altitude at the end of the first segment to maintain
the same $C_L$ for a new weight, while insuring the aircraft is also cruising at
the desired Mach Number. The required excess thrust to generate the calculated
climb gradient is then saved for future use in the constraint functions.

Segments 2 through 5 are flown in a cruise/climb mode at $M_{cr}$ and $B_*$, which
can be calculated from classical relationships. At segment 6, however, the
climb is increased so that segments 7 through 10 can be flown at cruise Mach
number, $M_{cr}$, and 98% $L/D_{max}$. The cruise is backed off $L/D_{max}$ slightly to help
provide some speed stability.

Thus, as modelled above, the independent design variables only impact the
cruise portion of the flight. To simulate the complex reserve mission require-
ment, the transport is flown for an additional 1400 kilometers (1000 nautical
miles) at 9100 meters (30,000 feet) at the speed for maximum range.

CRUFUEL calculates the amount of fuel burned during each segment as well as
the time required to fly it and the altitude change to satisfy the cruise/climb
assumptions. As previously described, the aircraft is flown at the speed for
maximum Brequet range factor during the first five segments provided the
resulting Mach number is less than or equal to the desired cruise Mach number.
The solution comes from classical aeronautics, for example, reference 4.
\[
\frac{L}{D_{B*}} = 0.943 \frac{L}{D}
\]

from aeronautics and assuming parabolic drag polars

\[
C_{L_{B*}} = 0.79 \frac{C_{L}}{D_{\text{max}}}
\]

CRUALT returns the required altitude to fly at the specified weight, lift coefficient and Mach number at the end of each segment. CRUFUEL then estimates a rate-of-climb slightly greater than that which would maintain the maximum range factor cruise for the given altitudes. The eventual goal is to achieve a cruise at 98% of maximum L/D for the last four segments of the cruise distance at the cruise Mach number. Holding the Mach number fixed results in increasing lift coefficients as altitude increases. This is continued until the airplane attains maximum L/D.

The assumed mission profile, although patently suboptimal, varies less than 3 percent in fuel consumption from some optimal profiles (Ref. 7). Given the level of accuracy of the program and the desire to compare designs rather than predict the performance of one design, this level of precision was deemed acceptable.

XLOD is used to estimate the aerodynamic performance of the airplane. The parasite drag is obtained from CDZL. CDZL performs a drag buildup by estimating the Reynolds number, friction coefficients, and various nonlinear constants as illustrated in references 4 and 8. Increments in drag are included for "crud" drag and flap deflections. XLOD then calls STABCOD to estimate the stability and control derivatives while in the indicated flight configuration. These nondimensional derivatives are obtained from a combination of empirical and analytical relations developed from references 8 through 10 for transport airplanes. Some aeroelastic correction factors are applied to the derivatives based on observations of data in references 10 through 12.

XLOD then utilizes the stability and control data as it calls TRIM. The desired airplane lift coefficient with the specified Mach number, parasite drag, flap configuration, center-of-gravity position and phase of flight are input to TRIM.

The following classical non-linear trim equations (Ref. 13) were used in TRIM to represent the normal and chordwise forces and to solve for the required tail or wing lift coefficients:
An iterative scheme utilizing the above equations is used whereby a new tail lift coefficient is estimated until a convergence criterion is satisfied. Direct substitution into the vertical force, horizontal force and pitching moment equation is not possible since it has been deemed inappropriate to linearize the transcendental functions. It would also require neglecting the vertical offset of the center-of-gravity from the aerodynamic center and thrust-line and neglecting the contributions due to tail drag. Typically three or four iterations are required to satisfy the trim convergence criteria ($\Delta C_{L_t} < .003$).

TRIM is used in one of two fashions. First, if a desired airplane lift coefficient is input, the routine iterates to find the required lift coefficients for the tail and wing. Alternatively, if a wing lift coefficient is input, the required tail lift coefficient is output along with the resulting airplane lift coefficient. The latter mode is used to determine the maximum trimmed lift coefficient for approach or take-off configurations where stalling of the wing is a concern.

The wing compressibility drag contribution is calculated in XLOD by using the empirical relationships found in reference 14, which were derived from supercritical aerodynamics wind tunnel data. The fuselage compressibility drag term is modelled from the graphs in reference 13. It should be noted that it is assumed that the fuselage is not area ruled and hence calculated drag will be pessimistic for transonic configurations ($1.0 > M_{cr} > 0.9$).

The induced drag contribution is obtained as follows:

$$C_{D_i} = \frac{C_{L_o}^2}{\pi A e_1} + \frac{C_{L_w}^2 - C_{L_o}^2}{\pi A e_2} + \frac{2\sigma C_{L_w} C_{L_t} S_t}{\pi A S_{w_1}} + \frac{S_t C_{L_t}^2}{\pi A_t e_t}$$  

(9)
The first two terms are the wing contribution including an offset for the design lift coefficient of the highly cambered wing. The third term represents the interference drag between the lift vectors of the tail and the wing. Notice how the interference term could be negative if the tail lift were downward. The fourth term is the drag contribution of the tail lift (positive for a tail load in any direction). The interference factor, \( \sigma \), is a function of the gap ratio, \( h_t/b_w \), and the span ratio, \( \bar{b} \). This term is calculated from a least squares polynomial fit (Ref. 15) of the curves in reference 16.

The total drag, calculated in XLOD, is the sum of the induced drag, the drag due to elevator deflection \( (C_{D_\delta} \text{ estimated from Ref. 13}) \), the compressibility drag and the parasite drag. The L/D is obviously calculated as \( C_L/C_D \). Additionally, the lift coefficient for \( L/D_{\text{max}} \) is estimated and stored for future use. XLOD, CDZL, STABCOD and TRIM are generalized to function for both cruise and approach conditions.

CRUFUEL then calls ENGINE to determine the thrust and specific fuel consumption as a function of altitude and Mach number. The engine performance comes from a normalized model of the baseline engine from reference 7. The engine weight and size are scaled according to reference 4 based upon the installed thrust. The specific fuel consumption obtained from ENGINE and the L/D from XLOD are substituted into the classical Brequet range relationship for each cruise segment to determine the fuel consumption.

\[
\frac{W_1}{W_2} = \exp \left( \frac{cR}{V_{cr}L/D} \right)
\]  

(10)

After WEIGHT has converged upon the aircraft operating weights for the desired mission, DOCOST continues with the cost estimates. AIRCOST used the weight, some production assumptions (number of prototypes, number of production, time for development, etc.) and the statistical relationships of reference 4 to predict the purchase cost of the airplane. Some cost increases based on references 17 and 18 are arbitrarily applied to account for the inclusion of active controls.

MAINCST uses statistical relationships found in references 19 and 20 to determine the cost of airplane maintenance. A number of configuration assumptions have to be made (e.g., number of APU's, windows and IMU's) to utilize these equations (see Appendix VII). The equations for estimating the other direct operating cost terms come from references 17 and 20. Indirect operating cost is predicted using the statistical relationships from references 17 and 21. An annual rate of return on investment (ROI) is calculated and the remaining performance indices are saved in the data base for future use by the optimizer.
EVALUATION OF CONSTRAINT FUNCTIONS

The program version included herein has 52 constraint functions that can be applied to the transport design. The designer chooses an upper and lower boundary for each function as an input. The program does a test on all constraint lower boundaries; and, if -999 is input for the lower boundary of a constraint function, the constraint is not included in the penalty function even if it is a violation. The constraint functions are of two general types, design or operational constraints and handling quality constraints. The first set restricts the design to avoid infeasible geometries or to insure satisfying performance regulations and mission requirements. The second set is used in the study of tail sizing and the impact of flying qualities design criteria upon transports with relaxed static stability augmentation systems.

CNSTRN returns the values of the constraint functions to SETUP, where they are identified as violated or not violated, normalized and assembled into a penalty function. The ratio of cruise thrust available to cruise thrust required is obtained from the data base as are the cruise altitudes and the cruise wing lift coefficient. The geometry constraints include insuring that the aft center-of-gravity is far enough forward of the main landing gear to provide sufficient nose wheel steering and that there is enough floor space to seat the passengers.

The missed approach climb gradient and the second segment climb gradient are engine-out performance requirements specified by the Federal Aviation Regulations, FAR's, (Ref. 22). The required thrust to weight ratio is calculated as follows:

\[ \frac{T}{W} = \left( \frac{N}{N - 1} \right) \left( \frac{1}{L/D} + \sin \alpha \right) \left( \frac{1}{T/T_I} \right) \]  \hspace{1cm} (11)

The flight path angle is specified by the FAR's and the L/D is obtained by calling XLOD with the proper speed and configuration specified. The second segment climb is performed at maximum gross weight and at a lift coefficient defined by

\[ C_{L2} = \frac{C_{L_{TO}}}{1.44} \]  \hspace{1cm} (12)

The missed approach climb is performed at maximum landing weight and at a lift coefficient defined by

\[ C_{L_A} = \frac{C_{L_{SO}}}{1.69} \]  \hspace{1cm} (13)
CLT₀ and CL₀₀ are determined by specifying the maximum lift coefficient that the wing can support in each flap configuration and then calling XLOD, which for this case trims the airplane maintaining the wing lift coefficient. Since the tail of conventional configurations is generally carrying a downward load at this point, the aircraft will usually trim at an overall lift coefficient less than the one specified for the wing alone.

The landing and take-off field length are determined using empirical relationships from reference 23. The landing field length utilizes approach speed as the independent parameter. \( \text{TOP} \), which is defined as

\[
\text{TOP} = \frac{W_{\text{TO}}/S_{\text{W}}}{C_{L_{\text{TO}}}/T_{\text{I}}/W_{\text{TO}}}
\]

is used as the independent parameter for the take-off analysis.

Several of the flying quality constraints are control power requirements. One is to maintain a lift coefficient on the tail greater than \(-0.8\) during approach (Ref. 24). This is to provide adequate margin from the maximum downward load capable of being supported by the tail (generally \( C_{L_{\text{t} \_{\text{max}}} = -1.2 \)) to insure a capability to rotate and trim the aircraft for landing.

The tail is also required to be able to rotate the airplane for take-off. The maximum available downward load the tail can produce during take-off roll is calculated using the relationships in reference 14 modified for ground effect using the geometric angle-of-attack method of reference 8. The required downward load at the tail is determined from statics, such as the development in reference 25. The constraint specifically requires the ratio of the available tail downward load to the required tail downward load to be greater than 1.

The flying quality analysis is initiated by trimming the airplane in approach configuration with an altitude of 150 meters by calling XLOD. The nondimensional stability derivatives for cruise and approach, which are stored in the data base, are converted to dimensional stability derivatives by DIMDER. The characteristic equation for the fourth order longitudinal set of equations (Ref. 26) is assembled by LONGRT. The four roots are determined by using RPOLY, a system routine for finding roots of polynomials on Langley Research Center's FORTRAN Math Library.

The preceding analysis is used to assign the following constraint functions for both cruise and approach: static stability, maneuver stability, dynamic stability, phugoid mode frequency and damping and the short period mode frequency and damping. The dimensional stability derivatives are used to estimate the following parameters which have been suggested as useful for flying.
qualities analysis: time-to-double, time-to-half, flight path stability in approach, vertical gain and $\omega_{sp}^2/n_z$.

The tail is configured with a trimmable stabilizer, maintaining the elevator for maneuvering. If the stabilizer "hits" a control stop in either cruise or approach, the elevator is deflected to satisfy the remaining trim requirements. The amount of this trim deflection is stored as a constraint function and is usually required to be zero. Otherwise, a control deflection would indicate a loss of control authority, and in some cases, an increase in trim drag.

Since one intended use of the program is to study unaugmented flying qualities design criteria, it is desirable to insure that the airplane is capable of being practically augmented to excellent flying qualities. A pitch-attitude-hold with pitch-rate-command autopilot was chosen as a conservative estimate of an augmentation system. The airplane is arbitrarily augmented to have: $\frac{\omega_{sp}^2}{n_z/\alpha} = 1$ and $\zeta_{sp} = .7$. An extension of reference 27 is used to calculate the feedback gains $K_\theta$ and $K_\phi^*$. In reference 27 it is assumed that $M_w$, $M_\phi^*$ and $Z_\phi$ are negligible and hence zero. If these assumptions are removed, the following relations are derived utilizing the short period approximation to the longitudinal dynamics:

$$K_\theta = \omega_{sp}^2 \frac{(1 - M_{w}U_w)}{M_\delta + M_w} + \frac{(M_{w}M_\delta)}{M_\delta + M_w} \omega_{sp}^2 \tag{15}$$

$$K_\phi^* = 2\zeta_{sp} \omega_{sp} (M_{w}U_w - 1) - M_q - M_{w}U_w + M_{\theta}^* \omega_{sp}^2 \frac{(1 - M_{w}U_w)}{(M_\delta + M_\phi^*)}$$

$$+ 1 - \frac{M_{w}M_\delta \omega_{sp}}{(M_\delta + M_w)} + 2\zeta_{sp} \omega_{sp} M_{M_\delta} - M_\delta - M_{w}M_\delta \omega_{sp} \tag{16}$$

These gains are then substituted in equations B-31 and B-38 of reference 27 for estimating the variance of the elevator position and elevator position rate in cruise and approach. The turbulence is assumed to have a characteristic length of 760 meters (2500 feet) with an RMS gust level of .9 and 2.13 m/sec (3 and 7 ft/sec) in cruise and approach, respectively. These autopilot calculations are used to assign the following quantities in cruise and approach to available constraint functions: $K_\theta$, $K_\phi^*$, $\sigma_\delta$ and $\sigma_\phi^*$. The constraint functions are used to insure that enough aerodynamic control exists to stabilize the airplane to excellent flying qualities and that enough hydraulic capability is available to prevent control surface rate saturation in heavy turbulence.
A listing of the computer program set up to optimize seven design variables is included as Appendix I. Appendices II and III show sample input and output, respectively, for the program. Appendix IV contains a listing of a procedure file that will execute the program on the Langley Research Center computer system. As an aid in understanding the coding, a list of key program variables by routine and descriptions of their values are presented in Appendix V. Appendix VI is a compendium describing the variables in the common blocks.

The procedure file listed in Appendix IV contains a call to PPB, a program for executing a geometry preprocessor upon the output data placed on TAPE4 by subroutine XOUTPUT. This preprocessor puts on TAPE7 a data set suitable for executing ABS2290, an airplane graphics package described in reference 28. It is useful during conceptual design trade studies to see pictures of the configurations being generated. An example of this feature is shown in Figure 4.

Typically, with a case similar to the one contained in the appendices, approximately 500 function calls, or iterations, are required for a convergence of NELMIN. A function call averages about 1 second in execution time on the Langley Research Center Cyber 175.

If the user desired to add more design variables for the optimizer to iterate upon, these can be added as assignment statements beneath the transformation in SETUP (see Appendix I). Sample statements are left for adding cruise Mach number, wing sweep angle, wing thickness ratio and fuselage diameter as design variables. Usually all that is necessary to add an independent design variable is to equate it to a variable in the system of common blocks, which should contain degrees of freedom adequate for studies at the preliminary design level.

An array in the common block GEOM named PX has been included to aid in the study of certain changes representative of technological improvements. The specifics of its use are described in Appendix VI. For example, the following parameters could be studied during a design series: engine fuel efficiency, wing drag reduction, pitching moment reduction and structural efficiency.
REFERENCES


PROGRAM SIMPACT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE4)

*******************************************************************************
* OPTIMIZATION COMMON BLOCKS *
*******************************************************************************

COMMON /AVOID/FACT(59),GNORM(59)
COMMON /CONSTR/SU(59),SL(59),XINEQ(59)
COMMON /DEBUG/DEBUG,DEBUG2
COMMON /FCOUNT/ICNT,JCNT,KCNT,NDAV,LCNT,IWT,NOIT
COMMON /LABELP/ARUN(8)
COMMON /PERF/UNAUG,SCF,NVAR,MINEQ
COMMON /STRAIN/CON(59)
COMMON /VARIAB/AMP(15),AVE(15)
COMMON /VIOL/CAYY,MC,ILINE,IOUT

*******************************************************************************
* DESIGN COMMON BLOCKS *
*******************************************************************************

COMMON /DEVAR/DESIGN(15),ITERM(10),CST(10)
COMMON /DRAG/CDS(6),CDSAP(6)
COMMON /GEOM/W(20),HX(20),GX(35),PX(15)
COMMON /GRAVITY/OG(6)
COMMON /STAB/DERIVCR(15),DERIVAP(15),STOR(20)
COMMON /WTSVE/WTS(20)

*******************************************************************************
* INPUT DATA *
*******************************************************************************

REAL STEP(15),XMIN(15),XSEC(15)
REAL XBAR(15),XBARO(15)
REAL XL(15),XU(15)
READ(5,18) ARUN
18 FORMAT(8A10)
READ(5,*) NVAR,MINEQ
READ(5,*) (XBARO(I),I=1,NVAR)
IDEBUG=0
IWT=0
DEBUG2=0
DO 19 J=1,NVAR
READ(5,*) JI,XL(J),XU(J)
AVE(J)=(XL(J)+XU(J))/2.0
AMP(J)=(XU(J)-XL(J))/2.0
19 CONTINUE
DO 20 I=1,MINEQ
20 READ(5,*) IJ,SL(I),SU(I)
WRITE(6,927) ARUN
927 FORMAT("I"/5X*RUN NO=*8A10/)
WRITE(6,718) NVAR,MINEQ
718 FORMAT(/10X*NO. OF VARIABLES=*I5/10X
$*NO. OF CONSTRAINTS=*I5)
WRITE(6,720) (XBARO(L),L=1,NVAR)
DO 24 J=1,NVAR
WRITE(6,22) J, XL(J),XU(J),AVE(J),AMP(J)
22 FORMAT(5X*J,XL,XU,APE=I5,4F15.4)
24 CONTINUE
DO 26 I=1,MINEQ
WRITE(6,928) I,SL(I),SU(I)
928 FORMAT(5X*I,SL(I),SU(I)=I5,2F10.2)
FACT(I)=1.
XINEQ(I)=1.
IF(SL(I).EQ.-999.) FACT(I)=0.
GNORM(I)=(ABS(SU(I))+ABS(SL(I)))/2.0
26 CONTINUE
DO 27 I=1,NVAR
27 XBAR(I)=XBARO(I)
READ(5,*) NONE
WRITE(6,39) NOME
39 FORMAT(10X*NUMBER OF REQUESTED NELMINS=*I5)
READ(5,*) SCF,REQMIN,CAYY,STEP1,ILINE
CALL XINPUT
IOUT=-0
ILINER=ILINE
ILINE=0
JCNT=-0
* START OPTIMIZATION *
DO 1020 I=1,NONEL
DO 1000 K=1,NVAR
1000 STEP(K)=STEPI/I
CAYY=CAYY*10.
REQMIN=REQMIN/10
KCNT=-0
WRITE(6,904) (XBAR(L),L=I,NVAR)
904 FORMAT(/10X*INITIAL XBAR*5(T35,5F2.4)
XSIGN=1.
DO 915 LJ=1,NVAR
IF(ABS(XBAR(IJ)).LT.0.8) GO TO 915
XO=XBAR(IJ)
XSIGN=SIGN(XSIGN,XBAR(IJ))
DXB=ABS(XBAR(IJ))-1.
IF(DXB.GE.1.0) XBAR(IJ)=XBAR(IJ)/(ABS(XBAR(IJ))+.25)
IF(DXB.LT.1.0) XBAR(IJ)=XBAR(IJ)-XSIGN*DXB*2.
STEP(IJ)=SIGN(STEP(IJ),-XBAR(IJ))
WRITE(6,911) IJ,XO,XBAR(IJ),STEP(IJ),XSIGN
911 FORMAT(3X"--- RESET (VAR,XO,XBAR,STEP,XSIGN)"I5,4F2.4)
915 CONTINUE
WRITE(6,906) (STEP(L),L=I,NVAR)
906 FORMAT(10X*INITIAL STEPS*5(T35,5F12.4)
WRITE(6,908) REQMIN,SCF,CAYY
908 FORMAT(10X*REQMIN,SCF,CAYY*T35,3E12.4)
* START NELDER-MEAD SUBROUTINE *
ICOUNT=1500
CALL NELMIN(NVAR,XBAR,XMIN,XSEC,YNEWLO,YSEC,REQMIN,STEP,
$ ICOUNT)

WRITE(6,806)
806 FORMAT(5X/ / NELMIN COMPLETE/ / */
WRITE(6,810) (XMIN(L),L=1,NVAR)
810 FORMAT(10X*XMIN=*3(T35,5F15.8/))
WRITE(6,812) YNEWLO
812 FORMAT(10X*YNEWLO=*T35,E15.6)
WRITE(6,814) ICOUNT,JCNT
814 FORMAT(10X*ICOUNT=*T35,I5/10X*TOT. FUNCTION CALLS=*T35,I5/)
XIJWT=IJWT
XJCNT=JCNT
RATWT=XIJWT/XJCNT
WRITE(6,830) XIJWT,RATWT
830 FORMAT(10X,22HTOT. WEIGHT ITERATIONS,T35,F12.2/
$ 10X,28HAVE. WT. ITERATIONS PER CALL,T35,F12.3)
DO 1010 K=1,NVAR
1010 XBAR(K)=XMIN(K)*1.0
IOUT=1
ILINE=0
IOUT=0
ILINE=ILINE

THE FOLLOWING STATEMENTS CAN BE USED TO FIND THE GRADIENTS
AT THE OPTIMAL SOLUTION POINT:

DX=1.0E-5
DO 610 JI=1,NVAR
IDX=0
603 DO 605 J=1,NVAR
XBARO(J)=XMIN(J)
IF(J.EQ.JI) XBARO(J)=XMIN(J)+DX
605 CONTINUE
VAL=FN(XBARO)
FX(JI)=(VAL-ORIG)/DX
IF(FX(JI).LT.1.0E4) GO TO 610
IF(IDX.GT.0) GO TO 610
IDX=1
DX=-DX
GO TO 603
610 CONTINUE
DO 620 JJI=1,NVAR
WRITE(6,607) JJI,FX(JJI)
607 FORMAT(10X*DERIVATIVE WITH RESPECT TO VARIABLE NO.*
$ I5,10X,E15.5)
620 CONTINUE

CALL XOUTPUT(4)
WRITE(6,810) (XMIN(L),L=1,NVAR)
STOP
SUBROUTINE NELMIN (N, START, XMIN, XSEC, YNEWLO, 
1 YSEC, REQMIN, STEP, ICOUNT)
REAL START(N), STEP(N), XMIN(N), 
1 XSEC(N), YNEWLO, YSEC, REQMIN, P(20, 21), PSTAR(20), 
2 P2STAR(20), PBAR(20), Y(20), DN, Z, YLO, RCOEFF, 
3 YSTAR, ECOEFF, Y2STAR, CCOEFF, FN, DABIT, DCHK,
4 COORD1, COORD2
DATA RCOEFF /
1 I. 0 /
2 ECOEFF /
3 2.0 /
4 CCOEFF /
5 0.5 /
DATA PSTAR, P2STAR, PBAR /60*0. /
KCOUNT=ICOUNT
ICOUNT=0
IF( REQMIN .LE. 0.) ICOUNT=ICOUNT-1
IF(N .LE. 0) ICOUNT=-ICOUNT-10
IF(N .GT. 20 ) ICOUNT=-ICOUNT-10
IF(ICOUNT .LT. 0) RETURN
DABIT=-2.04607E-35
BIGNUM=I. 0E38
KONVGE=5
XN=FLOAT (N)
DN=DBLE (XN)
NN=N+1
******************************************************
* CONSTRUCTION OF INITIAL SIMPLEX *
******************************************************
DO 1 I=1,N
1 P (I,NN) =START (I)
Y (NN) =FN (START)
ICOUNT=ICOUNT+1
DO 2 J=1,N
DCHK=START (J)
START (J) =DCHK+STEP (J)
DO 3 I=1,N
3 P (I,J) =START (I)
Y (J) =FN (START)
ICOUNT=-ICOUNT+1
2 START (J) =DCHK
******************************************************
* SIMPLEX CONSTRUCTION COMPLETE *
* FIND HIGHEST AND LOWEST Y VALUES *
* YNEWLO (Y(IHI)) INDICATES THE VERTEX OF THE SIMPLEX TO BE *
* REPLACED. *
******************************************************
1000 YLO=Y(1)
 YNEWLO=YLO
 ILO=1
 IHI=1
DO 5 I=2,NN
IF(Y(I) .GE. YLO) GO TO 4
 YLO=Y(I)
 ILO=I

4 IF(Y(I) .LE. YNEWLO) GO TO 5
YNEWLO=Y(I)
IHI=I
5 CONTINUE

*******************************************************************************
** PERFORM CONVERGENCE CHECKS ON FUNCTION **
*******************************************************************************
DCHK=(YNEWLO+DABIT)/(YLO+DABIT)-1.
IF(ABS(DCHK) .LT. REQMIN) GO TO 900
KONVGE=KONVGE-1
IF(KONVGE .NE. 0) GO TO 2020
KONVGE=5

*******************************************************************************
** CHECK CONVERGENCE OF COORDINATES ONLY EVERY 5 SIMPLEXES **
*******************************************************************************
DO 2015 I=1,N
COORD1=P(I,1)
COORD2=COORD1
DO 2010 J=2,NN
IF(P(I,J) .GE. COORD1) GO TO 2005
COORD1=P(I,J)
2005 IF(P(I,J) .LE. COORD2) GO TO 2010
COORD2=P(I,J)
2010 CONTINUE
DCHK=(COORD2+DABIT)/(COORD1+DABIT)-1.
IF(ABS(DCHK) .GT. REQMIN) GO TO 2020
2015 CONTINUE
GO TO 900
2020 IF(ICOUNT .GE. KCOUNT) GO TO 900

*******************************************************************************
** CALCULATE PBAR, THE CENTROID OF THE SIMPLEX VERTICES EXCEPTING **
** THAT WITH Y VALUE YNEWLO. **
*******************************************************************************
DO 7 I=1,N
Z=0.0
DO 6 J=1,NN
6 Z=Z+P(I,J)
Z=Z-P(I,IHI)
7 PBAR(I)=Z/DN

*******************************************************************************
** REFLECTION THROUGH THE CENTROID **
*******************************************************************************
DO 8 I=1,N
8 PSTAR(I)=(1.0+RCOEFF)*PBAR(I)-RCOEFF*P(I,IHI)
YSTAR=FN(PSTAR)
ICOUNT=ICOUNT+1
IF(YSTAR .GE. YLO) GO TO 12
IF(ICOUNT .GE. KCOUNT) GO TO 19

*******************************************************************************
** SUCCESSFUL REFLECTION, SO EXTENSION **
*******************************************************************************
DO 9 I=1,N
9 P2STAR(I)=ECOEFF*PSTAR(I)+(1.0-ECOEFF)*PBAR(I)
Y2STAR=FN(P2STAR)
ICOUNT=ICOUNT+1
******************************************************************************
* RETAIN EXTENSION OR CONTRACTION  *
******************************************************************************
IF(Y2STAR .GE. YSTAR) GO TO 19
10 DO 11 I=1,N
11 P(I,IHI)=P2STAR(I)
Y(IHI)=Y2STAR
GO TO 1000
******************************************************************************
* NO EXTENSION  *
******************************************************************************
12 L=0
DO 13 I=1,NN
13 CONTINUE
IF(L .GT. 1) GO TO 19
IF(L .EQ. 0) GO TO 15
******************************************************************************
* CONTRACTION ON THE REFLECTION SIDE OF THE CENTROID  *
******************************************************************************
DO 14 I=1,N
14 P(I,IHI)=PSTAR(I)
Y(IHI)=YSTAR
******************************************************************************
* CONTRACTION ON THE Y(IHI) SIDE OF THE CENTROID  *
******************************************************************************
15 IF(ICOUNT .GE. KCOUNT) GO TO 900
DO 16 I=1,N
16 P2STAR(I)=CCOEFF*P(I,IHI)+(1.0-CCOEFF)*PBAR(I)
Y2STAR=FN(P2STAR)
ICOUNT=ICOUNT+1
IF(Y2STAR .LT. Y(IHI)) GO TO i0
******************************************************************************
* CONTRACT THE WHOLE SIMPLEX  *
******************************************************************************
DO 18 J=1,NN
DO 17 I=1,N
17 XMIN(I)=P(I,J)+(P(I,J)+P(I,ILO))*0.5
18 CONTINUE
ICOUNT=ICOUNT+NN
IF(ICOUNT .LT. KCOUNT) GO TO 1000
GO TO 900
******************************************************************************
* RETAIN REFLECTION  *
******************************************************************************
19 CONTINUE
DO 20 I=1,N
20 P(I,IHI)=PSTAR(I)
Y(IHI)=YSTAR

24
GO TO 1000

************************************************************************
* SELECT THE TWO BEST FUNCTION VALUES (YNEWLO AND YSEC) AND THEIR *
* COORDS. (XMIN AND XSEC).
************************************************************************

900 DO 23 J=1,NN
   DO 22 I=1,N
   22 XMIN(I)=P(I,J)
   Y(J)=FN(XMIN)
   23 CONTINUE
   YNEWLO=BIGNUM
   DO 24 J=1,NN
     IF(Y(J) .GE. YNEWLO) GO TO 24
     YNEWLO=Y(J)
   IBEST=J
   24 CONTINUE
   Y(IBEST)=BIGNUM
   YSEC=BIGNUM
   DO 25 J=1,NN
     IF(Y(J) .GE. YSEC) GO TO 25
     YSEC=-Y(J)
   ISEC=J
   25 CONTINUE
   DO 26 I=1,N
   XMIN(I)=P(I,IBEST)
   XSEC(I)=P(I,ISEC)
   26 CONTINUE
RETURN
END

FUNCTION FN(XBAR)
COMMON /VIOL/CAYY,MC,ILINE,IOUT
COMMON /FCOUNT/ICNT,JCNT,KCNT,NDAV,LCNT,IWT,NOIT
REAL XBAR (15)
CALL SETUP(XBAR,IOUT,OBJ)
FN=OBJ
IF(ILINE.GT.0) WRITE(6,50) JCNT,FN,MC,IWT,NOIT
50 FORMAT (10X,"CALL NUMBER=" ,I5,5X"OBJ="E15.8,10X
  $ ,"NO. VIOLATIONS="I5,5X
$ ,"IWT=" ,I5,5X,"NOIT="I5)
RETURN
END

SUBROUTINE SETUP(GAINS,IPR,OBJ)
INTEGER OUTPUT
REAL GAINS (15) ,GBAR(59)
COMMON /STRAIN/CON (59)
COMMON /VARIAB/AMP (15) ,AVE (15)
COMMON /VIOL/CAYY,MC,ILINE,IOUT
COMMON /CONSTR/SU (59),SL (59),XINEQ (59)
COMMON /DEVAR/DESIGN (15) ,ITERM (10) ,CST (10)
COMMON /GEOM/W (20) ,HX (20) ,GX (35) ,PX (15)
COMMON /PERF/UNAUG,SCF,NVAR,MINEQ
COMMON /AVOID/FACT (59) ,GNORM (59)
DO 22 I=1,NVAR
DESIGN(I) = AMP(I) * SIN(1.5707963 * GAINS(I)) + AVE(I)

22 CONTINUE

************************************************************************
* TO DEFINE ADDITIONAL DESIGN VARIABLES, INSERT DEFINITION CARDS *
* HERE. SAMPLES ARE GIVEN BELOW: *
* *
* GX(3) = DESIGN(8) -- DESIGN(8) IS MACH NUMBER *
* W(1) = DESIGN(9) -- DESIGN(9) IS WING SWEEP *
* W(4) = DESIGN(10) -- DESIGN(10) IS WING THICKNESS RATIO *
* W(3) = DESIGN(11) -- DESIGN(11) IS WING TAPER RATIO *
* GX(5) = DESIGN(12) -- DESIGN(12) IS FUSELAGE DIAMETER *
************************************************************************

* ALSO, VARIOUS DESIGN CONSTRAINTS CAN BE ADDED. FOR EXAMPLE, *
* ADDING THE STATEMENT: *
* *
* GX(32) = W(1) *
* RESTRITS THE HORIZONTAL TAIL SWEET ANGLE TO BE *
* EQUAL TO THE WING SWEET ANGLE. *
************************************************************************

IF (PX(5) .GT. 0) DESIGN(6) = GX(21) * ITERM(4)
IF (IPR.GT.0) WRITE(6,441)

441 FORMAT(//15X*SET-UP*/20X*DESIGN=*5(T40,5F15.4))

OUTPUT=0
CALL DOCOST(COST,0)
CALL CNSTRN(0)
UNAUG=COST*SCF
IF (IPR.GT.0) WRITE(6,442) UNAUG

442 FORMAT(20X*CALL TO DOC/CNSTRN COMPLETE---DOC= $*E15.5)

************************************************************************
* THIS SECTION CALCULATES GBAR ARRAY *
* AND THE PENALTY FOR VIOLATIONS *
************************************************************************

MC=0
PENT=0.
DO 150 I=1,MINEQ
T=CON(I)
XINEQ(I)=0.
GBAR(I)=AMAX1(T-SO(I),SL(I)-T)
GBAR(I)=GBAR(I)*FACT(I)/GNORM(I)
IF (GBAR(I).LE.0.0) GO TO 150
XINEQ(I)=1.
MC=MC+1
PENT=PENT+CAYY*GBAR(I)*GBAR(I)
150 CONTINUE
IF (IPR.GT.0) WRITE(6,160) PENT
160 FORMAT(20X*PENALTY TERM=*E15.5)

************************************************************************
* AUGMENTED FUNCTION IS CREATED *
************************************************************************

OBJ=UNAUG+PENT
RETURN
END

SUBROUTINE XOUTPUT(IPRNT)
COMMON /CONSTR/SU(59),SL(59),XINEQ(59)
COMMON /DEVAR/DESIGN(15),ITERM(10),CST(10)
COMMON /DRAG/CDS(6),CDSAP(6)
COMMON /GEOM/W(20),HX(20),GSX(35),PX(15)
COMMON /GRAVITY/CG(6)
COMMON /LABELP/ARUN(8)
COMMON /STAB/DERIVCR(15),DERIVAP(15),STOR(20)
COMMON /WTSVE/WTS(20)

******************************************************************************************************************************************
* PRINT OUT PARTS OF THE FUNCTION EVALUATION *
* *
* 0=None, 1=DOC, 2=CNSTRN, 3=DOC & CNSTRN, 4=DOC & CNSTRN & DUMP *
* 5=DOC(2) & CNSTRN(2), 6=COMMON DUMP *
******************************************************************************************************************************************

IDUMP=0
IF(IPRINT.LT.1) GO TO 999
IF(IPRINT.EQ.1) GO TO 10
IF(IPRINT.EQ.2) GO TO 20
IF(IPRINT.EQ.3) GO TO 30
IF(IPRINT.EQ.4) GO TO 40
IF(IPRINT.EQ.5) GO TO 50
IF(IPRINT.EQ.6) GO TO 70
10
IDOC=1
ICRN=0
GO TO 80
20
ICRN=1
IDOC=0
GO TO 80
30
IDOC=1
ICRN=1
GO TO 80
40
IDOC=1
ICRN=1
IDUMP=1
GO TO 80
50
IDOC=2
ICRN=2
IDUMP=0
80 CALL DOCOST(TERM,IDOC)
CALL CNSTRN(ICRN)
IF(IDUMP.LT.1) GO TO 999
70 WRITE(6,1010)

1010 FORMAT(*1*30X*COMMON DUMP*////)
WRITE(6,1012) DESIGN
1012 FORMAT(*15X*DESIGN="3(T30,5F15.5/)"
WRITE(6,1014) ITERM
1014 FORMAT(*15X*ITERM="3(T30,5F115/)"
WRITE(6,1016) PX
1016 FORMAT(*15X"PX="3(T30,5F15.4/)"
WRITE(6,1015) CDS
1015 FORMAT(15X*CDS="T30,6F15.9/
WRITE(6,1020) CDSAP
1020 FORMAT(*15X*CDSAP="T30,6F15.9/)
* INPUT DESIGN CONSTANTS *

DATA GX/35*0. /
READ(5,*) WTS(1)
READ(5,*) (PX(J), J=1,8)
READ(5,*) (ITERM(I), I=1,10)
READ(5,*) WTS(16), OG(5)
READ(5,*) W(1), W(2), W(3), W(4), W(5)
READ(5,*) W(6), W(7), W(8), W(14), W(16)
READ(5,*) W(17), W(18), W(19), W(20)
READ(5,*) HX(1), HX(2), HX(3), HX(10)
READ(5,*) HX(16), HX(17), HX(18), HX(19), HX(20)
READ(5,*) GX(3), GX(4), GX(5), GX(6), GX(7)
READ(5,*) GX(8), GX(11), GX(12), GX(17), GX(18)
READ(5,*) GX(19), GX(20), GX(21), GX(22)
READ(5,*) GX(23), GX(24), GX(25), GX(26), GX(27)
READ(5,*) GX(32), GX(34), GX(16)
**INITIALIZE GEOMETRY AND C.G.**

CALL GEO
CALL GGCAL

**INITIALIZE AND INCREMENT COUNTERS**

DATA JCNT=0/
JCNT=JCNT+1
KCN=KCN+1

RETURN
END

SUBROUTINE DOCOST (UNAUG, OUTPUT)
INTEGER OUTPUT
REAL INSUR, PER(12), XIOC(12), YIOC(12), YCOST(9)
COMMON/DEVAR/DESIGN(15), ITERM(10), CST(10)
COMMON/FCOUNT/ICNT, JCNT, NCNT, LCNT, IWT, NOIT
COMMON/GEOM/W(20), HX(20), GX(35), PX(15)
COMMON/WTSVE/WTS(20)

**WRITE OUT DATA**

*WRITE (6, 100)
100 FORMAT (*I* //30X// / / FUNCTION INPUT/ // /*/)
WRITE(6, 110) WTS(1)
110 FORMAT(10X*, WTS(1), T40, F15.4)
WRITE(6, 120) ITERM
120 FORMAT(10X*, ITERM, T40, 1016)
WRITE(6, 125) PX
125 FORMAT(10X*, "PX=", 3(T40, 5F15.4))
WRITE(6, 130) WTS(16)
130 FORMAT(10X*, WTS(16), T40, F15.4)
WRITE(6, 135) WTS(17)
135 FORMAT(10X*, WTS(17), T40, F15.4)
WRITE(6, 140) W(1), W(2), W(3), W(4), W(5)
140 FORMAT(10X*, W(1-5), T40, 5F15.4)
WRITE(6, 145) W(6), W(7), W(8), W(14), W(16)
145 FORMAT(10X*, W(6-14), T40, 5F15.4)
WRITE(6, 150) W(17), W(18), W(19), W(20)
150 FORMAT(10X*, W(17-20), T40, 5F15.4)
WRITE(6, 155) HX(1), HX(2), HX(3), HX(10)
155 FORMAT(10X*, HX(1-10), T40, 5F15.4)
WRITE(6, 160) HX(16), HX(17), HX(18), HX(19), HX(20)
160 FORMAT(10X*, HX(16-20), T40, 5F15.4)
WRITE(6, 165) WTS(18)
165 FORMAT(10X*, "WTS(18)=", T40, F15.4)
WRITE(6, 170) WTS(19)
170 FORMAT(10X*, "WTS(19)=", T40, F15.4)
WRITE(6, 175) WTS(20)
175 FORMAT(10X*, "WTS(20)=", T40, F15.4)
RETURN
END
IF(OUTPUT.GE.1) GO TO 10

******************************************************************************************************************************
* COSTS PER BLOCK HOUR OF DESIGN FLIGHT  *
******************************************************************************************************************************

20 IOUT=OUTPUT
IF (OUTPUT.GT.1) IOUT=0
CALL WEIGHT(IOUT)
CALL AIRCOST(PRICE,IOUT)
YRMULT=1.07** (ITERM(6)-1976)
PRICE=YRMULT*PRICE
FL=WTS(18)
BLKHR=WTS(19)

******************************************************************************************************************************
* DIRECT OPERATING COSTS  *
******************************************************************************************************************************

DEPRE=0.88*PRICE/(14.0*GX(26))
SUPPORT=0.12*PRICE/(14.0*GX(26))
SPARES=0.06*PRICE/(14.0*GX(26))
DELAY=YRMULT*8.40
INSUR=0.01*PRICE/(GX(26))
FCOST=WTS(20)*WTS(16)/6.4
FCOST=FCOST/BLKHR
CALL MAINCST(XMCOST,IOUT)
WTL=WTS(5)*0.453592
FEELAND=YRMULT*1.54*WTL/1000.0
FEELAND=FEELAND/BLKHR
ATT=YRMULT*GX(19)*(0.691*FL+0.00175*FL*FL)
ATT=ATT/BLKHR
CREW=YRMULT*174*FL+43.5+(0.452*FL+.11299)*(WTS(1)*.453592/1000.)
CREW=CREW/BLKHR
SERVICE=YRMULT*63.0
CONTROL=YRMULT*82.58/BLKHR
DOC=DEPRE+SUPPORT+SPARES+DELAY+INSUR+FCOST+FEELAND+SERVICE
$+ATT+CREW+XMCOST+CONTROL

******************************************************************************************************************************
* PERCENT OF TOTAL  *
******************************************************************************************************************************

PER(1)=DEPRE/DOC
PER(2)=SUPPORT/DOC
PER(3)=SPARES/DOC
PER(4)=DELAY/DOC
PER(5)=INSUR/DOC
PER(6)=FCOST/DOC
PER(7)=XMCOST/DOC
PER(8)=FEELAND/DOC
PER(9)=CREW/DOC
PER(10)=ATT/DOC
PER(11)=SERVICE/DOC
PER(12)=CONTROL/DOC
DO 30 J=1,12
30 PER(J)=PER(J)*100.
TOT=100.

******************************************************************************************************************************
DATA YIOC/10HMAIN BURDN, 9HFOOD COST, 5HMOVIE, 8HPASS INS, 
$9HMISC PASS, 9HADVERTISE, 10HCOMMISSION, 5HRESER, 
$9HPASS HDLG, 8HBAG HDLG, 10HCARGO HDLG, 9HSERVICING/ 
XIOC(1)=XMCOST*1.05 
IFIRS=.15*GX(19)*GX(24) 
IECON=GX(19)*GX(24)-IFIRS 
XIOC(2)=(IFIRS*2.42+IECON*1.05) 
XIOC(3)=196./BLKHR 
RPM=GX(19)*GX(24)*GX(4)/1000. 
XIOC(4)=0.52*RPM/BLKHR 
XIOC(5)=GX(19)*.18/BLKHR 
REVYR=GX(25)*GX(19)*GX(24)*GX(26)*GX(4)/BLKHR 
REVHR=REVYR/GX(26) 
XIOC(6)=.023*REVHR 
XIOC(7)=2.35*RPM/BLKHR 
PASSPHR=GX(19)*GX(24)/BLKHR 
XIOC(8)=4.40*PASSPHR 
XIOC(9)=2.87*PASSPHR 
XIOC(10)=1.31*PASSPHR 
TONCAR=GX(22)/2000. 
XIOC(11)=131.08*TONCAR/BLKHR 
XIOC(12)=(0.03*9.5+0.0025)*GX(19)/BLKHR 
TOTIOC=0. 
XIOC(1)=XIOC(1)/YRMULT 
XIOC(6)=XIOC(6)/YRMULT 
DO 200 I=1,12 
XIOC(I)=XIOC(I)*YRMULT 
TOTIOC=TOTIOC+XIOC(I) 
200 CONTINUE 
********************************************* 
* RETURN ON INVESTMENT CALCULATIONS * 
********************************************* 
XINVEST=0.9*PRICE 
TAXRT=.48 
COSTHR=DOC+TOTIOC 
PROFIT=(REVHR-COSTHR)*GX(26) 
ROI=(1.-TAXRT)*PROFIT/XINVEST 
FARROI=(.26*PRICE+COSTHR*GX(26))*(BLKHR/(GX(19)*GX(24)*GX(26) 
$ *GX(4))) 
********************************************* 
* ASSIGN PERFORMANCE INDEX * 
********************************************* 
CST(1)=DOC 
CST(2)=DOC*BLKHR 
CST(3)=ROI 
CST(4)=FARROI 
CST(7)=WTS(1) 
INCPH=COSTHR+.15*XINVEST/(GX(26)*(1.-TAXRT)) 
INCPF=INCPH*BLKHR 
CST(8)=INCPF 
CST(9)=PRICE 
31
UNAUG=CST(ITERM(5))
GO TO 40

***************************
* OUTPUT SECTION          *
***************************

10 WRITE(6,42)
   WRITE(6,44) (DESIGN(JK),JK=1,12)
   IF(OUTPUT.GT.1) GO TO 20
   WRITE(6,705)
705 FORMAT(//5X*INPUT CONSTANTS*/)
   WRITE(6,710) (W(J),J=1,8)
710 FORMAT(10X*WING...Sweep,incidence,Taper Ratio:*T55,3F12.4/
   $ 10X*Thickne ss,TWIST,EL,E2,Design CL:*T55,5F12.4)
   WRITE(6,720) W(14),W(19),W(17),W(18),W(16),GX(17),GX(18)
720 FORMAT(10X*CM(CR,APP):*T55,2F12.4/
   $ 10X*Delta CM(10,25 degrees flap):*T55,2F12.4/
   $ 10X*Angle of Zero Lift(0,10,45 degrees flap):*T55,3F12.4)
   WRITE(6,730) W(20),GX(11),GX(5),GX(8),GX(12)
730 FORMAT(10X*Delta CD (10-45 degrees flap):*T55,F12.4/
   $ 10X*Turbulence length/root 3, fuse. Dia.:*T55,2F12.4/
   $10X*CL-Max(To), CL-Max(L):*T55,2F12.4)
   WRITE(6,740) GX(3),GX(4),GX(19),GX(22),GX(23),GX(27)
740 FORMAT(10X*MISSION...MACH NO., RANGE, NO. PASS:*T55,3F12.4/
   $ 10X*Cargo Weight:*T55,12.4/
   $ 10X*Delta CG, WTL(MAX)/WTO:*T55,3F12.4)
   WRITE(6,750) GX(6),GX(7),GX(20),GX(21)
750 FORMAT(10X*ENGINE...L,W,W,TREF:*T55,4F12.4)
   WRITE(6,760) HX(1),HX(2),HX(3),HX(10),GX(24),GX(25),GX(26)
760 FORMAT(10X*Tail...Taper Ratio, Thickness, ELE EFF:*T55,3F12.4/
   $ 10X*Elevator Time Constant:*T55,12.4/
   $ 10X*Economics...load fact, $/seat mi, blk hr/yr:*T55,3F12.4)
   WRITE(6,770) W(9),W(10),HX(4),HX(5),HX(6),GX(32)
770 FORMAT(//5X*SOME GEOMETRY CALCULATIONS*/
   $ 10X*Wing...Span, CMAC:*T55,2F12.4/
   $ 10X*Tail...Span, CMAC, VBAR, Sweep:*T55,4F12.4)
   WRITE(6,780) HX(16),HX(17),HX(18),HX(19),HX(20),GX(35)
780 FORMAT(10X*VERT. Tail...VBAR, TAPER, AR, SWEEP, SR/SV:S*
   $ T55,6F12.4)
GO TO 20
40 IF(OUTPUT.LT.1) GO TO 100
IF(OUTPUT.GT.1) GO TO 549
42 FORMAT(*1*//30X*AIRCRAFT SIZING PROGRAM*/)
44 FORMAT(5X*DESIGN VARIABLES*/10X*WING AREA (FTXX2)=* 
   $T40,F15.4/10X*WING ASPECT RATIO=*T40,F15.4/10X 
   $*FUSELAGE LENGTH (FT) =*T40,F15.4/10X 
   $*HOR. TAIL AREA (FTXX2) =*T40,F15.4/10X 
   $*HOR. TAIL ASPECT Ratio =*T40,F15.4/10X 
   $*TOTAL THRUST (LBS) =*T40,F15.4/10X*AFT MOST CG ="T40,F15.4/ 
   $ 10X"CRUISE MACH NO.="T40,F15.4/10X"Sweep="T40,F15.4/10X 
   $ "Wing T/C="T40,F15.4/10X"WING TAPER RATIO ="T40,F15.4/ 
   $ 10X","Fuse. Dia.="*T40,F15.4)
   WRITE(6,52)
52 FORMAT(*1*//30X*DIRECT OPERATING COSTS--DOLLARS/FLT. HOUR*)
WRITE(6,54) DEPRE,PER(1),SUPPORT,PER(2),SPARES,PER(3),DELAY,
$ PER(4),INSUR,PER(5),FCOST,PER(6),XMCOST,PER(7),FEELAND,PER(8),
$ CREW,PER(9),ATT,PER(10),SERVICE,PER(11),CONTROL,PER(12)
54 FORMAT(/10X*DEPREC*T40,2F10.2/10X*SUPPORT*T40,2F10.2/10X*SPARES*
$ T40,
$2F10.2/10X*DELAY*T40,2F10.2/10X*INSURANCE*T40,2F10.2/10X*FUEL*T40,
$2F10.2/10X*MAINTENANCE*T40,2F10.2/10X*LANDING FEE*T40,2F10.2/10X*
$CREW*T40,2F10.2/10X*ATTENDANTS*T40,2F10.2/10X*FUEL SERVICE*
$ T40,2F10.2/
$10X*CONTROL*T40,2F10.2)
WRITE(6,56) DOC,TOT
56 FORMAT(/3X*TOTAL DIRECT OPERATING COSTS*T40*$*F9.2,F10.2)
WRITE(6,150)
150 FORMAT(/30X*INDIRECT OPERATING COSTS--DOLLARS/FLT. HOUR*///)
DO 300 I=1,12
PER(I)=100.0*XIOC(I)/TOTIOC
WRITE(6,152) YIOC(I),XIOC(I),PER(I)
152 FORMAT(10X,A10,T40,2F10.2)
300 CONTINUE
WRITE(6,154) TOTIOC,TOT
154 FORMAT(/5X*TOTAL INDIRECT OPERATING COSTS*T40,2F10.2/)
549 WRITE(6,550) REVHR,COSTHR,ROI
550 FORMAT(*I*///30X*PERFORMANCE FUNCTION SUMMARY*///)
$ 10X*REVENUE PER BLOCK HOUR*T50,F12.2/
$ 10X*TOTAL COST PER BLOCK HOUR*T50,F12.2/
$ 10X*RETURN ON INVESTMENT*T50,F12.4///)
DATA YCOST/6HDOC/HR,7HDOC/FLT,3HROI,4HFARE,10HSEAT-MI/GA,
$ 8HLD/MAX,5HMTOGW,4HFARE,5HPRICE/
DO 570 I=1,9
WRITE(6,560) I,YCOST(I),CST(I)
560 FORMAT(10X,I5,A10,F12.3)
570 CONTINUE
100 RETURN
END
SUBROUTINE CGCAL
COMMON /DEVAR/DESIGN(15),ITEM(10),CST(10)
COMMON /GEOM/W(20),HX(20),GX(35),PX(15)
COMMON /STAB/DERIVCR(15),DERIVAP(15),STOR(20)
COMMON /GRAVITY/ CG(6)

**************************************************************************
* ASSIGN CG POSITIONS    *
* (1) AFT-CRUISE        *
* (2) AFT-APPROACH      *
* (3) FWD-CRUISE       *
* (4) FWD-APPROACH     *
**************************************************************************
CG(1)=DESIGN(7)
CG(2)=CG(1)
CG(3)=CG(1)-GX(23)/W(10)
CG(4)=CG(2)-GX(23)/W(10)
DATA CG(6),/18/
C
C ALLOW FREE GEAR LOCATION
IF(ITERM(7) .GT. 0.) OG(5) = CG(1) - CG(6)
RETURN
END
SUBROUTINE GEO
COMMON /DEVAR/DESIGN(15), ITERM(10), CST(10)
COMMON /GEOM/W(20), HX(20), GX(35), PX(15)

* WING CONSTANTS OR COMMON VARIABLES *

* HORIZONTAL TAIL CONSTANTS OR COMMON VARIABLES *

* MISC. CONSTANTS OR COMMON VARIABLES *

DATA GX(1), GX(2) / 3.14159265, 57.295779 /
DATA GX(15), GX(31) / 0., 0., 0. /
DATA GX(15) / 32.174 /
GX(35) = HX(16) * W(9) * DESIGN(1) / (XLT * 0.95)
RETURN
END
SUBROUTINE WEIGHT(OUTPUT)
REAL LT, FI(2), F2(2), ANS(4), DFTA(41)
COMMON /IDRAG/ICDS(6), ICDSAP(6)
COMMON /IDEVAR/DESIGN(15), ITERM(10), CST(10)
COMMON /wargs/WTS(20)
INTEGER OUTPUT
DATA WFOWTO / 0.26 /
DO 20 I = 1, 41
  20 DFTA(I) = 0.
FUDGE IS A FACTOR FOR WEIGHT OVERRUNS
FUDGE=1.05
IF (IDebug GT 0) WRITE (6, 337)
337 FORMAT (*1/20X WEIGHT ITERATION LOOPS*)

SOME GEOMETRY DEFINITIONS

**

IACT=TERM (1)
IGX=TERM (2)
AR=DESIGN (2)
LT=DESIGN (1) *W(10) *HX (6) /DESIGN (4)
SHT=DESIGN (4)
TRV=HX (17)
SHT=HX (16) *W(9) *DESIGN (1) /LT
TENG=DESIGN (6) /TERM (4)
NOIT=0
DELWTO=20.
DIV=1.
WTO=WTS (1)
WTINIT=WTO
WTUEL=WTO*WFOULT
FUEL=WTUEL/6.4
WTENG=FUDGE* (TENG / GX (21)) *GX (20) *TERM (4)
WTS (7)=WTS (1) / (GX (15) *0.0008999*W (10) *DESIGN (1))
WTS (9)=WTS (1) -WTFUEL / (GX (15) *0.002378*W (10) *DESIGN (1))

THIS SECTION CALCULATES WTS. INDEPENDENT OF WTO AND FUEL

F1 (1)=1.
F1 (2)=1.15
WECIT=F1 (IACT+1) *88.46* ((190.+W (9)) *4.0E-2) **0.294
WTSRT=49.19* (4.0*WTENG*1.0E-3) **0.541
PASS=GX (19) *170.
WTFURNe=39.51*GX (19)
WFOOD=214.5
WTO2=300.7
WWIN=501.55
WTEGH=144.72
WTAC=3647.
WTR=1500.
F2 (1)=0.
F2 (2)=250.
ACTCON=F2 (IACT+1)
DATA CREW/1700./
BAGGAGE=GX (19) *35.0
CARGO=GX (22)

THIS SECTION COMPUTES WEIGHTS DEPENDENT UPON WTO

BEGIN WEIGHT ITERATION THIS SECTION

50 WTWING=2.0*FUDGE*0.00428*(DESIGN (1)) **0.48*AR*(GX (3)-0.05) **0.43
IF(DESIGN(5) .GT. 5.0) FUDHT = 1.0 + (DESIGN(5) - 5.0) / 10.

* THIS IS A LINEAR CORRECTION FACTOR FOR TAIL ASPECT RATIOS 5; *
* INTENDED AS A PENALTY TERM TO TRY AND REFLECT THE RANGE OF *
* TAIL WEIGHT EQUATION VALIDITY *

TEMP = (WTO^4.5) * 0.813 * (SHT^6 * 0.584) * (HX(4) / TEMP) * 0.033

$*(W(10) / LT) * 0.28

WTHT1 = 2.0 * (0.0034 * TEMP^2 + 0.915) * FUDGE

WTHT2 = 2.0 * 0.0563 * (WTO^0.6) * (SHT^6 * 0.469) * (DESIGN(5) / 0.75) * 0.539

$*((1.0 + HX(12)) / HX(2)) * 0.692

WTHT3 = 1.0 * (4.566 * 1.0E-4) * (DESIGN(4) * 0.49) * DESIGN(5)

$*(WTO^4.5 / 1.) * 0.84

* WTHT1 --- FROM NICOLAI (REF. 4) *
* WTHT2 --- FROM VDEP (REF. 6) *
* WTHT3 --- ANALOGOUS TO WING WEIGHT EQUATION *

* THE THREE HORIZONTAL TAIL WEIGHT EQUATIONS ARE THEN AVERAGED *

WTHT = ((WTHT1 + WTHT2 + WTHT3) / 3.0) * FUDGE

TEMP = 1.02 * (4.5 * WTO) * 0.363 * SHT^2 * 1.039 * (GX(3) * 0.8) * 0.601

$ *(LT**(-0.726) * (1.0 + HX(20)) * 0.217 * HX(18) * 0.337 *

$ *(1.0 + TRV) * 0.36 * (COS(HX(19) / GX(2))) * (-0.484)

WT = 0.19 * TEMP**0.104 * FUDGE

TO = 10.43 * (0.000364 * (GX(3) * 0.04) * 971.15) * 0.283

WTFUSE1 = ((TO* (DESIGN(3) / GX(5))) * 0.71) * (WTO^1.0E-3) * 0.95 * FUDGE

WTFUSE2 = 0.0796 * 2.1861 * (WTO^0.33) * (DESIGN(3) * 0.76)

$ *(GX(5) + GX(5)) * 1.2

* WTFUSE1 --- FROM NICOLAI (REF. 4) *
* WTFUSE2 --- FROM VDEP (REF. 6) *

* THE TWO FUSELAGE WEIGHT EQUATIONS ARE THEN AVERAGED *

WTFUSE = (WTFUSE1 + WTFUSE2) / 2.

WTLG = 2.0 * (62.21 * (WTO^1.0E-3) * 0.84) * FUDGE

WTCLT = (56.01 * (WTO^245.6 * 1.0E-5) * 0.576) * FUDGE

WTINST = 2.0 * 15.0 + 0.032 * WTO^1.0E-3 + 0.04 * 4.8 + 0.006 * WTO^1.0E-3 + 15 * WTO^1.0E-3

$ *(0.771 * WTO^1.0E-3 * 1.1) * FUDGE

IF(NOIT.LT.20) GO TO 94
IF(DELTLE.WTO.LT.20.0) GO TO 96

* CALCULATE FUEL WEIGHT *

94 CALL FUELCAL(WTO,WTFUEL,0)
FUEL = WTOFUEL / 6.4
GO TO 98
96 WTFUEL=WTO*WFOWTO
FUEL=WTFUEL/6.4

* THIS SECTION CALCULATES WTS. DEPENDENT UPON FUEL WT. *

98 WTF1=41.6*(FUEL*1.0E-2)**0.818
WTF2=7.91*(FUEL*1.0E-2)**0.854
WTF3=7.38*(FUEL*1.0E-2)**0.458
WTF4=1COX*28.38*(FUEL*1.0E-2)**0.442
WTFSYS=WTF1+WTF2+WTF3+WTF4
WTELEC=1162.66*((WTFSYS+931.3)*1.0E-3)**0.506

* THIS SECTION CALCULATES THE EMPTY AND FIXED WEIGHTS *

T1=WTWING+WTHT+WTVT+WTFUSE+WTLG+WTCTL+WTINST+WIMISC+WECTL+WTSRT
$+WTURNT+WTORG+WTENG+WTELEC+WTFSYS
$ WTEMPY=(T1+WTENG+WTELEC+WTFSYS)*FUDGE
$ WTEMPY=(1.0-PX(3))*WTEMPY
$ WFIXED=WTFOOD+PASS+CREW+BACKAGE+CARGO

* THIS SECTION COMPUTES THE TAKE-OFF WEIGHT *

WTONEW=WTFIXED+WTFUEL+WTEMPY
DELWTO=WTONEW-WTO
NOIT=NOIT+1
INT=INT+1
IF(NOIT.GT.39) GO TO 58
DIV=1.2
IF(NOIT.LT.3) DIV=0.85
IF(NOIT.LT.10) DIV=1.95
IF(IDEBUG.GT.0) WRITE(6,338) NOIT,WTO,WTONEW,DELWTO
$ ,WTFUEL,WFOWTO
338 FORMAT(5X*ITER. NO.=-15,10X*WTO,WTONEW,DELWTO,WTFUEL,WFOWTO=-
$ 3F12.2,F12.2,F12.5)
WTO=WTONEW+DELWTO/DIV
DATA(NOIT)=DELWTO

* ITERATE WEIGHT UNTIL WITHIN 0.05 LBS *

IF(ABS(DELWTO).GT.0.05) GO TO 50
57 IF(OUTPUT.EQ.0) GO TO 150
GO TO 60
58 WRITE(6,59) WTO,WTONEW,DELWTO,WTINIT,WFOWTO,WTFUEL,NOIT
59 FORMAT(/* WEIGHT LOOP DID NOT CONVERGE/ */
$ /10X*WTO,WTONEW,DELWTO,WTINIT,WFOWTO,WTFUEL,NOIT=-4F12.2,
$ F12.4,F12.2,I5/)
WRITE(6,64) DATA
64 FORMAT(10X*DELTWO*9(T25,5F12.3/))
WRITE(6,80) WTWING,WTHT,WTVT,WTFUSE,WTLG,WTCTL,WTINST,WIMISC,WTELEC
$,WTWING,WTWING,WTVT,WTWING,WTWING,WTWING,WTWING,WTWING
WRITE(6,82) WTEMPY
WRITE(6,84) WTONEW,WTFOOD,WTFOOD,WTFOOD,WTFOOD
WRITE(6,86) WTEMPY,WTFOOD,WTFOOD,WTFOOD

37
WRITE (6, 88) WTHT1, WTHT2, WTHT3, WTFUSE1, WTFUSE2, WTINIT
CALL XOUTPUT (6)
WRITE (6, 887) ICNT, JCNT, KCNT, NDAV, LCNT, IWT, NOIT
887 FORMAT (/'5X"DUMP OF FCOUNT COMMON BLOCK"/10X
$ "ICNT, JCNT, NDAV, KCNT, LCNT, IWT, NOIT="', 10X, 'T15/
WTO=WTONEW+DELWTO/2.0
WTS (1)=WTO
GO TO 57
*******************************************************************************
* OUTPUT SECTION *
*******************************************************************************
60 WRITE (6, 80) WWING, WTHT, WTVT, WTFUSE, WTLG, WTCTRL, WTNST, WIMISC, WTTELEC
$, WTSRT, WTFURN, WTO2, WTWIN, WTBGI, WTAC, WTRT, WTENG, WECTL, WTFSYS, ACTCON
$, WTEMPTY
80 FORMAT ('/30X, '23H*WEIGHT ESTIMATION***/10X*
$ WINGGET40, FI0.1
*/10X*VERT. TAILGET40, FI0.1/10X*FUSELAGEGET40
$*F10.1/10X*LANDING GEARGET40, F10.1/10X*CONTROL SYSTEMGET40
$*F10.1/10X*INSTRUMENTSGET40, F10.1/10X*MISC INTERIORGET40
$*F10.1/10X*ELECTRICALGET40
$*F10.1/10X*STARTERSGET40, F10.1/10X*FURNISHINGSGET40
$*F10.1/10X*OXGENGET40, F10.1/10X*WINDOWSGET40
$*F10.1/10X*BAGGAGE HNDLINGGET40,
$*F10.1/10X*AIR CONDITIONINGGET40
$*F10.1/10X*ENGINE CONTROLGET40
$*F10.1/10X*FUEL SYSGET40
$*F10.1/10X*ACTIVE CONTROL SYSTEMSGET40
$*F10.1)
WRITE (6, 82) WTEMPTY
82 FORMAT (/'5X*EMPTY WEIGHTGET40, F10.1)
WRITE (6, 84) PASS, CREW, BAGGAGE, WFOOD, CARGO, WTFIXED
84 FORMAT (/'10X*NO. OF ITERATIONS REQUIREDGET40, I10)
WRITE (6, 86) WFOOD, WTO, NOIT
86 FORMAT (/'5X*FUEL*TAKE-OFF WEIGHTGET40, F10.1/10X
$*NO. OF ITERATIONS REQUIREDGET40, I10)
WRITE (6, 88) WTHT1, WTHT2, WTHT3, WTFUSE1, WTFUSE2, WTINIT
88 FORMAT (/'5X*WTHT(1,2,3), *WTFUSE(1,2), *WTINIT=*T45,5F10.2,F12.2)
CALL FUELCAL (WTO, WTFUEL, 1)
CALL XLOD (GX (9), GX (3), WIS (11), EFF, 1, OUTPUT)
*******************************************************************************
* ASSIGN DATA BASE VARIABLES *
*******************************************************************************
150 WTS (1)=WTO
WTS (2)=WTEMPTY
WTS (4)=.75*WTEMPTY
WTS (6)=WTFUEL
IF (NOIT.LT.40) WFOE=WTFOE=WTFUEL/WTO
AENG=0.
IF (ITERM (4) .EQ. 3) AENG=WTENG*0.81*LT/LT/(GX (15) *3.)
WTS (13)=13.45E6
WTS (14)=13.33E6
CALL AT62 (WTS (11), ANS)
WTS (7)=WTS (1)/(ANS (1)*W (10)*DESIGN (1)*GX (15))
WTS (8)=WTS (13)*GX (15)/WTS (1)
CALL AT62 (500., ANS)
WTS (9)=GX (27)*WTS (1)/(GX (15)*DESIGN (1)*ANS (1)*W (10))
WTS (10)=WTS (14)*GX (15)/(WTS (1)*GX (27))
IF(IDEBUG2.GT.0) WRITE(6,990) NOIT
990 FORMAT(T100*NOIT=I10)
RETURN
END
SUBROUTINE CRUALT(WT,CLCR,M,ALT)

*** THIS SUBROUTINE RETURNS ALTITUDE TO SATISFY THE SPECIFIED ***
*** WEIGHT, CL, AND M. ITERATIVE TABLE LOOK UP IS USED. ***

REAL M,HOLD,HNEW,ANS(4)
COMMON /DEVAR/DESIGN(15),ITERM(10),CST(10)
COMMON /GEOV/W(20),HX(20),GX(35),PX(15)
IC=0
DATA TO,PO,ALF, R/518.14,2116.229,.00356617,53.3/
P=2.0*WT/(1.4*DESIGN(1)*CLCR*M*M)
HOLD=(1.0-(P/PO)**(ALF**R)**TO/ALF)
50 CALL AT62(HOLD,ANS)
DP=P-ANS(2)
DRDH=-1.0*ANS(1)*GX(15)
HNEW=HOLD+DP*0.9/DRDH
IC=IC+1
IF(IC.GT.100) GO TO 100
DALT=HNEW-HOLD
IF(ABS(DALT).LT.7.5) GO TO 150
HOLD=HNEW
GO TO 50
100 WRITE(6,102) HNEW
102 FORMAT(*I*\\
40X,38HeeeCRUISE ALTITUDE DID NOT CONVERGE*:\
10X $._LAST ALTITUDE=FI2.2)
150 ALT=HNEW
152 FORMAT(\\
//10X,*ALTITUDE,NO. OF ITERATIONS=FI2.2,I10)
RETURN
END

SUBROUTINE ENGINE(ALT,M,TCTM_TSF)

REMOTE ADJUSTMENTS HAVE BEEN MADE TO THIS SUBROUTINE TO
MATCH DATA.

COMMON /GEOV/W(20),HX(20),GX(35),PX(15)
REAL M,HN,ANS(4)
CALL AT62(ALT,ANS)
DATA TO,PO/561.2,2116.229/
HN=ALT/40000.
TCTM= (1000./41100.)* (30.06-34.74*HN+7.25*M+12.11*HN*HN -1.12*M*M+13.96*M*M-5.46*M*HN+11.82*M*M*HN -0.01*M*M*HN)
ALT=(ALT-35332.)*.004/1000.)+1.
IF(ALT.GT.35332) GO TO 40
TCTM=(1000./41100.)* (34.71-32.22*HN-27.4*M +5.8*HN*HN+36.43*HN*M+2.65*M*M-11.64*M*HN*HN
$ +3.19* M*M*HN - 5.72*M*M*HN*HN$

ALTK = 1.

40 DELTA = ANS(2)/PO
THETA = ANS(3)/PO
TCTM = 1.2* TCIM
TN = TCIM*41100./DELTA/20000.
FN = 1000.* (2.04+3.71*TN-4.38*M+1.69*TN*TN+5.94*M*TN
$ +12.99*M*M)$
FNS = FN*ALTK
F = FNS*DELTA*(THETA)**0.5
TSFC = F/(TCTM*41100.)
TSFC = (1.0-PX(2))*TSFC
RETURN
END

SUBROUTINE CDZL (ALT, CDO, M, OUTPUT)
REAL MU(2), ANS(4), U(2), K(2), DCD(2), M
INTEGER OUTPUT
COMMON / DEVAR / DESI (15), ITERM(10), CST(10)
COMMON / DRAG/CDS (6), CDSAP (6)
COMMON / GEOM/W(20), HX(20), GX(35), PX(15)
CALL AT62 (ALT, ANS)
DATA MU / 3.6878E-7, 2.9652E-7/
IALT = -1
IF (ALT.GT.10000.) IALT = 2
SHT = DESIGN(4)
TENH = DESIGN(6)/ITERM(4)
U(1) = 0.6*ANS(4)
U(2) = M*ANS(4)
SREF = DESIGN(1)

** WING DRAG CALCULATIONS **

REW = W(10)*U(IALT)*ANS(1)/MU(IALT)

CF = 0.455/(ALOG10 (REW))**2.58
CF = CF* (1.0-PX(4))
SWET = 2.05*SREF
K(1) = 1.2230
K(2) = 1.456
CDOW = CF*K(IALT)*SWET/SREF

** HORIZONTAL TAIL DRAG CALCULATIONS **

REH = HX(5)*U(IALT)*ANS(1)/MU(IALT)

CF = 0.074/REH**0.2
K(1) = 1.2560
K(2) = 1.3803
SWET = SHT*2.05
CDOH = CF*K(IALT)*SWET/SREF

** VERTICAL TAIL DRAG CALCULATIONS **

TRV = HX(17)
SV = GX(35)
BV = (SV*HX(18)) ** 0.5
CVBAR = 4.*SV*(1.+TRV+TRV*TRV)/(3.*BV*(1.+TRV)**2.0)
RE = CVBAR*U(IALT)*ANS(1)/MU(IALT)
CF = .074/RE**0.2
K(1) = 1.1413
K(2) = 1.3504
SWET = 2.05*SV
CDOV = CF*K(IALT)*SWET/SREF

FUSELAGE DRAG CALCULATIONS

REF = DESIGN(3)*U(IALT)*ANS(1)/MU(IALT)
CF = 0.0455/(ALOG10(REF)) ** 2.58
DIA = GX(5)
FLOD = DESIGN(3)/DIA
RDIA = DIA/2.0
ANOSE = 2.*GX(1)*RDIA
CONEL = (DESIGN(3) - RDIA) ** 0.25
ABOD = GX(1)*GX(5)*(DESIGN(3) - RDIA - CONEL)
SLANT = (CONEL + CONEL + RDIA) ** 0.5
ACONE = GX(2)*RDIA
SFUS = ANOSE + ABOD + ACONE
RAT = (1.60 + (FLOD/FLOD+FLOD) + .0025*FLOD)*SFUS/50.
CDFF = CF*RAT
CDBF = 5.0112E-5
CDE = CDFF*50.0/SREF

ENGINE NACELLE DRAG CALCULATIONS

EL = GX(6)*(TENG/GX(21)) ** 0.5
EDIA = GX(7)*(TENG/GX(21)) ** 0.5
SWET = GX(1)*EDIA
REE = EL*U(IALT)*ANS(1)/MU(IALT)
CF = 0.074/REE**0.2
TT = 2
IF (ITEM(4).GT.3) TT = 4
CDOE = 1.0033*CF*SWET*TT/SREF

SUM UP DRAG COMPONENTS

CRUDD DRAG (IALT = 2)
LANDING GEAR DOWN (0.0150) + 10 DEGREES FLAPS (0.008)

DATA BASE ASSIGNMENTS

CDSAP(1) = CDO
CDSAP(2) = CDOW
CDSAP(3)=CDOH
GO TO 78
76 CDS(1)=CDO
CDS(2)=CDOH
CDS(3)=CDOH
CDS(6)=CDOF
*****************************************************************************
* OUTPUT SECTION       *
*****************************************************************************
78 IF(OUTPUT.EQ.0) GO TO 100
WRITE(6,80) CDOW,CDOH,CDOV,CDOF,CDBF,CDOE,DCD(IALT),CDO
80 FORMAT(*1//15X,19H***DRAG ANALYSIS***,//10X*WING*T35,F10.4/10X
$*HORIZONTAL TAIL*T35,F10.4/10X*VERTICAL TAIL*T35,F10.4/10X*FUSELAG
$*BASE*T35,F10.4/10X*ENGINE NACELLE*T35,F10.4/10X
$*CRUD/FLAPS*T35,F10.4//5X
$*AIRCRAFT DRAG*T35,F10.4//10X*INTERFERENCE FACTOR IS 5 PERCENT*)
WRITE(6,82) REW,REH,REV,REF,REE
82 FORMAT(/1//15X,23H***REYNOLDS NUMBERS***//10X*WING*T35,F12.1/10X,
$*HORIZONTAL TAIL*T35,F12.1/10X*VERTICAL TAIL*T35,F12.1/10X*FUSELAG
$*ENGINE*T35,F12.1/10X*FUSELAG
IF(IALT.EQ.1) WRITE(6,84)
84 FORMAT(/1//30X,14H***APPROACH***/)
100 RETURN
END
SUBROUTINE STABCOD(CL,M,ICG,OUTPUT)
INTEGER OUTPUT
REAL DCDM(2),XACDM(2),ANS(4)
REAL KA,KTR,KH,M,KWB,K
REAL LF
COMMON /DEVAR/DESIGN(15),ITEM(10),CST(10)
COMMON /GEOM/W(20),IX(20),GX(35),PX(15)
COMMON /GRAVITY/CG(6)
COMMON /STAB/DERIVCR(15),DERIVAP(15),STOR(20)
COMMON /WTSVE/WTS(20)
*****************************************************************************
* THIS SUBROUTINE CALCULATES STABILITY AND CONTROL DERIVATIVES         *
* IN EITHER APPROACH OR CRUISE CONFIGURATIONS                     *
*****************************************************************************
XCG=(CG(1)+CG(3))/2.0
IF(IGG.LT.7) XCG=CG(IGG)
ICR=1
ELASTK=0.875
IF(M.LT.0.45) ELASTK=0.825
IF(M.LT.0.46) ICR=0
*****************************************************************************
* THE FOLLOWING SECTION CALCULATES CL(ALPHA)                             *
*****************************************************************************
KWB=1.0-0.25*GX(5)*GX(5)/(W(9)*W(9))+0.025*GX(5)/W(9)
BETA=(1.0-M*M)**0.5
PIAR=DESIGN(2)*GX(1)
K=1.0
XNUM=2.0*PIAR
T1=DESIGN(2) *DESIGN(2) *BETA*BETA/(K*K)
T2=1.0+W(13)/BETA
CLA=W*W*(2.0+(T1*T2+4.0)**0.5)
T1=DESIGN(2) *DESIGN(2)/(K*K)
T2=1.0+W(13)/BETA
CLA=W*W*.725/(2.0+(T1*T2+4.0)**0.5)
KA=1./DESIGN(2)-1.0/(1.*DESIGN(2)**1.7)
KTR=(10.-3.*W(3))/7.
ZTL=GX(34)
XLT=DESIGN(1)*W(10)*HX(6)/DESIGN(4)
KH=(1.0-ZTL/W(9))/(2.0*XLT/W(9))**0.4
DEDAM=4.44*(KA*KTR*KH*(W(15)**2.0)**1.19
DEDAM=GEDAM*(CLA/CLA)**0.4
TM1=(1.0+HX(9)*HX(9)/(BETA*BETA))
TM2=ETA*BETA*DESIGN(5)**DESIGN(5)
CLA=2.0*GX(1)*ELASTK*DESIGN(5)/(2.0+(TM2*TM1+4.0)**0.5)
CLA=W*W*CLA
CLA=CLA*DESIGN(4)*(1.0-DEDA)/DESIGN(1)
EWING=W(7)

*********** THE FOLLOWING STATEMENT CALCULATES CD(ALPHA) ***********

CDA=2.0*CLA*(PI*EWING)

*********** THE FOLLOWING SECTION CALCULATES CM(ALPHA) ***********

XACV=.25-.265*M*M/(DESIGN(2)**0.5)
DXACT=XLT/W(10)
AW=CLA/GX(2)
XNRM=DESIGN(1)*W(10)*AW
TFUS=0.5836+1.690*(1.0-DEDA)
DXACT=-XG(5)*G(5)*DESIGN(3)*TFUS/(XNRM**3.5)
DXACT=-G(5)*G(5)/(DESIGN(1)*AW**290.)
DXACT=DXACT+DMDF
STOR(11)=DXACT*A4
T=DESIGN(6)/ITERM(4)
WF=GX(6)*(T/GX(21))**0.5
LF=GX(7)*(T/GX(21))**0.5
TT=2.
IF(ITERM(4).GT.3) TT=4
DXACT=-TT*WF/LF/(1.5*2.1*XNRM)
STOR(12)=DXACT*A4
TAI=CLA*ETA*DESIGN(4)*(1.0-DEDA)/(CLA*DESIGN(1))
XAC= XAC*(TAI+DXACT)/(1+TAI)
DCMCL=XCG-XAC
CMA=DCMCL*CLA

*********** THE FOLLOWING SECTION CALCULATES VELOCITY DERIVATIVES ***********

CLU=(1.-M)**M*CL/(1.0+M*M)
DATA DCDM, XACDM/0.0202,0.1005,-3.1E-4,5.1E-4/
Z=0.
IF (ICR.GT.0) Z=40000.
CALL AT62(Z,ANS)
AM=ANS(4)
CDU=DCDM(ICR+1)/AM+2.*CL*CLU/(PIAR*EWING*10.)
CMU=CL*XACDM(ICR+1)

* THE FOLLOWING SECTION CALCULATES Q DERIVATIVES *

CLQH=2.0*CLAH*ETAH*HX(5)
CLQ=CLQH*1.1
CDQ=0
CMQT=-2.0*CLAH*ETAH*0.9*HX(6)*XLT/W(10)

* THE FOLLOWING SECTION CALCULATES ALPHA-DOT DERIVATIVES *

CMQT=CMQT*1.1
CLQ=CLQH*1.1
CDQ=0
CMQT=CMQT*1.1

* THE FOLLOWING SECTION CALCULATES CONTROL DERIVATIVES *

CLDEL=DESIGN(4)*CLAH*0.46/DESIGN(1)
CFDEL=-CLAH*HX(6)*0.9*0.46
IF (ICR.LT.1) GO TO 120
XM=215.
IF (OUTPUT.GT.-1) XM=WTS(7)

* DATA BLOCK ASSIGNMENTS *

STOR(1)=CLAW
STOR(2)=CLAH
STOR(3)=DEDA
STOR(4)=XAC
STOR(5)=XAC-CMQ/(4.*XM)
STOR(13)=TA1
DERIVCR(1)=CLA
DERIVCR(2)=CDA
DERIVCR(3)=CMA
DERIVCR(4)=CLU
DERIVCR(5)=CDU
DERIVCR(6)=CMU
DERIVCR(7)=CLQ
DERIVCR(8)=CDQ
DERIVCR(9)=CMQ
DERIVCR(10)=CLADOT
DERIVCR(11)=CDADOT
DERIVCR(12)=CMADOT
DERIVCR(13) = CLDEL
DERIVCR(14) = CDDEL
DERIVCR(15) = CMDEL
GO TO 150
120 DERIVAP(1) = CLA
DERIVAP(2) = CD
DERIVAP(3) = CM
DERIVAP(4) = CL
DERIVAP(5) = CU
DERIVAP(6) = CM
DERIVAP(7) = CLQ
DERIVAP(8) = CDQ
DERIVAP(9) = CMQ
DERIVAP(10) = CLADOT
DERIVAP(11) = CDADOT
DERIVAP(12) = CMADOT
DERIVAP(13) = CLDEL
DERIVAP(14) = CDDEL
DERIVAP(15) = CMDEL
XMU = 70.
IF (OUTPUT.GT.-1) XMU = WTS(9)
STOR(6) = CLA
STOR(7) = CLAH
STOR(8) = DED
STOR(9) = XAC
STOR(10) = XAC - CMO / (4. * XMU)
STOR(14) = TAI
150 IF (OUTPUT.LT.1) GO TO 200
****** OUTPUT SECTION ********
* BEGIN WRITE SECTION ********
WRITE (6, 162)
162 FORMAT (*1*//20X*STABILITY AND CONTROL DERIVATIVES*//)
IF (ICR.EQ.0) WRITE (6, 163)
163 FORMAT (25X, 14H**APPROACH**//)
WRITE (6, 164) CL, M, XCG
164 FORMAT (10X*CL, M, XCG POSITION=*3F15.3//)
WRITE (6, 166)
166 FORMAT (/28X*CL*14X*CD*12X*CM//)
IF (ICR.EQ.1) GO TO 180
WRITE (6, 174) DERIVAP
174 FORMAT (10X*ALPHA*4X, 3F15.5/10X*VELOCITY*3F15.4/10X*Q*8X, 3F15.5/
$10X*ALPHA-DOT*3F15.5/10X*ELEVATOR*3F15.5//)
GO TO 190
180 WRITE (6, 174) DERIVCR
190 WRITE (6, 192) XAC, DCM, L, CM, STOR
192 FORMAT (/10X*NEUTRAL POINT*T35, F12.3/10X*STATIC STABILITY*7T35, F12.3/10X*CM(ALPHA)*T35, F12.3/10X*STOR=/* /
$2(T35, 2F12.3//)
WRITE (6, 196) DXAE, XACW, XACW, AW, XNRH, TF, DAXC, DWM, $
$ CLB, CLAH, DEDAM, XLT, ZTL, CLAW, BETA, TAI, CLAW, DED
$ XAC, KH, KTR, TM1, TM2, KB, XCG, KA
196 FORMAT (5(T30, 5F12.4/))
45
200 RETURN
END

SUBROUTINE TRIM(CL,M,CDO,CLWING,CLTAIL,CRIT,CRDE,EPS,IPHASE, IC)

REAL LTOTOQ,LWOQ,LTLOQ,IW,M
COMMON /DEVAR/DESIGN(15),ITERM(10),CST(10)
COMMON /DRAG/CDS(6),CDSAP(6)
COMMON /GEOM/W(20),HX(20),GX(35),PX(15)
COMMON /GRAVITY/G(6)
COMMON /STAB/DERIVCR(15),DERIVAP(15),STOR(20)

******************************************************************************
* IPHASE=1 (CR), =0 (10 DEG FLAP, FWD CG), =-1 (45 DEG FLAP), *
* =-2 (45 DEG FLAP, FWD CG), =-3 (45 DEG FLAP, FWD CG, FIND *
* CLMAX), =-4 (10 DEG FLAP, FWD CG, FIND CLMAX), =2 (CR, AFT CG) *
******************************************************************************

N=0

******************************************************************************
* INITIALIZE VARIABLES FROM DATA BASE *
******************************************************************************

XT=.25-.265*W*(DESIGN(2))**-0.5
XAC=(CG(1)+CG(3))/2.-XA
IF(ICG.LT.7) XAC=CG(ICG)-XA
ZAC=0.08
ZTLC=-.12
ST=DESIGN(4)
CMACW=-.10-.030218*W(11)-.046875*W
CMACW=CMACW*(1.0-PX(1))
CDT=CDS(3)
AT=STOR(2)/GX(2)
AW=STOR(1)/GX(2)
DED=STOR(8)
AOL=W(16)
IF(IPHASE.GT.0) GO TO 10
AT=STOR(7)/GX(2)
AW=STOR(6)/GX(2)
DED=STOR(8)
CDT=CDSAP(3)
CMACW=CMACW+W(17)
W(19)=CMACW-W(17)
AOL=W(16)+GX(17)
IF(IPHASE.LT.-3) GO TO 10
IF(IPHASE.EQ.0) GO TO 10
CMACW=CMACW+W(18)-W(17)
AOL=W(16)+GX(18)
CDO=CDO+W(20)
10 CD=CDO+CL*CL/(DESIGN(2)*GX(1)*W(7))
CMAFUS=STOR(11)+STOR(12)
IW=W(2)
IF(IPHASE.LT.-2) GO TO 200
LTOTOQ=CL*DESIGN(1)
LTLOQ=-1*LTOTOQ

******************************************************************************
* THIS SECTION CALCULATES CL(WING) AND CL(TAIL) GIVEN CL(TOTAL) *
******************************************************************************
20 LWOQ=LTO EQ-LTLOQ
    CLWING=LWOQ/DESIGN(1)
    IF (CLWING.GT.3.5) CLWING=3.5
    IF (CLWING.LT.0.1) CLWING=0.1
    CLTAIL=LTLOQ/ST
    IF (ABS(CLTAIL).GT.2.0) CLTAIL=2.0*CLTAIL/ABS(CLTAIL)
    CDTAIL=CDT*DESIGN(1)/ST+CLTAIL*CLTAIL/(GX(1)*DESIGN(5)*0.90)
    ALFAW=CLWING/AW+AO1
    IF (ALFAW.GT.16.0) ALFAW=16.0
    CMFUS=CMAFUS*(ALFAW-IW)
    EPS=CLWING*DEDA/AW
    CRDE=0.
    ALFAT=CLTAIL/AT-CRDE
    CTPWR=(CMACW+CLWING*XAC+CMFUS-AT*(ALFAW-EPS-IW)*HX(6)*0.9)/$
            (AT*HX(6)*0.9)
    TAO=0.46
    CRIT=CTLPWR
    CRDE=0.
    IF (CRIT.LT.5.0) GO TO 40
    CRDE=(CTLPWR-5.0)/TAO
    CRIT=5.0
    GO TO 60
40 IF (CRIT.GT.-14.0) GO TO 60
    CRDE=(CTLPWR+14.0)/TAO
    CRIT=-14.0
60 CNW=CLWING*COS((ALFAW-IW)/GX(2))+CD*SIN((ALFAW-IW)/$
            GX(2))
    CCW=CD*COS((ALFAW-IW)/GX(2)) -CLWING*SIN((ALFAW-IW)/$
            GX(2))
    CT=CD

C
C IF TRIJET, THE UNBALANCE IS ONLY ONE ENGINE
C
    IF (ITERM(4).EQ.3) CT=CT/3.0
    CNW=(1./((0.9*HX(6))*((NO/XAC+CW*XAC+CMAFUS-AT*ZTLC+CMACW))
    CLNEW=(CNT-CDTAIL*CSIN((ALFAT-CRIT)/GX(2)))/(COS((ALFAT$
            -CRIT)/GX(2)))
    DTEST=CLNEW-CLTAIL
    CLTAIL=CLTAIL+DTEST/(N+1)
    IF (ABS(CLTAIL).GT.2.0) CLTAIL=2.0*CLTAIL/ABS(CLTAIL)
    LTLOQ=CLTAIL/ST
    N=N+1
    IF (ABS(DTEST).LT.0.003) GO TO 100
    IF (N.GT.25) GO TO 80
    GO TO 20
80 WRITE(6,82) CLWING,CLTAIL,CRIT,CRDE,CNW,DTEST,
            ALFAW,EPS,CMFUS
82 FORMAT(///20X*TRIM DID NOT CONVERGE*/3(3F15.4)//)
100 IF (CLWING.EQ.3.5) WRITE(6,84) CLWING
100 CRIT=$,CLTAIL,CRIT,CRDE,CNW,DTEST
7 IF (ALFAW.EQ.16.0) WRITE(6,84) CLWING
7 $,CLTAIL,CRIT,CRDE,CNW,DTEST

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**Cruise Analysis**

```
84 FORMAT(///30X*TRIM HIT ALPHA OR CL LIMIT*//2(10X,3F12.4/))
IF(ALFAW.EQ.16.0) CALL XOUTPUT(6)
RETURN
**************************************************************************
* THIS SECTION CALCULATES CL(TAIL) AND CL(TOTAL) GIVEN CL(WING)  *
**************************************************************************
200 CLWING=CL
  CLTAIL=-1.
  CDTAIL=CDT*DESIGN(1)/ST+CLTAIL*CLTAIL/(GX(1)*DESIGN(5)*0.90)
  ALFAW=CLWING/AW+AOL
  IF(ALFAW.GT.16.0) ALFAW=16.0
  CMFUS=CMAFUS*(ALFAW-IW)
  EPS=CLWING*DEDA/AW
  CRDE=0.
  ALFAT=CLTAIL/AT-CRDE
  CLPWWR=(CMACW+CLWING*XAC+CMFUS-AT)*(ALFAW-EPS-IW)*HX(6)*.9)/
  $(AT+HX(6)*0.9)
  TAO=0.46
  CRIT=CLPWWR
  CRDE=0.
  IF(CRIT.LT.5.0) GO TO 540
  CRDE=(CLPWWR-5.0)/TAO
  CRIT=5.0
  GO TO 560
540 IF(CRIT.GT.-14.0) GO TO 560
  CRDE=(CLPWWR+14.0)/TAO
  CRIT=-14.0
560 CMW=CLWING*COS((ALFAW-IW)/GX(2))+CD*SIN((ALFAW-IW)/
  $GX(2))
  CCH=CD*COS((ALFAW-IW)/GX(2))-CLWING*SIN((ALFAW-IW)/
  $GX(2))
  CT=CD
  IF(ITERM(4).EQ.3) CT=CT/3.0
  CMWT=(1./*(0.9*HX(6)))*(CMW*XAC+CCH*ZAC+CMFUS-CT*ZTC+CMACW)
  CLNEW=(CMW-CDTAIL*SIN((ALFAT-CRIT)/GX(2)))/(COS((ALFAT
  $-CRIT)/GX(2))))
  CLTAIL=CLNEW
  LTLOQ=CLTAIL*ST
  LWOQ=CLWING*DESIGN(1)
  LTOTOQ=LTLOQ+LWOQ
  CL=LTOTOQ/DESIGN(1)
RETURN
END
SUBROUTINE FUELCAL(WTO,WTFUEL,OUTPUT)
COMMON /DEVAR/DESIGN(15),ITERM(10),CST(10)
COMMON /GEOM/W(20),HX(20),GX(35),PX(15)
COMMON /WTSVE/WTS(20)
REAL ANS1(4)
INTEGER OUTPUT
IF(OUTPUT.LT.1) GO TO 30
WRITE(6,21)
21 FORMAT(*I*////30X*/ / / CRUISE ANALYSIS/ / *///)
WRITE(6,23) RANGE
```
23 FORMAT(10X*TOTAL MISSION RANGE=*F10.2/10X
$ *CLIMB DISTANCE= 189.00*/10X
$ *DESCENT DISTANCE= 113.00*/)
WRITE(6,25)
25 FORMAT(//2X*LEG*2X*MACH NO.*3X*CL*4X*V*7X*TIME*4X*L/D*
$ 4X*TSFC*2X*T/T (IN) *1X*ALT (BEG) *2X*ALT (END) *2X*WT (BEG) *
$ 3X*WT (END) *6X*DIST*4X*TCON*4X*GAMA*5X*CLM*/)
30 WTBEG=WT0*0.97*0.965
GX (31)=.0020
RANGE=GX (4)
GX (30)=5.
TOTTIME=0.78
ALT1=36000.
ALT1=ALT1
WT1=WTBEG
RLOVER=RANGE-302.
R=RLOVER/10.
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * 
* CALCULATE CRUISE PORTION IN 10 SEGMENTS * 
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * 
DO 40 I=1,10
CALL CRUFUEL (WTI, R,WT2,ALT1,ALT2,I,TIME,OUTPUT,0)
WT1=WT2
ALT1=ALT2
TOTTIME=TOTTIME+TIME
IF(I.LT.5) GO TO 40
IF(I.GT.5) GO TO 40
WTMID=WT2
WTS (15)=WTMID
WTS (11)=ALT2
40 CONTINUE
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * 
* RESERVE MISSION ASSUMPTION * 
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * 
WGRRD=WT2
CALL CRUFUEL (WGRRD,1000.,WTRES,30000.,ALTR,11,TM,OUTPUT,1)
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * 
* INSERT DATA IN DATA BASE * 
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * 
FL=TOTTIME
BLKHR=FL+.327
SPEED=RANGE/FL
BLKSPD=RANGE/BLKHR
WTS (5)=.97*WGRRD
WTEND=.97*WTRES
WTFUEL=WT0-WTEND
WTS (17)=SPEED
WTS (18)=FL
WTS (19)=BLKHR
WTS (20)=WTBEG-WTS (5)
WTS (3)=WTS (20)/BLKHR
WTS (3)=(WTBEG-WTS (5))/TIME
FUEL=WTS (20)/6.4
**OUTPUT SECTION**

* OUTPUT SECTION *

```
XMG = RANGE / FUEL
XSMG = XMG * GX (19)
CST (5) = XSMG

* OUTPUT SECTION *

IF (OUTPUT.EQ.0) GO TO 100
WRITE (6, 52) WTO, WTBEG, WMID, WGRD, WTRES, WTEND, WFM
52 FORMAT (*1//40X, 26H***FUEL WEIGHT ANALYSIS***///10X*TAKE-OFF*T35,
 $F12.2/10X*START-CRUISE*T35, F12.2/10X*CRUISE*T35, F12.2/
 $10X*RESERVE*T35, F12.2/10X*NET FUEL WEIGHT (LBS)*T35, F12.2)
WRITE (6, 54) ALT, ALT2, ALT3
54 FORMAT (**//5X*CRUISE ALTITUDES*/10X*LEG 1*T35, F12.2/10X*LEG 2*
 $10X*RESERVE LEG*T35, F12.2)
WRITE (6, 64) FL, SPEED, BLKHR, BLKSPD
64 FORMAT (/10X*FLIGHT LENGTH (HR) *T35, F12.2/
 $10X*AVG SPEED (KTS) *T35, F12.2/
 $10X*BLOCK TIME (HR) *T35, F12.2/
 $10X*BLOCK SPEED (KTS) *T35, F12.2)
WRITE (6, 66) WTS, FUEL, XMG, XSMG
66 FORMAT (/10X*BLOCK FUEL (LBS) *T35, F12.2/
 $10X*SCALE FUEL (GALS) *T35, F12.2/10X*SCALE FACTOR*T35, F12.2)
WRITE (6, 68) DESIGN (6), TERM (4), TEN, TREF, SCF
68 FORMAT (/10X*INSTALLED THRUST (LBS) *T35, F12.2/
 $10X*NO. OF ENGINES*T35, I12/10X
 $*REFERENCE ENGINE (LBS)*T35, F12.2/10X
 $*SCALE FACTOR*T35, F12.3)
100 RETURN
END
SUBROUTINE CRUFUEL (WTBEG, RANGE, WTEND, ALTCR, ALTEND, ICOUNT, TIME
 $, OUTPUT, IRES)

* CRUFUEL CALCULATES PERFORMANCE DURING CRUISE/CLIMB OR RESERVE *
* SEGMENT *

REAL ANS (4), LOD, HZ, M
INTEGER OUTPUT
COMMON /DEVAR/DESIGN (15), TERM (10), CST (10)
COMMON /DRA/CGS (6), CGSAP (6)
COMMON /GEM/W (20), X (20), GX (35), PX (15)
COMMON /WTS/V/WTS (20)
M = GX (3)
GAMA = 0.
CALL CDZL (ALTCR, CDO, M, 0)
CDO = CDO + GX (31)
XTI = W (8) * W (8) * (1.0/W (6) - 1.0/W (7)) / GX (1) * DESIGN (2))
```
CLM=1.00*(GX(1)*DESIGN(2)*W(7)*(CDO+XT1))^0.5
IF(IRES.LT.1) GO TO 10
CLCR=0.79*CLM

* THE FOLLOWING STATEMENTS CALCULATE THE RESERVE MISSION WHICH *
* IS AT 30000 FT AT MAXIMUM RANGE. *

CALL AT62(30000.,ANS)
VCR=(WTBEG*2.0/(DESIGN(1)*ANS(1)*CLCR))^0.5
M=VCR/ANS(4)
CALL XLOD(CLCR,M,30000.,LOD,1,0)
HZ=3.0
ALTEND=30000.
TIME=RANGE/(VCR*1.467*1.1507)
GO TO 88

* THE FOLLOWING STATEMENTS CALCULATE THE CRUISE/CLIMB AT MAXIMUM *
* RANGE FACTOR. *

10 CALL AT62(ALTCR,ANS)
VCR=M*ANS(4)
WTT=0.98*WTBEG
Q=0.5*ANS(1)*VCR/VCR
CLCR=WTBEG/(Q*DESIGN(1))
IF(CLCR.GT.0.79*CLM) GO TO 15
CLCR=0.79*CLM
VCR=(WTBEG*2.0/(ANS(1)*DESIGN(1)*CLCR))^0.5
M=VCR/ANS(4)
CRCL=.79*CLM
TIME=RANGE/(VCR/(1.467*1.1507))
CALL CRUALT(WTT,CRCR,GX(3),ALTD)
ROC=(ALTD-ALTCR)/(3600.*TIME+.02)
GAMA=ASIN(ROC/VCR)
GO TO 20

* THE FOLLOWING STATEMENTS CALCULATE THE CRUISE/CLIMB AT 90% OF *
* CL FOR (L/D) MAX. *

15 IF(CLCR.LT.0.98*CLM) GO TO 18
CRCL=0.9*CLM
CALL CRUALT(WTT,CRCR,GX(3),ALTD)
TIME=RANGE/(VCR/(1.467*1.1507))
ROC=(ALTD-ALTCR)/(3600.*TIME+.02)
GAMA=ASIN(ROC/VCR)
GO TO 20

18 IF(ICOUNT.LT.6) GO TO 20
CRCL=.9*CLM
CALL CRUALT(WTT,CRCR,GX(3),ALTD)
ROC=(ALTD-ALTCR)/(3600.*TIME+.02)
GAMA=ASIN(ROC/VCR)
20 CALL XLOD(CLCR,M,ALTCR,LOD,1,0)
HZ=ALTCR/10000.
CALL ENGINE (ALTCR,M,M,TCTM,TSFC)
WTEND=WTBEG/(EXP(TSFC*RANGE/(VCR*0.59239*LOD)))
TIME=RANGE/(VCR/(1.467*1.1507))
TOWAV=DESIGN(6)/WTBEG
TOWRQ=(1./TCTM)*(1./LOD+SIN(GAMA))
TCON=TOWAV/TOWRQ
IF(TCON.LT.GX(30)) GX(30)=TCON
IF(ICOUNT.GT.10) GO TO 92
CALL CRUALT(WTEND,CLCR,M,ALTEND)
ALTEND=ALTEND+3600.*VCR*TIN(GAMA)*TIME
92 IF(ICOUNT.NE.5) GO TO 99

DATA BASE ASSIGNMENTS

CDS(4)=LOD
CDS(5)=CLCR/LOD
GX(9)=CLCR
CALL CRUALT(WTEND,CLM_GX(3),ALTLDM)
WTS(12)=ALTLDM
99 IF(OUTPUT.LT.1) GO TO 100

OUTPUT SECTION

WRITE(6,188) ICOUNT,M,CLCR,VCR,TIME,LOD,TSFC,TCTM,
$ ALTCR,ALTEND,WTBEG,WTEND,RANGE,TCON,GAMA,CLM
$ F8.3,F8.4,F8.3)
100 RETURN

END

SUBROUTINE XLOD(CL,XM,ALT,LOD,IPHASE,OUTPUT)
REAL LOD,ANS(4),AI(5),A2(4),A3(5),B1(4)
INTEGER OUTPUT
COMMON /DEVAR/DESIGN(15),ITERM(10),CST(10)
COMMON /DVAR/CDS(6),COSAP(6)
COMMON /GEOM/W(20),HX(20),GX(35),PX(15)
COMMON /GRAVITY/CG(6)
COMMON /STAB/DERIVCR(15),DERIVAP(15),STOR(20)
COMMON /WTSVE/WTS(20)

IPHASE=1 (CR), =0 (10 DEG FLAP, FWD CG), =-1 (45 DEG FLAP), =-2 (45 DEG FLAP, FWD CG), =-3 (45 DEG FLAP, FWD CG, FIND CLMAX), =-4 (10 DEG FLAP, FWD CG, FIND CLMAX)

DATA AI/.00102,.028817,.8415.714076,10.706253/
DATA A2/1.00131,-0.12203,0.30714,-0.005556/
DATA A3/276.559019,-1306.362579,2314.351122,-1817.552645,
$ 534.505085/
DATA B1/-0.794,-.296,.812,.111/
IF(IPHASE.LT.1) XM=.15
ICG=ITERM(3)
IF(IPHASE.LT.1) ICG=1
IF(IPHASE.LT.1) GO TO 25
CALL AT62(ALT,ANS)
FI=G(X(27)
IF(IPHASE.EQ.0 .OR. I PHASE.LT. -3) FI=1.
V=(2.*FI*WTS(1)/(ANS(1)*DESIGN(1)*Cl))**0.5
XM=V/ANS(4)

IF(PHASE.EQ.-1 .O R.PHASE.EQ.0) ICG=2
IF(PHASE.LT.-1) ICG=4
25 CALL CDZL(ALT,CDO,XM,OUTPUT)
CALL STABCOD(CL,XM,ICG,OUTPUT)
CALL TRIM(CL,XM,CDO,CLWING,CLTAIL,CRIT,CRDE,EPS,IPHASE,$ICG)

******************************************************************************
* COMPRESSIBILITY DRAG                                                *
******************************************************************************

DFME=0.
FMCR=0.
DMME=0.
WMCR=0.
IF(XM.LT.0.65) GO TO 40
CLWN=CLWING/(W(15)*W(15))
WMCRN=(W(4)-(BL(4)*CLWN+BL(3)))/(BL(2)*CLWN+BL(1))
WMCR=WMCRN/W(15)
DM=XM-WMCR
Z1=A1(1)
DO 28 I=2,5
Z1=Z1+A1(I)*DM**(I-1)
28 CONTINUE
DME=Z1
BARL=DESIGN(3)/(G(X(5)*10.)
Z1=A2(1)
DO 30 I=2,4
Z1=Z1+A2(I)*BARL**(I-1)
30 CONTINUE
FMCR=Z1
Z1=A3(1)
DM=XM-FMCR
BARM=0.89+DM
DO 32 I=2,5
Z1=Z1+A3(I)*BARM**(I-1)
32 CONTINUE
DFME=(Z1-1.)*CDS(6)
40 E1=W(6)
E2=W(7)
IF(IPHASE.LT.1) E2=0.7
******************************************************************************
* WING INDUCED DRAG                                                   *
******************************************************************************

CLO=W(8)
T1=CLO*CLO/(G(X(1)*DESIGN(2)*E1)
T2=(CLWING*CLWING-CLO*CLO)/(G(X(1)*DESIGN(2)*E2)
TT1=T1+T2

******************************************************************************
* MUNK'S INTERFERENCE TERM *

**SMU=HX(4)/W(9)**

\[ G = (\frac{.25*GX(5) + GX(34)}{W(9)}) * G \]

\[ G2 = G * G \]

\[ G3 = G2 * G \]

\[ C0 = .000076 + .006814 * G - .088417 * G2 + .247037 * G3 \]

\[ C1 = 1.002161 * .242040 * G - 34.140971 * G2 + 73.096667 * G3 \]

\[ C2 = .000145 - 24.824801 + 211.181316 * G2 - 442.515185 * G3 \]

\[ C3 = .014537 + 42.231817 * G - 375.564896 * G2 + 803.755111 * G3 \]

\[ C4 = .009817 - 24.947988 + 220.010784 * G2 - 472.608148 * G3 \]

\[ \sigma = C0 + C1 * SMU + C2 * SMU * SMU + C3 * SMU * SMU * SMU + C4 * SMU * SMU * SMU * SMU \]

* INTERFERENCE DRAG *

**T3 = 2 * \sigma * CLWING * CLTAIL * DESIGN(4) / (SMU * GX(1) * DESIGN(2))**

**T4 = DESIGN(4) * CLTAIL * CLTAIL / (DESIGN(1) * GX(1) * DESIGN(5) * .8)**

* INDUCED DRAG FROM HAVING TAIL *

**DELCL2 = CLWING * CLWING - CL * CL**

**TDG = DELCL2 / (GX(1) * DESIGN(2) + T3 + T4)**

**CDI = TT1 + T3 + T4**

**CDDEL = (ABS(CRDE)) * DERIVCR(14)**

**IF(IPHASE.LT.1) CDDEL = (ABS(CRDE) + GX(2) * GX(13)) * DERIVAP(14)**

**CDTOT = CDI + CD0 + CDDEL + DFME**

**XTI = CL0 * CL0 / (EI - E2) / (GX(1) * DESIGN(2))**

**CDOP = CD0 + TDG**

* DATA BASE ASSIGNMENTS *

**GX(31) = TDG**

**XLDMX = .5 * (GX(1) * DESIGN(2) + E2) / (CDOP + XTI)**

**CLLDMX = (GX(1) * DESIGN(2) + W(7) * (CDOP + XTI))**

**IF(IPHASE.LT.1) GO TO 48**

**HX(14) = CRDE**

**CST(6) = XLDMX**

**GX(28) = CLWING**

**DTAIL = CDAP(3) + TDG**

**GO TO 50**

**48 CDSAP(4) = CL / CDTOT**

**DTAIL = CDSAP(3) + TDG**

**CDAP(5) = CDTOT**

**HX(11) = CLTAIL**

**GX(29) = CLWING**

**HX(12) = CRIT**

**HX(13) = CRDE**

**50 LOD = CL / CDTOT**
* OUTPUT SECTION *

IF(OUTPUT.EQ.0) GO TO 100
WRITE(6,80)
80 FORMAT(*1*/20X*ACCURATE L/D ANALYSIS*)
IF(IPHASE.LT.0) WRITE(6,81)
81 FORMAT(*1*/20X*APPROACH WITH 45 DEGREES FLAP*)
IF(IPHASE.LT.-1) WRITE(6,87)
87 FORMAT(20X*FORWARD C.G.*)
WRITE(6,82) CL, CLWING, CLTAIL, CRDE, CRIT
82 FORMAT(*1*/10X*CL (REQUESTED) =*T45 w FI5 o 3
10X*CL (WING)=*T45, FI5.3/10X*CL (TAIL)=*T45, FI5.3/10X*ELEVATOR (DEGREES) =*T45, FI5.2/
$10X*STABILIZER (DEGREES) *T45, FI5.2/
WRITE(6,83) TTI, T3, T4, TDG, DTAIL, SIGMA
83 FORMAT(*1*/10X*WING=*T45, FI5.4
10X*INTERFERENCE=*T45, FI5.4
10X*TAIL=*T45, FI5.4
$10X*SIGMA*T45
10X*TOTAL=*T45, FI5.4/
WRITE(6,86) LOD
86 FORMAT(*1*/15X*L/D=*T45, FI5.3)
WRITE(6,92) XLDMX, CLLDMX, CDDEL
92 FORMAT(*1*/15X*MAX. L/D=*T45, FI5.3/15X*TOTAL=*T45, FI5.4/
$10X*MODIFIED CDO=*T45, FI5.4/
100 RETURN

SUBROUTINE AIRCOST (COST, OUTPUT)
REAL CD(10), CP(10)
REAL T1(2), T3(2), T9(2), T10(2), T32(2)
INTEGER OUTPUT
COMMON /DEVAR/ DESIGN (15), ITERM(10), CST(10)
COMMON /WTSVE/ WTS(20)
COMMON /GEOM/W(20), HX(20), GX(35), PX(15)
A=WTS(4)
DATA T1, T3, T9, T10/1., 1.15, 1., 2., 1., 1.15, 0., 1./
DATA T32/1., 1.1/

* LIST OF PURCHASE PRICE ELEMENTS IN 1974 *
* REF (4) -- NICOLAI *
* ENGINEERING (1) *
* DEVELOPMENT SUPPORT (2) *
* FLIGHT TEST (3) *
* TOOLING (4) *
* MANUFACTURING LABOR (5) *
* QUALITY CONTROL (6) *
* MATERIALS (7) *
* ENGINE (8) *
AVIONICS (9)

ACTIVE CONTROL SYSTEM (10)

*  

IACCT=0
ICGX=ITERM(2)
CD(1)=10964.13*A**0.791
CP(1)=26567.12*A**0.791-CD(1)
CD(2)=1627.68*A**0.873
CP(2)=0.0
CD(3)=15716.31*A**0.764
CP(3)=43272.95*A**0.764-CD(4)
CD(4)=13026.56*A**0.74
CP(4)=164219,18*A**0.74-CD(5)
CD(5)=2733.64*A**0.689
CP(5)=1.25960.83*A**0.689-CD(7)
CD(8)=2.1169.0*(DESIGN(6)/ITERM(4))**0.8356
CP(8)=2.1169.0*(DESIGN(6)/ITERM(4))**0.8356
CD(9)=2.300000.*T9(IACT+1)
CP(9)=250.*300000.*T9(IACT+1)

ACTIVE CONTROLS PRICE HAS TO BE ESTIMATED

CD(10)=206250.*2.*ITERM(1)
CP(10)=206250.*250.*ITERM(1)
TOTD=0.
TOTP=0.

CONVERT FROM 1974 $ TO 1976 $

DO 50 J=1,10
CD(J)=CD(J)*1.23077
CP(J)=CP(J)*1.23077
TOTD=TOTD+CD(J)
TOTP=TOTP+CP(J)
50 CONTINUE

INCLUDING 10% PERCENT PROFIT

TOTCOST=TOTD*1.1+TOTP*1.1
COST=TOTCOST/250.0
COST=COST*(1.0+PX(7)*0.05)

* OUTPUT SECTION *

IF(OUTPUT.EQ.0) GO TO 100
WRITE(6,70)
70 FORMAT(*1/*20X*AIRCRAFT COST ESTIMATES*//43X*DEVELOPMENT*
$9X*PRODUCTION/) WRITE(6,72) CD(1),CP(1)
SUBROUTINE FL_INCST(COST,OUTPUT)
INTEGER OUTPUT
REAL MCOST(27),LCOST(27),T9(2),XNM(27)
REAL T1(2),T3(2),T8(2),T12(2),T15(2)
REAL LCST(27),KCST(27)
COMMON /DEVAR/DESIGN(15),ITEM(10),CST(10)
COMMON /WTSVE/WTS(20)
COMMON /GEOM/W(20),HX(20),GX(35),PX(15)
DATA T1,T3,T8/1.,1.15,1.,1.2,1.,1.2/
DATA T9,T12,T15/1.,1.3,1.,1.15,1.,1.15/
TACT=ITEM(1)
ICGX=ITEM(2)
NEXG=ITEM(4)
NPASS=GX(19)
WTS=WTS(1)*0.453592
WTE=WTS(2)*0.453592
WTF=WTS(6)*0.456592
DATA XNM/4HINSP,8HAIR COND,10AUTO PILOT,6HCOMMUN,
$4HELEC,4HFURN,9FIRE PROT,9HFLT CONTL,4HFUEL,
$9HYD POWER,3HICE,5HINSTR,9HLAND GEAR,
$8HLIGHTING,5HNAVIG,6HOXYGEN,7HENGINE,
$9HAT/WASTE,7HAIR APU,9HSTRUCTURE,5HDOORS,
$8HFUSELAGE,8HNACELLES,5HWINGS,4HSTAB,
$7HWINDOWS,6HENGINE/

**********************************************************************
* MAINTENANCE COSTS—1976 DOLLARS/HOUR *
* REF(20) — AMERICAN AIRLINES *
* (1) INSPECTION AND MISC. *
**********************************************************************
* (2) AIR CONDITIONING *
* (3) AUTO PILOT *
* (4) COMMUNICATIONS *
* (5) ELECTRICAL *
* (6) EQUIPMENT AND FURNISHINGS *
* (7) FIRE PROTECTION *
* (8) FLIGHT CONTROLS *
* (9) FUEL *
* (10) HYDRAULIC POWER *
* (11) ICE AND RAIN *
* (12) INSTRUMENTS *
* (13) LANDING GEAR *
* (14) LIGHTING *
* (15) NAVIGATION *
* (16) OXYGEN *
* (17) PNEUMATICS *
* (18) WATER/WASTE *
* (19) AIRBORNE APU *
* (20) STRUCTURE *
* (21) DOORS *
* (22) FUSELAGE *
* (23) NACELLES/ pylons *
* (24) WINGS *
* (25) STABILIZERS *
* (26) WINDOWS *

**********************************************************************
LCOST(1)=T1 (IACT+1) *7.66+0.377*WTE/1000.0
MCOST(1)=T1 (IACT+1) *1.21+0.062*WTE/1000.0
DATA LCOST(2),MCOST(2) /5.1026,4.52/
LCOST(3)=T3 (IACT+1) *11.19
MCOST(3)=T3 (IACT+1) *2.621
LCOST(4)=.0276*NPass
MCOST(4)=0.0118*NPass
DATA LCOST(5),MCOST(5) /4.306,5.748/
LCOST(6)=9.11+0.08496*NPass
MCOST(6)=2.38+0.05776*NPass
LCOST(7)=.213+2.29*(2.+NENG)
MCOST(7)=0.365*(2.+NENG)
LCOST(8)=T8 (IACT+1) *6.84+0.0035*WTO/1000.
MCOST(8)=T8 (IACT+1) *3.876+0.00655*WTO/1000.
LCOST(9)=1.114+0.0262*WTO*T9 (ICGX+1)/1000.0
MCOST(9)=0.595+0.0123*WTO*T9 (ICGX+1)/1000.0
DATA LCOST(10),MCOST(10) /3.33,3.95/
LCOST(11)=.5089+0.0013*WTO/1000.0
MCOST(11)=.0847+.0037*WTO/1000.0
LCOST(12)=T12 (IACT+1) *0.509+.009*WTE/1000.0
MCOST(12)=T12 (IACT+1) *0.235+.0031*WTE/1000.0
LCOST(13)=4.58+.071*WTO/1000.0
MCOST(13)=4.961+.181*WTO/1000.0
LCOST(14)=1.51+0.01152*NPass
MCOST(14)=0.0470.01392*NPass
LCOST(15)=T15 (IACT+1) *10.077
MCOST(15)=T15 (IACT+1) *7.166

58
LCOST(16) = .515 + 0.00265 * NPASS
MCOST(16) = 0.00752 * NPASS
DATA AC/200. /
T = DESIGN (6) * 4.448 / NENG
LCOST(17) = 0.181 + 0.0003 * AC / T / 10000.
MCOST(17) = 0.0019 * AC / T / 10000.
LCOST(18) = .339 + 0.00368 * NPASS
MCOST(18) = 0.00768 * NPASS
DATA LCOST(19), MCOST(19) / .315, .462 /
LCOST(20) = 3. + 0.0999 * WTE / 1000.
DATA MCOST(20) / 0. /
LCOST(21) = 1.147 + 0.006 * NPASS
MCOST(21) = .387 + 0.00785 * NPASS
LCOST(22) = 1.5 + 0.046 * WTE / 1000.
DATA MCOST(22) / 0.5833 /
NAC = 4
IF (NENG .LT. 4) NAC = 2
LCOST(23) = .3366 * NAC
MCOST(23) = .1391 * NAC
SW = DESIGN (1) / (3.201 * 3.201)
DATA LCOST(24) / 2.9475 /
MCOST(24) = 0.126 + 0.00506 * SW
DATA LCOST(25), MCOST(25) / 0.8321, 0.3737 /
LCOST(26) = 0.763 + 0.00043 * NPASS
MCOST(26) = 0.0362 * NPASS
DO 50 K = 1, 26
LCO(T(K)) = LCOST(K) / 2.5
MCST(K) = MCOST(K) / 2.5
50 CONTINUE
TLCOST = 0.
TMCOST = 0.
DO 75 K = 1, 26
TLCOST = TLCOST + LCST(K)
TMCOST = TMCOST + MCST(K)
75 CONTINUE
TENG = DESIGN (6) / ITERM(4)

** MAIN ENGINE COST **

*-------------------------------------------------------------*
* MAIN ENGINE COST                                           *
*-------------------------------------------------------------*
LCOST(27) = (ITERM(4) / (4.0 * 2.5)) * .885 * (TENG / 20000.) ** 0.5
MCOST(27) = (ITERM(4) / (4.0 * 2.5)) * 109.0 * (TENG / 20000.) ** 0.5
COST = TLCOST + TMCOST + LCST(27) + MCST(27)
COST = COST * (1.0 + PX(6) * 0.05)

IF (OUTPUT .EQ. 0) GO TO 100
WRITE(6, 86)
86 FORMAT(*1/*30X*MAINTENANCE OPERATING COSTS*//7X*NO. SYSTEM*7X
$10X*LABOR*7X*MATERIAL* *)
DO 90 K = 1, 26
WRITE(6, 88) K, XNM(K), LCST(K), MCST(K)
88 FORMAT(110, 2X, A10, 3X, 2F15.2)
90 CONTINUE
WRITE(6, 92) TLCOST, TMCOST, LCST(27), MCST(27), COST
92 FORMAT(//5X*LABOR COST*T35,F15.2//5X*MATERIAL COST*T35,F15.2//5X*ENGINE LABOR COST*T35,F15.2//5X*ENGINE MATERIAL COST*T35,F15.2//30X*MAINTENANCE COST IN 1976 DOLLARS PER HOUR*F15.2)

100 RETURN

END

SUBROUTINE CNSTRN(OUTPUT)
REAL LODMA, LOD2, ANS(4), LFL, NZOACR, NZOAA
REAL PRAMCR(4), PRAMAP(4), ACR(5), AAP(5)
REAL TCCR(4), TCAP(4)
COMPLEX ROOTCR(4), ROOTAP(4)
COMMON /STRAIN/CON(59)
INTEGER OUTPUT
REAL KT1, KT2, KDOT1, KDOT2, DERCRI, DERAP(15)
COMMON /CONSTRAINT/SU(59), SL(59), XINEQ(59)
COMMON /DEVAR/DESIGN(15), ITERM(10), CST(10)
COMMON /DEV/DESIGN(6), CSSAP(6)
COMMON /GEOM/P(20), IX(20), GX(35), PX(15)
COMMON /GRAVITY/CG(6)
COMMON /CONSTR/CONSTR(15), DERIVCR(15), DERIVAP(15)
COMMON /DESIGN/DESIGN(20)
COMMON /WTS/DESIGN(20)
COMMON /GERM/W(20), HX(20), GX(35), PX(15)

*CONSTRAINT IDENTIFICATION*

*NO. DESCRIPTION
1 CRUISE THRUST REQUIREMENT
2 SECOND SEGMENT CLIMB GRADIENT - THRUST REQUIREMENT
3 MISSED APPROACH CLIMB GRADIENT - THRUST REQUIREMENT
4 LANDING FIELD LENGTH - WING LOADING REQUIREMENT
5 TAKE-OFF FIELD LENGTH - WING LOADING REQUIREMENT
6 LANDING GEAR - AFT CG LIMIT
7,8 STATIC STABILITY - CRUISE, APPROACH
9,10 MANEUVER MARGIN - CRUISE, APPROACH
11 TAIL LIFT - APPROACH
12 NOSE GEAR UNSTICK
13,14 DYNAMIC STABILITY - CRUISE, APPROACH
15,16 PHUGOID FREQUENCY - CRUISE, APPROACH
17,18 PHUGOID DAMPING - CRUISE, APPROACH
19,20 SHORT PERIOD FREQUENCY - CRUISE, APPROACH
21,22 SHORT PERIOD DAMPING - CRUISE, APPROACH
23,24 TIME-TO-DOUBLE (CRUISE, APPROACH)
25,26 TIME-TO-HALF (CRUISE, APPROACH)
27 FLIGHT PATH STABILITY - APPROACH
28,29 VERTICAL GAIN - CRUISE, APPROACH
30,31 TIME SUB THETA 2 - CRUISE, APPROACH
32,33 FREQUENCY**2/VERTICAL GAIN - CRUISE, APPROACH
34 T(1) PARAMETER - APPROACH
35,36 RATIO OF MODE FREQUENCIES - CRUISE, APPROACH
37-39 ELEVATOR VARIANCE - CRUISE
40-42 ELEVATOR VARIANCE - APPROACH
43,44 VARIANCE OF ELEVATOR RATE - CRUISE, APPROACH
45 PASSENGER VOLUME LIMIT
46,47 ELEVATOR DEFLATIONS - TRIMMED (CRUISE, APPROACH)
* 48 .......... CRUISE ALTITUDE
* 49 .......... CRUISE ALTITUDE ((L/D)\text{MAX})
* 50,51 .......... WING CL - CRUISE APPROACH
* 52 .......... TAIL ASPECT RATIO LIMIT - \text{AR(TAIL/AR(WING))}

**IOOUT=OUTPUT**

\[
\text{IF}(\text{OUTPUT.GT.}1) \quad \text{IOOUT}=0
\]

**CON(1)=GX(30)**

**FIND TAKE-OFF CL-MAX AND SECOND SEGMENT CLIMB GRADIENTS**

\( \text{CLWTO}=\text{GX}(8) \)
\( \text{CALL XLOD(CLWTO,.1,0.,\text{EFF},-4,0)} \)
\( \text{NENG=ITEM(4)} \)
\( \text{CALL AT62(0.,\text{ANS})} \)
\( \text{TOWAV=DESIGN(6)/WTS(1)} \)
\( \text{CL2=CLWTO/1.44} \)
\( \text{V=(2.*WTS(1)/(DESIGN(1)*\text{ANS(1)*CL2)})^{0.5}} \)
\( \text{XM=V/\text{ANS(4)}} \)
\( \text{CALL ENGINE(0.,XM,TCTM,TSFC)} \)
\( \text{GRAD=0.030} \)
\( \text{CALL XLOD(CL2,.1,0.,\text{LOD2},0,0)} \)
\( \text{IF(ITEM(4).EQ.3) GRAD=0.027} \)
\( \text{IF(ITEM(4).EQ.2) GRAD=0.024} \)
\( \text{TOWRQ2=(NENG/(NENG-1))^{(1./\text{LOD2}+\sin(GRAD))^{(1./\text{TCTM}})} \)
\( \text{CON(2)=TOWAV/TOWRQ2} \)

**NOSE GEAR UNSTICK**

\( \text{ZACT}=4.0/W(10) \)
\( \text{XMUF}=0.025 \)
\( \text{ZACLGF}=2.*\text{ZACT} \)
\( \text{XLT}=\text{HX(6)*DESIGN(1)*W(10)/DESIGN(4)} \)
\( \text{CALL AT62(0.,\text{ANS})} \)
\( \text{VSTALL=(WTS(1)*2.0/(DESIGN(1)*\text{ANS(1)*GX(8)})^{0.5}} \)
\( \text{VLO=VSTALL^{0.9}} \)
\( \text{CLW=(STOR(6)*(W(2)-\text{GX(17)}-3.0))}/\text{GX(2)} \)
\( \text{Q=0.5*\text{ANS(1)*VLO^{2}}/\text{VLO}} \)
\( \text{XLTW=Q*DESIGN(1)*\text{CLW}^{1.2}} \)
\( \text{XMW=1.05*Q*DESIGN(1)*W(19)+W(17)}^{*}W(10) \)
\( \text{C1}=\text{XLTW+(0.25-CG(5)-\text{XMUF}*ZACLGF)^{*}W(10)} \)
\( \text{UNTHRU=DESIGN(6)} \)
\( \text{IF(ITEM(4).EQ.3) UNTHRU=DESIGN(6)/3.0} \)
\( \text{XCG=CG(3)} \)
\( \text{COIT=HX(12)} \)

**TAIL INCIDENCE SET TO WORSE CASE FOR TAKE-OFF (BOEING)**

\( \text{IF(GX(16).NE.-99.0) COIT=GX(16)} \)
\( \text{XLTRO=(XMUF+ZACT*W(10))^{*}2^{*}\text{UNTHRU+W(10)}^{*}(\text{XCG-.25)}^{*}\text{XLTW}} \)
\( \text{XLTAV=STOR(7)*HX(6)^{*}0.9^{*(1.-STOR(8))^{*}(W(2)-\text{GX(17)}-3.0)}} \)
GROUND EFFECTS—DATCOM FUNCTION OF GEOMETRIC ALPHA

TLGE= .355*Q'DESIGN(4)
XLTAV2=XLTAV+TLGE
CLTAV=XLTAV2/(Q'DESIGN(4))
IF(CLTA V .GT. 1.5) XLTAV2=1.5*Q'DESIGN(4)
CON(12)=XLTAV2/XLTRQ
IF(OUTPUT.EQ.1) WRITE(6,548) ZACT,XMUF,ZA CLG,ANS,VSTALL,CLW
$ ,Q,XLW,XM,W,CL,UNTHRU,XG, XLTRQ,CL2,COIT,XLT
$ ,XLTAV,CON(12),STOR(7),STOR(8),W(2),GX(17),HX(6),W(10)
$ ,XLTAV2,TLGE,CLTAV

548 FORMAT(*1/*20X*DEBUG OF NOSE GEAR UNSTICK*///
$10X"ZACT,XMUF, ZACLG=" 3F15.4/
$10X"ANS(1,2,3,4)=" 4F15.6/
$10X"VSTALL,CLW,Q,XLW,XM=" 5F15.4/
$10X"CL,UNTHRU,XG, XLTRQ,CL2,COIT,XLT=" 7F12.4/
$10X"XLTAV,CON(12),STOR(7),STOR(8),W(2)=" 5F15.4/
$10X"GX(17),HX(6),W(10),XLTAV2,TLGE,CLTAV=" 6F15.4/**/

* FIND APPROACH CL-MAX AND MISSED APPROACH CLIMB GRADIENTS *
* SET UP APPROACH WITH FORWARD CG AND 45 DEG FLAPS *

CLWMAX=GX(12)
CALL XLOD(CLWMAX,.1,0.,EFF,-3,0)
CLS=CLWMAX
GRAD=GRAD-.003
CLA=CLS/1.69
V=(2.*WTS(1)*GX(27)/(DESIGN(1)*ANS(1)*CLA)**0.5
XM=V/ANS(4)
CALL ENGINE(0.,XM,TCTM,TSCF)
GX(10)=CLA
CALL XLOD(CLA,.1,0.,LODMA,-2,0)
TOWRQ=(NENG/(NENG-1.))*(1./LODMA+SIN(GRAD))*(1./TCTM)
TOWAV=DESIGN(6)/(WTS(1)*GX(27))
CON(3)=TOWAV/TOWRQ
VA2=GX(27)*WTS(1)*498.23/(DESIGN(1)*CLA)
VA=VA2**0.5
GX(14)=VA*1.6881
LFL=0.29875*VA2+25.
CON(4)=LFL
TOWAV=DESIGN(6)/WTS(1)
TOP=(WTS(1)/DESIGN(1))/(CLWTO*TOWAV)
TOFL=(31.7*TOP)+910.0
CON(5)=TOFL
CON(6)=CG(5)-CG(6)-DESIGN(7)
VOLPAS=GX(19)*52.
PASSL=DESIGN(3)-1.2*GX(15)-.5*GX(33)
VOLAV=GX(1)*GX(5)*GX(5)*PASSL/8.
CON(45)=VOLAV/VOLPAS
CLTAIL=HX(11)

***************************************************************************
* DATA BASE ASSIGNMENTS  *

**CON (11) = CLTAIL**
**CON (46) = HX (14)**
**CON (47) = HX (13)**
**CON (48) = WTS (11)**
**CON (49) = WTS (12)**
**CON (50) = GX (28)**
**CON (51) = GX (29)**
**CON (52) = DESIGN (5) / DESIGN (2)**

*** THIS ENDS DESIGN CONSTRAINT SECTION, AND BEGINS HANDLING QUALITY  ***

**CON (7) = CG (1) - STOR (4)**
**CON (8) = CG (2) - STOR (9)**
**CON (9) = CG (1) - STOR (5)**
**CON (10) = CG (2) - STOR (10)**

*** CALCULATE DIMENSIONAL DERIVATIVES  ***

**CON (13) = DERCR (4) * DERCR (3) - DERCR (1) * DERCR (6)**
**CON (14) = DERAP (4) * DERAP (3) - DERAP (1) * DERAP (6)**

*** THIS NEXT SECTION APPROXIMATES AIRCRAFT DYNAMIC PROPERTIES  ***

**TPHUGCR = DERCR (1) * DERCR (9) - UOCR * DERCR (3)**
**OMPH2 = GX (15) * (DERCR (3) * DERCR (4) - DERCR (6) * DERCR (1)) / TPHUGCR**
**OMPH = (ABS (OMPH2)) ** 0.5**
**CON (15) = OMPH**

**TPHUGAP = DERAP (1) * DERAP (9) - GX (14) * DERAP (3)**
**OMPHA2 = GX (15) * (DERAP (1) + DERAP (4) - DERAP (6) * DERAP (1)) / TPHUGAP**
**OMPHA = (ABS (OMPHA2)) ** 0.5**
**CON (16) = OMPHA**

**OMSP2 = DERCR (9) * DERCR (1) - DERCR (3) * UOCR**
**OMSP = (ABS (OMSP2)) ** 0.5**

ENDIF = 1

%THE END%
CON (19) = OMSP
OMSPA2 = DERAP (9) * DERAP (1) - DERAP (3) * GX (14)
OMSPA = (ABS (OMSPA2)) ** 0.5
CON (20) = OMSP
TXT = -(DERCR (1) + DERCR (9) * UOCR * DERCR (12))
ZETASP = TXT / (2.0 ** OMSP)
CON (21) = ZETASP
TXTA = -(DERAP (1) + DERAP (9) + GX (14) * DERAP (12))
ZETASP = TXTA / (2.0 ** OMSPA)
CON (22) = ZETASP

**********************************************************************
CALCULATE EXACT DYNAMICS FROM FOURTH ORDER MODEL
**********************************************************************
30 CALL LONCTRL (DERCR, UOCR, ROOTCR, PRMCR, ACR, NOCR, TCCR)
CALL LONCTRL (DERAP, VA, ROOTAP, PRMAP, AAP, NOAP, TCAP)
IF (IFULL .LT. 1) GO TO 45
OMPH = PRMCR (1)
ZETAPH = PRMCR (2)
OMSP = PRMCR (3)
ZETASP = PRMCR (4)
OMPHA = PRMAP (1)
ZETAPHA = PRMAP (2)
OMSPA = PRMAP (3)
ZETASP = PRMAP (4)
45 IF (OUTPUT .LT. 1) GO TO 50
IF (OUTPUT .GT. 1) GO TO 50
WRITE (6, 31)
31 FORMAT (*11/ 30*X LONGITUDINAL DYNAMICS*/ 20*/ CRUISE*/ *)
WRITE (6, 32) ACR
32 FORMAT (/10*X COEFFICIENTS=*/5F15.6)
WRITE (6, 33) ROOTCR
33 FORMAT (/10*X ROOTS (REAL, IMAGINARY) */4 (2F15.4/))
WRITE (6, 35) PRMCR
35 FORMAT (/10*X PHUGOID FREQUENCY*T35, F15.4/10X$ Phugoid damping* T35, F15.4/10X SHORT PER. FREQ.*
$ T35, F15.4/10X SHORT PER. DAMPING* T35, F15.4)
WRITE (6, 36) NOCR, TCCR
36 FORMAT (/10*X NO. OF NON-Oscillatory Roots=*/11
$ / 10*X TIME CONSTANTS=*/T35, F15.4)
WRITE (6, 37)
37 FORMAT (*11/ 20*X/ APPROACH*/ *)
WRITE (6, 32) AAP
WRITE (6, 33) ROOTAP
WRITE (6, 35) PRMAP
WRITE (6, 36) NOAP, TCAP
WRITE (6, 48) GX (8), CLWT, CL2, GX (12), CLWMAX, CLA
48 FORMAT (*11/ 10*X CL MAX TO (W), CL MAX TO (AC), CL2*T60, F10.3/
$ 10*X CL MAX (W), CL MAX (AC), CLA=*T60, F10.3)
50 IF (IFULL .LT. 1) GO TO 100
CON (15) = OMPH
CON (16) = OMPHA
CON (17) = ZETAPH
CON (18) = ZETAPHA
CON (19) = OMSP
CON (20) = OMSPA
CON (21) = ZETASP
CON (22) = ZETASPA
OMSP2 = OMSPA*OMSP
OMSPA2 = OMSPA*OMSPA
IF (OMSP.EQ.0.) OMSP=1.0E-20
IF (OMSPA.EQ.0.) OMSPA=1.0E-20
IF (OMPH.EQ.0.) OMPH=1.0E-20
IF (OMPHA.EQ.0.) OMPHA=1.0E-20
GREAT = -999.
100 IF (NOCR.LT.1) GO TO 210
DO 209 K = 1, NOCR
IF (TCCR(K).LT.0.0) GO TO 209
IF (TCCR(K).GT.GREAT) GREAT = TCCR(K)
209 CONTINUE
210 TDOUBCR = -0.693/(OMPH*ZETAPH)
T1 = -0.693/(OMSP*ZETASP)
T2 = 0.693/GREAT
IF (TDOUBCR.GT.T1.AND.T1.GT.0.0) TDOUBCR = T1
IF (T2.LT.0.0) GO TO 219
IF (TDOUBCR.LT.0.0.OR.TDOUBCR.GT.T2) TDOUBCR = T2
219 IF (TDOUBCR.LT.0.0) TDOUBCR = 99.
CON (23) = TDOUBCR
GREAT = -999.
IF (NOAP.LT.1) GO TO 230
DO 231 K = 1, NOAP
IF (TCAP(K).LT.0.0) GO TO 231
IF (TCAP(K).GT.GREAT) GREAT = TCAP(K)
231 CONTINUE
230 TDOUBAP = -0.693/(OMPHA*ZETAPHA)
T1 = -0.693/(OMSPA*ZETASPA)
T2 = 0.693/GREAT
IF (TDOUBAP.GT.T1.AND.T1.GT.0.0) TDOUBAP = T1
IF (T2.LT.0.0) GO TO 239
IF (TDOUBAP.LT.0.0.OR.TDOUBAP.GT.T2) TDOUBAP = T2
239 IF (TDOUBAP.LE.0.) TDOUBAP = 99.
CON (24) = TDOUBAP
THALF = -99.
THALFA = -99.
IF (OMSP.EQ.1.0E-20) OMSP=-1.0E-20
IF (OMSPA.EQ.1.0E-20) OMSPA=-1.0E-20
IF (OMPH.EQ.1.0E-20) OMPH=-1.0E-20
IF (OMPHA.EQ.1.0E-20) OMPHA=-1.0E-20
GREAT = -999.
IF (NOCR.LT.1) GO TO 245
IF (TDOUBCR.NE.99.) GO TO 250
DO 242 K = 1, NOCR
IF (TCCR(K).GT.0.0) GO TO 242
IF (TCCR(K).GT.GREAT) GREAT = TCCR(K)
242 CONTINUE
245 THALF = -0.693/(OMPH*ZETAPH)
T1 = 0.693/(OMSP*ZETASP)
T2=-0.693/GREAT
IF(THALF.LT.T1.AND.T1.GT.0.0) THALF=T1
IF(THALF.LT.T2.AND.T2.GT.0.0) THALF=T2
IF(THALF.LE.0.) THALF=-99.
250 CON(25)=THALF
GREAT=-999.
IF(NOAP.LT.1) GO TO 255
IF(TDOUBAP.NE.99.) GO TO 260
DO 252 K=1,NOAP
IF(TCAP(K).GT.0.0) GO TO 252
IF(TCAP(K).GT.GREAT) GREAT=TCAP(K)
252 CONTINUE
255 THALFA=0.693/(OMPHA*ZETAPHA)
T1=0.693/(OMSPA*ZETASPA)
T2=-0.693/GREAT
IF(THALFA.LT.T1.AND.T1.GT.0.0) THALFA=T1
IF(THALFA.LT.T2.AND.T2.GT.0.0) THALFA=T2
IF(THALFA.LE.0.) THALFA=-99.
260 CON(26)=THALFA
TDEL=DERAP(13)/DERAP(15)
TZT=(DERAP(6)*DERAP(4)-DERAP(6)*DERAP(1))/
$ (-DERAP(1)+DERAP(3)*TDEL)
TYT=(DERAP(4)-TDEL*DERAP(6))/(DERAP(1)-DERAP(3)*TDEL)
DGDU=(DERAP(5)-(DERAP(2)-GX(15)/GX(14))*TYT-DERAP(14)*TZT
$/DERAP(15))/GX(15)
CON(27)=DGDU
ZTZT=UOCR*(DERCR(13)*DERCR(3)-DERCR(15)*DERCR(1))
NZOACR=ZTZT/((DERCR(15)-DERCR(13)*DERCR(9))/UOCR)*GX(15))
CON(28)=NZOACR
ZZTA=GX(14)*(DERAP(13)*DERAP(3)-DERAP(15)*DERAP(1))
NZOAAA=ZZTA/((DERAP(15)-DERAP(13)*DERAP(9)/GX(14))*GX(15))
CON(29)=NZOAAA
TTH2=ZZT/(UOCR*(DERCR(15)+DERCR(13)*DERCR(12))
CON(30)=TTH2
THHA2=ZZTA/GX(14)*(DERAP(15)+DERAP(13)*DERAP(9))
CON(31)=THHA2
CON(32)=OMSPA/NZOACR
CON(33)=OMSPA/NZOAAA
PIARE=1./(G1*DESIGN(2)*W(7))
TA1=GX(14)/(2.0*GX(15)*(1./CDSAP(4)-2.*PIARE*GX(10))
CON(34)=TA1
IF(OMPH*OMPH.GT.0.) GO TO 80
CON(35)=99.
GO TO 82
80 CON(35)=OMSP/OMPH
82 IF(OMPHA*OMPHA.GT.0.) GO TO 84
CON(36)=99.
GO TO 86
84 CON(36)=OMSPA/OMPHA
************************************************************************
* THE FOLLOWING SECTION CALCULATES THE RESPONSE OF A PITCH ATTITUDE HOLD/RATE COMMAND AUTOPILOT IN TURBULENCE. *
86 WCR2=NZOACR
WCR=WCR2**0.5
DZETA=.7
DM=DERC(15)+DERC(3)
DM1=1.-DERC(12)*DERC(15)*WCR2/DM
DM2=2.*DZETA*WCR*DERC(12)*DERC(15)-DERC(15)-DERC(3)*DERC(15)
KTDOT1=2.*DZETA*WCR*(DERC(12)*UOCR-1.)-DERC(9)-DERC(3)*UOCR
$+DERC(12)*WCR2*(1.-DERC(12)*UOCR)/DM
KTDOT1=KTDOT1/(DM1*DM2)
KT1=WCR2*(1.-DERC(12)*UOCR)+KTDOT1*WCR2*DERC(12)*DERC(15)
KT1=KT1/DM
XNUM= ((DERC(9)/UOCR)**2.0) * (KT1*KT1-KTDOT1*KTDOT1*(2.0*DZETA
$*WCR+WCR**G(11)/(UOCR))
TSTO=WCR**G(11)/UOCR
DENOM=TSTO-(1.+2.*DZETA*TSTO/WCR)+ (2.*DZETA*WCR+TSTO)
SIG=ABS(XNUM/DENOM) **0.5
CON(37)=3.0*SIG
HX(15)=3.0*SIG

ASSUME THAT CRUISE RMS IS 3 FT/SEC

CON(38)=KTDOT1
CON(39)=KT1
WA2=NZOAA.
WA=W/A2**0.5
DM=DERAP(15)+DERAP(3)
DM1=1.-DERAP(12)*DERAP(15)*WA2/DM
DM2=2.*DZETA*WA*DERAP(12)*DERAP(15)-DERAP(15)-DERAP(3)*DERAP(15)
KTDOT2=2.*DZETA*WA*DERAP(12)*G(14)-1.)-DERAP(9)-DERAP(3)*G(14)
$+DERAP(12)*WA2*(1.-DERAP(12)*G(14))/DM
KTDOT2=KTDOT2/(DM1*DM2)
KT2=WA2*(1.-DERAP(12)*G(14))+KTDOT2*WA2*DERAP(12)*DERAP(15)
KT2=KT2/DM
XNUM= ((DERAP(9)/G(14))**2.0) * (KT2*KT2-KTDOT2*KTDOT2*(2.0*WA*DZETA
$+WA2*G(11)/(G(14)))
TSTO=WA2*G(11)/G(14)
DENOM=TSTO-(1.+2.*DZETA*TSTO/WA) * (2.0*DZETA*WA+TSTO)
SIGA=ABS(XNUM/DENOM) **0.5
CON(40)=7.0*SIGA
GX(13)=7.0*SIGA

ASSUME THAT APPROACH RMS IS 7 FT/SEC

CON(41)=KTDOT2
CON(42)=KT2
TA=HX(10)
TUR=G(11)/UOCR
AO=TUR*TA
A2=TA*(2.*DZETA*WCR+WCR2*TUR)+1.+2.*DZETA*WCR*TUR
A1=TA*(1.+2.*DZETA*WCR*TUR+TUR)
A3=WCR2*(TA+TUR)+2.*DZETA*WCR
A4=WCR
WV1=-A1*A4+A2*A3
\[ XNUM = (1./TA) \times (D\text{ERCR}(9)/UOCR) \times KTDOT1 \times KTDOT1 \times VVL \]
\[ XNUM = XNUM - A3 \times TUR \times (D\text{ERCR}(9)/UOCR) \times 2.0 \times KT1 \times KT1 \]
\[ DEN = AO \times A3 \times A1 \times (A1 \times A4 - A2 \times A3) \]
\[ SIGDOT = (ABS(XNUM/DEN)) \times 0.5 \]
\[ CON(43) = 3.0 \times SIGDOT \]
\[ TUR = GX(11)/GX(14) \]
\[ AO = TUR \times TA \]
\[ A2 = TA \times (2. \times D\text{ETA} \times WA + WA2 \times TUR) + 1. + 2. \times D\text{ETA} \times TUR \times WA \]
\[ A1 = TA \times (1. + 2. \times D\text{ETA} \times WA + TUR \times TUR) \]
\[ A3 = WA2 \times (TA + TUR) + 2. \times D\text{ETA} \times WA \]
\[ A4 = WA2 \]
\[ VVL = -A1 \times A4 + A2 \times A3 \]
\[ XNUM = XNUM - A3 \times TUR \times (D\text{ERAP}(9)/UOCR) \times 2.0 \times KT2 \times KT2 \]
\[ DEN = AO \times A3 \times A3 + A1 \times (A1 \times A4 - A2 \times A3) \]
\[ SIGDOTA = (ABS(XNUM/DEN)) \times 0.5 \]
\[ CON(44) = 7.0 \times SIGDOTA \]

************* OUTPUT SECTION *************

IF (OUTPUT.EQ.0) GO TO 999
WRITE(6, 102)
102 FORMAT(*1/20*AIRCRAFT OPTIMIZATION CONSTRAINTS*//5X
$*DESIGN CONSTRAINTS*/14X*ID*5X*CONSTRAINT*T49*VALUE*
$9X*SL*10X*SU*9X*VIOLATION?)
WRITE(6, 112) (I, CON(I), SL(I), SU(I), XINEQ(I), I=1, 6)
112 FORMAT(10X, I5, * CRUISE THRUST*T45, 4F12.4/10X, I5, * 2ND SEGMENT C
$LIMB*T45, 4F12.4/10X, I5, * MISSED APPROACH CLIMB*T45, 4F12.4/10X, I5
$* LANDING*T45, 4F12.4/10X, I5* TAKE-OFF*T45, 4F12.4/10X, I5
$* LANDING GEAR LIMIT*T45, 4F12.4)
WRITE(6, 116) CON(45), SL(45), SU(45), XINEQ(45)
116 FORMAT(13X*45 PASSENGER VOLUME*T45, 4F12.4)
WRITE(6, 117) CON(48), SL(48), SU(48), XINEQ(48)
117 FORMAT(13X*48 CRUISE ALTITUDE*T45, 4F12.4)
WRITE(6, 118) CON(49), SL(49), SU(49), XINEQ(49)
118 FORMAT(13X*49 CRUISE ALTITUDE(L/D(MAX))*T45, 4F12.4)
WRITE(6, 119) CON(50), SL(50), SU(50), XINEQ(50),
$ CON(51), SL(51), SU(51), XINEQ(51)
119 FORMAT(13X*50 CRUISE WING CL*T45, 4F12.4/
$ 13X*51 APPROACH WING CL*T45, 4F12.4)
WRITE(6, 120) CON(52), SL(52), SU(52), XINEQ(52)
120 FORMAT(13X*52 AR(TAIL)/AR(WING)*T45, 4F12.4)
WRITE(6, 122)
122 FORMAT(*//5X*HANDLING QUALITY CONSTRAINTS*)
WRITE(6, 128) (I, CON(I), SL(I), SU(I), XINEQ(I), I=7, 10)
128 FORMAT(*1/10X, I5* STATIC STAB. (CR)*T45, 4F12.4/10X, I5
$* STATIC STAB. (AP)*
ST45, 4F12.4/10X, I5* MANEUVER MARGIN (CR)*T45, 4F12.4/10X, I5
$* MANEUVER MARGIN (AP)*T45, 4F12.4)
WRITE(6, 132) (I, CON(I), SL(I), SU(I), XINEQ(I), I=11, 15)
132 FORMAT(10X, I5* TAIL LIFT (AP)*T45, 4F12.4/10X, I5* NOSE GEAR UNSTI
$CK*T45, 4F12.4/10X, I5* DYN. STAB. (CR)*T45, 4F12.4/10X, I5
$* DYN. STAB. (AP)*T45, 4F12.4/10X, I5* PHUGOID FREQ (CR)*T45,
$4F12.4)
WRITE(6,136) (I,CON(I),SL(I),SU(I),XINEQ(I),I=16,20)
136 FORMAT(10X,I5 PHUGOID FREQ (AP)*T45,4F12.4/10X,I5
$ PHUGOID DAMPING (CR)*T45,4F12.4/10X,I5 PHUGOID DAMPING (AP)*
$T45,4F12.4/10X,I5 PHUGOID DAMPING (CR)*T45,4F12.4/10X,I5
$ SHORT PER. FREQ. (CR)*T45,4F12.4)
WRITE(6,141) (I,CON(I),SL(I),SU(I),XINEQ(I),I=21,25)
141 FORMAT(10X,I5 SHORT PER. DAMP (CR)*T45,4FI2.4
$ SHORT PER. DAMP (AP)*T45,4FI2.4
$ TIME-TO-DOUBLE (CR)*T45,4FI2.4
$ TIME-TO-DOUBLE (AP)*T45,4FI2.4)
WRITE(6,146) (I,CON(I),SL(I),SU(I),XINEQ(I),I=26,30)
146 FORMAT(10X,I5 TIME-TO-IFF (AP)*T45,4FI2.4
$ FLIGHT PATH STAB. (AP)*T45,4FI2.4
$ VERT. GAIN (CR)*T45,4FI2.4
$ VERT. GAIN (AP)*T45,4FI2.4
$ T(THETA(2)) (CR)*T45,4FI2.4)
WRITE(6,147) (I,CON(I),SL(I),SU(I),XINEQ(I),I=31,40)
147 FORMAT(10X,I5 T(THETA(2)) (AP)*T45,4FI2.4
$ NZA (CR)*T45,4FI2.4
$ NZA (AP)*T45,4FI2.4
$ T(1) (AP)*T45,4FI2.4
$ TIME-TO-HALF (CR)*T45,4FI2.4)
WRITE(6,152) (I,CON(I),SL(I),SU(I),XINEQ(I),I=41,44)
152 FORMAT(10X,I5 THETA-DOT GAIN (AP)*T45,4FI2.4
$ THETA-DOT GAIN (CR)*T45,4FI2.4
$ ELE-DOT VAR. (CR)*T45,4FI2.4
$ ELE-DOT VAR. (AP)*T45,4FI2.4)
WRITE(6,157) (I,CON(I),SL(I),SU(I),XINEQ(I),I=46,47)
157 FORMAT(10X,I5 TRIM ELEVATOR (CR)*T45,4FI2.4
$ TRIM ELEVATOR (AP)*T45,4FI2.4)
WRITE(6,167)
167 FORMAT(1HL/)
999 RETURN
END

SUBROUTINE DIMDER(U,ICR,C)
REAL C(15),A(15),ANS(4)
COMMON /DEVAR/DESIGN(15),ITERM(10),CST(10)
COMMON /DRAG/CDS(6),CDSAP(6)
COMMON /GEOM/UX(20),UX(20),GX(35),PX(15)
COMMON /STAB/DERIVCR(15),DERIVAP(15),STOR(20)
COMMON /WTSVE/WTS(20)

** DIMDER CONVERTS FROM NON-DIMENSIONAL TO DIMENSIONAL STABILITY **
** DERIVATIVES. **

IF(ICR.EQ.0) GO TO 20
DO 15 I=1,15
15 A(I)=DERIVCR(I)
XMU=WTS(7)
CALL AT62(WTS(11),ANS)
DRAC=CDS(5)
XY=WTS(13)
CL=GX(9)
WT=WTS(15)

69
GO TO 30
20 DO 25 I=1,15
25 A(I)=DERIVAP(I)
  XMU=WTS(9)
  CALL AT62(500.,ANS)
  DRAG=CDSAP(5)
  XXY=WTS(14)
  CL=GX(10)
  WT=WTS(1)+GX(27)
30 T1=ANS(1)*DESIGN(1)*U/32.174/WT
  C(1)=T1*(-A(1)-DRAG)/2.0
  C(2)=T1*(CL-A(2))/2.0
  T2=ANS(1)*DESIGN(1)*U/(2.0*XXY)
  C(3)=A(3)*W(10)*T2
  C(4)=T1*(-CL-A(4))
  C(5)=T1*(-DRAG-A(5))
  C(6)=W(10)*A(6)*2.0*T2
  C(7)=-W(10)*A(7)*2.0*T2
  C(8)=0.
  C(9)=W(10)*A(9)*T2/2.0
  C(10)=A(10)/(4.0*XXY)
  C(11)=0.
  C(12)=ANS(1)*DESIGN(1)*W(10)*A(12)/(4.0*XXY)
  C(13)=-T1*A(13)/2.
  C(14)=-T1*A(14)/2.
  C(15)=T2*A(15)
RETURN
END
SUBROUTINE LONGRT(DIM,U,ROOT,PARAM,A,NO,TCONST)
REAL DIM(15),PARAM(4),A(5),CM(2),ZET(2)
REAL TCONST(4)
COMPLEX ROOT(4),CM(4)

LONGRT FINDS ROOTS OF FOURTH ORDER DYNAMICS MODEL *

A(1)=1.
A(2)=-DIM(9)-U*DIM(12)-DIM(1)-DIM(5)
A(3)=DIM(1)*DIM(9)-DIM(3)*U-DIM(2)*DIM(4)*DIM(5)*DIM(9)+U*DIM(12)$+DIM(1))
A(4)=-DIM(5)*DIM(1)*DIM(9)-U*DIM(3))+DIM(4)*(DIM(2)*DIM(9)
$+32.174*DIM(12))-DIM(6)*U*DIM(2)-32.174)
A(5)=32.174*(DIM(4)*DIM(3)-DIM(6)*DIM(1))
IDEGRE=4
CALL RPOLY(IDEGRE,A,ROOT,IERR)
IF(IERR.LT.0) WRITE(6,22) IDEGRE
22 FORMAT(*14//'*ROOT SOLVER BROKE DOWN—ONLY*15* TERMS FOUND*//)
CM(1)=0.
CM(2)=0.
ZET(1)=1.
ZET(2)=1.
DO 25 I=1,4
TCONST(I)=0.
PARAM(I)=0.
ASSUME THE ROOTS ARE GIVEN IN PAIRS

DO 35 IROOT=-1:4
  D=AIMAG(ROOT(IROOT))
  IF(D.EQ.0.0) GO TO 30
  ICOM=ICOM+1
  COM(ICOM)=ROOT(IROOT)
  GO TO 35
30 ICON=ICON+1
  TCONST(ICON)=ROOT(IROOT)
35 CONTINUE
  JCOM=0
  IF(ICOM.LT.1) GO TO 200
  DO 40 I=1,ICOM,2
    D=AIMAG(COM(I))
    E=COM(I)
    JCOM=JCOM+1
    COM(JCOM)=(D*E)**0.5
    ZET(JCOM)=-E/OM(JCOM)
  40 CONTINUE
200 NO=ICON

*************************************************************************
* PHUGOID(1,2); SHORT PERIOD(3,4) *
*************************************************************************

IF(OM(1).GT.OM(2)) GO TO 250
210 PARAM(3)=OM(2)
  PARAM(4)=ZET(2)
  PARAM(1)=OM(1)
  PARAM(2)=ZET(1)
  GO TO 275
250 IF(OM(1).LT.0.8) GO TO 210
  PARAM(3)=OM(1)
  PARAM(4)=ZET(1)
  PARAM(1)=OM(2)
  PARAM(2)=ZET(2)
275 IF(NO.LT.1) GO TO 999
  SMALL=100.
  SMALL2=100.
  DO 300 I=1,NO
    IF(TCONST(I).LT.SMALL) SMALL=CONST(I)
300 CONTINUE
  DO 310 I=1,NO
    IF(TCONST(I).LT.SMALL2.AND.TCONST(I).NE.SMALL)
      SMALL2=CONST(I)
310 CONTINUE
  R12=ABS(SMALL*SMALL2)
  ZT=-(SMALL*SMALL2)/(2.0*R12**0.5)
  IF(R12.EQ.0.0) ZT=0.
  IF(PARAM(3).EQ.0.) PARAM(3)=R12**0.5
IF (PARAM(4) .EQ. 1.0) PARAM(4) = ZT
999 RETURN
END
APPENDIX II - SAMPLE INPUT DECK

MIL 8785B LEVEL III (SIMPACT) (Title)

(Number of design variables, Number of constraints)

7 52

(-.2170 .3383 -.1576 -.1123 -.3620 .0358 .1895) (Initial XBAR)

(Number of design variables, lower bound, upper bound)

1 1000. 4000.
2 3. 15.
3 120. 260.
4 100. 1600.
5 2. 15.
6 10000. 120000.
7 -.5 1.

(Constraint number, lower bound, upper bound)

1 1. 2.
2 1. 5.
3 1. 5.
4 1000. 8000.
5 2000. 10000.
6 0. 1.0
7 -999. 999.
8 -1.0 -0.10
9 -999. 999.
10 -999. 999.
11 -.8 .8
12 1. 3.00
13 -999. 999.
14 -999. 999.
15 -999. 999.
16 -999. 999.
17 -999. 999.
18 -999.0 999.0
19 -999. 999.
20 -999. 999.
21 -999.0 999.0
22 -999.0 999.0
23 -999. 999.
24 -999. 999.
25 -999. 999.
26 -999. 999.
27 -.3 .24
28 -999. 999.
29 -999. 999.
30 -999. 999.
31 -999. 999.
32 -999.0 999.0
33 -999.0 999.0
34 -999. 999.
35 -999. 999.
36 -999. 999.
37 -999. 999.
38 -999. 999.
39 -999. 999.
40 -999. 999.
41 -999. 999.
42 -999. 999.
43 -999. 999.
44 -999. 999.
45 1. 2.5
46 -1.1.
47 -1.1.
48 30000. 46000.
49 30000. 52000.
50 .1 .75
51 1. 2.7
52 0.1.

2

1. 1.0E-6 1.0E10 .2 0

190000.

0. 0. 0. 0. 0. 0. 0. 0.
1 0 7 2 1 1979 0 0 0 0

.75 .65

21.2 2.0 .38 .14 .5.

.98 .850 0.3 -.15 -1.

-.15 -.25 -.12 .025

.4 .1 .46 .2

.08 .36 1.8 35. .3

.8 3000. 16.667 22.58 8.33

2.2 1443.38 3.15 -5.25 -12.725

200. 8370. 41100. 7500.

4.0 .55 .09 3200. .70

30. 0. -99.

(Number of calls to NELMIN)

(SCF, REQMIN, CAYY, STEP, INLINE)

(WTS(1))

(PX(1-- 8))

(ITERM(1-- 10))

(WTS(16), CG(5))

(W(1-- 5))

(W(6-- 8, 14, 16))

(W(17-- 20))

(HX(1-- 3, 10))

(HX(16-- 20))

(GX(3-- 7))

(GX(8, 11, 12, 17, 18))

(GX(19-- 22))

(GX(23-- 27))

(GX(32, 34, 16))
### APPENDIX III - SAMPLE OUTPUT CORRESPONDING TO SAMPLE INPUT

**RUN NO:- MIL 07850 LEVEL III (SIMPACT)**

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**NUMBER OF REQUESTED HELMINS**: 2
### Function Input

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<td>INITAIL STEPS</td>
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<td>REMIN,SCF,CAYY</td>
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### NELMIN Complete

| XMIN=  | -1.1324977  | 1.6366605  | -1.1769764  | 0.0231573  | -1.4870473 |
| YNEWLD=| 20364349    | 16912692   |             |             |             |
| ICOUNT=| 817         | 817        |             |             |             |
| TOT FUNCTION CALLS=| 825         |             |             |             |             |

| TOT WEIGHT ITERATIONS | 2973.00 |
| AVE. WTITERATIONS PER | 3.604  |
| INITAIL XBAR | -0.1813 | 0.1860 | -0.1577 | 0.0523 | -0.4877 |
| INITAIL STEPS | 100000 | 10000 | 10000 | 10000 | 10000 |
| REOMIN,SCF,CAYY | 10000E-07 | 10000E+01 | 10000E+13 |

### NELMIN Complete

| XMIN=  | -1.12147188 | 1.68652137 | -1.17771096 | 0.03229337 | -1.48798586 |
| YNEWLD=| 20313423    | 16913646   |             |             |             |
| ICOUNT=| 484         | 484        |             |             |             |
| TOT FUNCTION CALLS=| 1317         |             |             |             |             |

| TOT WEIGHT ITERATIONS | 4421.00 |
| AVE. WTITERATIONS PER | 3.637  |
### Aircraft Sizing Program

**Design Variables**

- Wing Area (FT²): 2146.4400
- Wing Aspect Ratio: 10.7338
- Fuselage Length (Ft): 172.8536
- Horn Tail Area (FT²): 911.4927
- Horn Tail Aspect Ratio: 3.4714
- Total Thrust (LBS): 8229.2021
- AF Post CG: 14469
- Cruise Mach No: 1
- Swept: 1
- Wing T/C: 1
- Wing Taper Ratio: 1
- Fuse DIA: 1

**Input Constants**

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**Some Geometry Calculations**

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***Weight Estimation***

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**Empty Weight**

196200.2

**Passengers**

3400.0

**Crew**

1700.0

**Baggage**

7000.0

**Wing**

2147.3

**Cargo**

7500.0

**Fixed Weight**

50414.8

**Fuel**

74813.1

**Take-Off Weight**

281429.7

**No. of Iterations Required**

1

**WHT1(1,2,3), WHTFUSE(1,2), VWTINIT**

6835.43  7829.81  6419.39  57851.38  36892.78  281429.74

77
### CRUISE ANALYSIS

#### TOTAL MISSION RANGE = 3000.00
#### CLIMB DISTANCE = 180.00
#### DESCENT DISTANCE = 113.00

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<th>CL</th>
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<th>TIME</th>
<th>L/D</th>
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<th>ALT(EG)</th>
<th>ALT(END)</th>
<th>WT(EG)</th>
<th>WT(END)</th>
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### FUEL WEIGHT ANALYSIS

| TAKE-OFF | 261425.74 |
| START-CRUISE | 263432.31 |
| MID-CRUISE | 244203.84 |
| END-CRUISE | 225844.37 |
| AFTER RESERVE | 213004.63 |
| AFTER DESCENT/TAXI | 206814.68 |

**NET FUEL WEIGHT (LBS)**

74015.05

### CRUISE ALTITUDES

| LEG 1 | 3000.00 |
| LEG 2 | 43026.59 |
| RESERVE LEG | 30000.00 |

---

| FLIGHT LENGTH (HR) | 6.67 |
| AVERAGE SPEED (KTS) | 449.82 |
| BLOCK TIME (HR) | 7.60 |
| BLOCK SPEED (KTS) | 428.80 |
| CLOCK FUEL (LBS) | 44359.42 |
| CLOCK FUEL (GALS) | 6931.00 |
| NAUT. M3/GAL | 43 |
| NAUT. SEAT M3/GAL | 86.57 |
| INSTALLED THRUST (LBS) | 82253.26 |
| NO. OF ENGINES | 2 |
| ENGINE THRUST (LRS) | 31126.63 |
| REFERENCE ENGINE (LBS) | 42000.00 |
| SCALE FACTOR | 1.001 |

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78
***DRAG ANALYSIS***

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INTERFERENCE FACTOR IS 5 PERCENT

***REYNOLD'S NUMBERS***

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STABILITY AND CONTROL DERIVATIVES

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| NEUTRAL POINT      | 0.340|
| STATIC STABILITY   | 0.226|
| CM(ALPHA)          | -1.511|

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79
ACCURATE L/D ANALYSIS

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INDUCED DRAG COMPONENTS

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DRAG COEFFICIENTS

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L/D = 18.477

MAX. L/D = 19.446

MODIFIED CDD = 0.0193

AIRCRAFT COST ESTIMATES

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TOTAL COST PER AIRCRAFT = 16535361.72
### MAINTENANCE OPERATING COSTS

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#### MAINTENANCE DOLLAR IN 1976 DOLLARS PER HOUR

#### DIRECT OPERATING COSTS--DOLLARS/FLT. HOUR

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<td>MAINTENANCE</td>
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#### TOTAL DIRECT OPERATING COSTS

$2005.07 100.00

#### INDIRECT OPERATING COSTS--DOLLARS/FLT. HOUR

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#### TOTAL INDIRECT OPERATING COSTS

$908.28 100.00
PERFORMANCE FUNCTION SUMMARY

REVENUE PER BLOCK HOUR  4243.12
TOTAL COST PER BLOCK HOUR  2913.34
RETURN ON INVESTMENT  1229

1  DOC/HQ  2003.063
2  DOC/FLT  14027.968
3  ROI  123
4  FARE  0.006
5  SEAT-MI/EA  86.568
6  LYD(MAX)  10.466
7  MTOW  281429.737
8  FARE  31749.000
9  PRICE  4536.000

DEBUG OF NOSE GEAR UNSTICK

ZACT,XMUZ,IALGZ=  12650  30250  5301
AHS(1,2,3,4)=  602377  02116  233417  2894150000  1116449001
VSTALL,CLW,Q,XYA=  2239352  3642  482730  452795297  -4494054408
CT,UNTHRU,XCC,XTRO,CLZ,COIY,XTL=  715390  822532621  01810  267736962  13773  -123103  777760
XLTVW,CON(12),STOR(7),STOR(8),V(12)=  -0524224919  29739  30719  2915  20000
GX(171,8X(6),W(10),XLTVZ,TLGE,CLTVZ=  -52500  21893  19926  -796221595  15620.3564  -180046
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<td>CRUD/FLAPS</td>
<td>0.029</td>
</tr>
<tr>
<td><strong>Aircraft Drag</strong></td>
<td>0.0376</td>
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</table>

Interference factor is 5 percent.

### Reynolds Numbers

<table>
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<tr>
<th>Component</th>
<th>CD</th>
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</thead>
<tbody>
<tr>
<td>Wing</td>
<td>6.183040*10^-6</td>
</tr>
<tr>
<td>Horizontal Tail</td>
<td>6.0315340*10^-6</td>
</tr>
<tr>
<td>Vertical Tail</td>
<td>6.0300350*10^-6</td>
</tr>
<tr>
<td>FUSELAGE</td>
<td>7.8000060*10^-3</td>
</tr>
<tr>
<td>ENGINE</td>
<td>9.0000002*10^-3</td>
</tr>
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</table>

### Approach

**Stability and Control Derivatives**

### Approach

<table>
<thead>
<tr>
<th>( \text{CL, MC, position} )</th>
<th>1.713</th>
<th>1.102</th>
<th>1.447</th>
</tr>
</thead>
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<tr>
<td><strong>CL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CM</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NEUTRAL POINT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>STATIC STABILITY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CM(ALPHA)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>STOR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From the table above, we can see that the values vary significantly for different conditions. For instance, the CL (lift coefficient) changes from 1.713 to 1.102 to 1.447, indicating changes in the aerodynamic performance under different conditions. The CD (drag coefficient) also shows variability, which is critical for understanding the aerodynamic drag and optimizing performance.

The CM (moment coefficient) further illustrates the momentary behavior of the aircraft under these conditions. The neutral point, static stability, and CM(ALPHA) are crucial for understanding the aircraft's stability characteristics, with values indicating the aircraft's response to control inputs.

The STOR values provide insight into the longitudinal stability, with changes in values indicating the aircraft's sensitivity to changes in control inputs. The table is comprehensive, showing a range of values for different conditions, which is essential for flight dynamics and control system design.

Overall, the data is detailed and comprehensive, offering a rich understanding of the aircraft's aerodynamic and stability characteristics under various conditions.
ACCUPATE L/D ANALYSIS

APPROACH WITH 45 DEGREES FLAP

CL(REQUESTED)* 1.713
CL(WING) = 1.761
CL(TAIL) = -0.114
ELEVATION(DEGREES)* 0.000
STABILIZER(DEGREES) -1.355

INDUCED DRAG COMPONENTS

WING* 1.303
INTERFERENCE* -0.048
TAIL = 0.003
(TAIL) = 0.0020
(TAIL) = 0.0050
SIGMA = 0.3715

DRAG COEFFICIENTS

INDUCED* 1.260
ZERO LIFT* 0.0625
ELEVATOR* 0.0000
WING(MACH), MCRIT)* 0.0000 0.0000
FUSE(MACH), MCRIT)* 0.0000 0.0000
TOTAL* 0.3001

L/D = 9.057

MAX.* L/D = 9.574
CL-L/D MAX* 1.358
MODIFIED COD* 0.0053

/\DIMENSIONAL STABILITY DERIVATIVES/\/

DFRCK =
-1.4613  0.0221  -0.0004
-0.1126  -0.0046  -0.0000
-0.0197  0.0000  -0.3444
 0.0030  0.0000  -0.0002
-36.3072  -0.0446  -1.5935

DERAP =
-1.5728  0.3281  -0.0004
-1.3999  -0.0430  -0.0060
-0.0208  0.0000  -0.3632
 0.0108  0.0000  -0.0004
-16.7913  -0.0263  -5.9844

84
### LONGITUDINAL DYNAMICS

<table>
<thead>
<tr>
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<th>APPROACH</th>
</tr>
</thead>
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</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>-0.008</td>
<td>0.0544</td>
</tr>
<tr>
<td>-0.008</td>
<td>0.0544</td>
</tr>
<tr>
<td>-0.4634</td>
<td>0.4779</td>
</tr>
<tr>
<td><strong>PHUGOID FREQUENCY</strong></td>
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</tr>
<tr>
<td><strong>PHUGOID DAMPING</strong></td>
<td>0.0145</td>
</tr>
<tr>
<td><strong>SHORT PER. FREQ.</strong></td>
<td>0.6856</td>
</tr>
<tr>
<td><strong>SHORT PER. DAMPING</strong></td>
<td>0.6961</td>
</tr>
<tr>
<td><strong>NO. OF NON-OFFICIAL ROOTS</strong></td>
<td>0</td>
</tr>
<tr>
<td><strong>TIME CONSTANTS</strong></td>
<td>0.0000</td>
</tr>
</tbody>
</table>

### APPROACH

| **COEFFICIENTS** | 1.000000 |
| **ROOTS (REAL, IMAGINARY)** | 0.0321 | 0.1277 |
| | -0.0321 | -0.1277 |
| | -0.4807 | -0.2134 |
| **PHUGOID FREQUENCY** | 0.1317 |
| **PHUGOID DAMPING** | 0.2439 |
| **SHORT PER. FREQ.** | 0.5332 |
| **SHORT PER. DAMPING** | 0.9164 |
| **NO. OF NON-OFFICIAL ROOTS** | 0 |
| **TIME CONSTANTS** | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| **CL-MAX TOW (W), CL-MAX TO (AC), CLZ** | 2.200 | 1.976 | 1.372 |
| **CL-MAX (W), CL-MAX (AC), CLA** | 3.150 | 2.095 | 1.713 |
### Aircraft Optimization Constraints

#### Design Constraints

<table>
<thead>
<tr>
<th>ID</th>
<th>Constraint</th>
<th>Value</th>
<th>SL</th>
<th>SU</th>
<th>Violation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cruise Thrust</td>
<td>1.1009</td>
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<tr>
<td>2</td>
<td>2nd Segment Climb</td>
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<td>3</td>
<td>Missed Approach Climb</td>
<td>1.3067</td>
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<td>4</td>
<td>Landing</td>
<td>79929.9572</td>
<td>1000.0000</td>
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<td>5</td>
<td>Take-Off</td>
<td>8104.5719</td>
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<td>46</td>
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<td>40000.0000</td>
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<td>30000.0000</td>
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#### Handling Quality Constraints

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<thead>
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<th>ID</th>
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<th>SL</th>
<th>SU</th>
<th>Violation</th>
</tr>
</thead>
<tbody>
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<td>7</td>
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<td>8</td>
<td>Static Stab. (AP)</td>
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<td>9</td>
<td>Maneuver Margin (CR)</td>
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<td>2.00000000</td>
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<td>75429.480</td>
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<td>14027.900</td>
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<td>XMIN</td>
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<td>-0.20534929</td>
<td>-0.15771279</td>
<td>-0.05279527</td>
</tr>
</tbody>
</table>

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APPENDIX IV - Procedure File used to Execute OPDOT on the Langley Research Center Computer System

OPDOT,T7770,CM70000.
USER(820235N)
CHARGE,101264,LRC.
GET,OPDOT1.
GET,INPUT=SM10.
FTN(I=OPDOT1,OPT=2,R=0)
ATTACH(FTNMLIB/UN=LIBRARY,NA)
LDSET(PRESET=ZERO,LIB=FTNMLIB)
LGO.
REWIND(TAPE4)
REWIND(LGO)
GET,PPB.
PPB.
REWIND(TAPE7)
ATTACH(LROGOSF/UN=LIBRARY)
GET,ABS2290/UN=I81500N.
ABS2290,TAPE7.
PLOT.CALPOST,11
CONT.//BLANK PAPER, LEROY .3 PEN,
CONT. BLACK INK, MULTIPLE PLOT MODE//
EXIT.

RM 1174 ARBUCKLE/SLIWA

(SM10 is static margin 10% case -- APPENDIX II)

(All variables set to zero since program is already operational)

(PPB is the binary code for the OPDOT plotting preprocessor)

(Reference 28)
### APPENDIX V - KEY PROGRAM VARIABLES

<table>
<thead>
<tr>
<th>SUBROUTINE</th>
<th>VARIABLE</th>
<th>DESCRIPTION [UNITS, IF APPLICABLE]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIMPACT (Main Program)</td>
<td>AMP</td>
<td>Amplitude of sinusoid transformation Z to X domain</td>
</tr>
<tr>
<td></td>
<td>AVE</td>
<td>Ave. of sinusoid transformation Z to X domain</td>
</tr>
<tr>
<td></td>
<td>CAYY</td>
<td>Penalizing weight for constraint violation</td>
</tr>
<tr>
<td></td>
<td>FACT</td>
<td>= 1 if constraint is to be considered, = 0 otherwise</td>
</tr>
<tr>
<td></td>
<td>GNORM</td>
<td>Constraint normalization—ave. of boundaries</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>Number of constraint violations</td>
</tr>
<tr>
<td></td>
<td>MINEQ</td>
<td>Number of constraint functions</td>
</tr>
<tr>
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APPENDIX V - cont.

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APPENDIX V - cont.

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### APPENDIX V - cont.

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<td>UNTHRU</td>
<td>Unbalanced thrust component during take-off roll</td>
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### APPENDIX VI - MAP OF COMMON BLOCKS USED WITHIN DESIGN SECTION OF PROGRAM

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<td>Direct operating cost per flight [$/flight]</td>
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### APPENDIX VI - cont.

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<td></td>
<td></td>
<td>12</td>
<td>$C_{M_{\dot{\alpha}}}$</td>
</tr>
</tbody>
</table>
### APPENDIX VI - cont.

<table>
<thead>
<tr>
<th>COMMON BLOCK</th>
<th>ARRAY</th>
<th>NO.</th>
<th>DESCRIPTION [UNITS, IF APPLICABLE]</th>
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<tbody>
<tr>
<td></td>
<td>DERIVCR</td>
<td>1</td>
<td>Cruise $C_{L\alpha}$</td>
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<tr>
<td></td>
<td>DERIVCR</td>
<td>2</td>
<td>Cruise $C_{D\alpha}$</td>
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<td>Cruise $C_{L\alpha}$</td>
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<td>Cruise $C_{D\alpha}$</td>
</tr>
<tr>
<td></td>
<td>DERIVCR</td>
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<td>Cruise $C_{M\alpha}$</td>
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<tr>
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<td>DERIVCR</td>
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<td>Cruise $C_{L\alpha}$</td>
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<td>DERIVCR</td>
<td>8</td>
<td>Cruise $C_{D\alpha}$</td>
</tr>
<tr>
<td></td>
<td>DERIVCR</td>
<td>9</td>
<td>Cruise $C_{M\alpha}$</td>
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<td>DERIVCR</td>
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<td>Cruise $C_{L\alpha}$</td>
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<tr>
<td></td>
<td>DERIVCR</td>
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<td>Cruise $C_{D\alpha}$</td>
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<td></td>
<td>DERIVCR</td>
<td>12</td>
<td>Cruise $C_{M\alpha}$</td>
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<td>DERIVCR</td>
<td>13</td>
<td>Cruise $C_{L\alpha}$</td>
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<td>DERIVCR</td>
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<td>Cruise $C_{D\alpha}$</td>
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<td></td>
<td>DERIVCR</td>
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<tr>
<td></td>
<td>STOR</td>
<td>1</td>
<td>Cruise $C_{L\alpha}$ wing</td>
</tr>
<tr>
<td></td>
<td>STOR</td>
<td>2</td>
<td>Cruise $C_{L\alpha}$ horizontal tail</td>
</tr>
<tr>
<td></td>
<td>STOR</td>
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<td>Stick fixed neutral point [% MAC]</td>
</tr>
<tr>
<td></td>
<td>STOR</td>
<td>4</td>
<td>Stick fixed maneuver point [% MAC]</td>
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</table>
## APPENDIX VI - cont.

<table>
<thead>
<tr>
<th>COMMON BLOCK</th>
<th>ARRAY</th>
<th>NO.</th>
<th>DESCRIPTION [UNITS, IF APPLICABLE]</th>
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<tbody>
<tr>
<td>WTSVE</td>
<td>WTS</td>
<td>6</td>
<td>Approach $C_L \alpha$ wing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>$C_L \alpha$ horizontal tail</td>
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<tr>
<td></td>
<td></td>
<td>8</td>
<td>$\frac{\partial C}{\partial \alpha}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>Stick fixed neutral point [% MAC]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>Stick fixed maneuver point [% MAC]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11</td>
<td>$C_{\text{mac}}$ fuselage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td>$C_{\text{mac}}$ engine</td>
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### WTS

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESCRIPTION [UNITS, IF APPLICABLE]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maximum gross weight at take-off [lbs]</td>
</tr>
<tr>
<td>2</td>
<td>Empty weight [lbs]</td>
</tr>
<tr>
<td>3</td>
<td>Fuel flow rate [lbs/block hour]</td>
</tr>
<tr>
<td>4</td>
<td>Manufacturers airframe weight [lbs]</td>
</tr>
<tr>
<td>5</td>
<td>Landing weight after mission [lbs]</td>
</tr>
<tr>
<td>6</td>
<td>Fuel weight including reserves [lbs] m</td>
</tr>
<tr>
<td>7</td>
<td>Aircraft specific density (cruise), $\frac{m}{S\alpha}$</td>
</tr>
<tr>
<td>8</td>
<td>Radius of gyration squared (cruise), Iy/m [ft]</td>
</tr>
<tr>
<td>9</td>
<td>Aircraft specific density (approach), $\frac{m}{S\alpha}$</td>
</tr>
<tr>
<td>10</td>
<td>Radius of gyration squares (approach), Iy/m [ft]</td>
</tr>
<tr>
<td>11</td>
<td>Altitude at mid cruise [ft]</td>
</tr>
<tr>
<td>12</td>
<td>$L/D_{\text{max}}$ at cruise altitude</td>
</tr>
<tr>
<td>13</td>
<td>Pitch moment of inertia (cruise), [slug-ft]</td>
</tr>
<tr>
<td>14</td>
<td>Pitch moment of inertia (approach), [slug-ft]</td>
</tr>
<tr>
<td>15</td>
<td>Weight at mid cruise [lbs]</td>
</tr>
<tr>
<td>16</td>
<td>Fuel cost [$/gal]</td>
</tr>
<tr>
<td>17</td>
<td>Cruise velocity [knots]</td>
</tr>
<tr>
<td>18</td>
<td>Flight time for mission [hrs]</td>
</tr>
<tr>
<td>19</td>
<td>Block time [hrs]</td>
</tr>
<tr>
<td>20</td>
<td>Weight of fuel to fly economic mission [lbs]</td>
</tr>
</tbody>
</table>
### APPENDIX VII - ASSUMPTIONS USED IN CALCULATING TRANSPORT DESIGN FACTORS

#### MISSION:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Cruise Mach Number</td>
<td>.80</td>
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<tr>
<td>Divergence Mach Number</td>
<td>.84</td>
</tr>
<tr>
<td>Design Range</td>
<td>6500 km</td>
</tr>
<tr>
<td>Number of Seats</td>
<td>200</td>
</tr>
<tr>
<td>Cargo</td>
<td>33400 N</td>
</tr>
<tr>
<td>Maximum Lift Coefficient</td>
<td>3.15</td>
</tr>
<tr>
<td>Landing Field Requirement</td>
<td>2440 m</td>
</tr>
<tr>
<td>Take-Off Field Requirement</td>
<td>3050 m</td>
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</tbody>
</table>

#### GEOMETRY:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Wing Sweep Angle</td>
<td>26.4 deg</td>
</tr>
<tr>
<td>Wing Thickness Ratio</td>
<td>.12</td>
</tr>
<tr>
<td>Wing Taper Ratio</td>
<td>.38</td>
</tr>
<tr>
<td>Wing Incidence Angle</td>
<td>2 deg</td>
</tr>
<tr>
<td>Wing Geometric Twist</td>
<td>5 deg</td>
</tr>
<tr>
<td>Tail Thickness Ratio</td>
<td>.10</td>
</tr>
<tr>
<td>Tail Sweep Angle</td>
<td>30 deg</td>
</tr>
<tr>
<td>Tail Taper Ratio</td>
<td>.4</td>
</tr>
<tr>
<td>Vertical Tail Sweep</td>
<td>35 deg</td>
</tr>
<tr>
<td>Ratio of Rudder Area to Vertical Tail Area</td>
<td>.30</td>
</tr>
<tr>
<td>Ratio of Elevator Chord to Horizontal Tail Chord</td>
<td>.25</td>
</tr>
<tr>
<td>Ratio of Flap Span to Wing Span</td>
<td>.6</td>
</tr>
<tr>
<td>Maximum Flap Deflection</td>
<td>45 deg</td>
</tr>
<tr>
<td>Fuselage Diameter</td>
<td>5.08 m</td>
</tr>
<tr>
<td>Height of Aerodynamic Center Above c.g.</td>
<td>.08 MAC</td>
</tr>
<tr>
<td>Height of Thrust Vector Above c.g.</td>
<td>-.12 MAC</td>
</tr>
<tr>
<td>Height of Horizontal Tail Above c.g.</td>
<td>0</td>
</tr>
<tr>
<td>Number of Engines</td>
<td>2</td>
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#### ECONOMICS:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Cost</td>
<td>20¢/liter</td>
</tr>
<tr>
<td>Load Factor</td>
<td>.55</td>
</tr>
<tr>
<td>Fare</td>
<td>9¢/seat-naut. mi</td>
</tr>
<tr>
<td>Utilization Rate</td>
<td>3200 hr/yr</td>
</tr>
<tr>
<td>Depreciation Period</td>
<td>14 yr</td>
</tr>
<tr>
<td>Residual Value</td>
<td>12 percent</td>
</tr>
<tr>
<td>Tax Rate</td>
<td>.48</td>
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<tr>
<td>Year of Study</td>
<td>1979</td>
</tr>
<tr>
<td>Assumed Annual Inflation Rate</td>
<td>.07</td>
</tr>
<tr>
<td>Number of Prototype Aircraft</td>
<td>2</td>
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</tbody>
</table>
### APPENDIX VII - cont.

<table>
<thead>
<tr>
<th>Aircraft Fleet Size</th>
<th>250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Production Rate</td>
<td>.5/month</td>
</tr>
<tr>
<td>Full Production Rate</td>
<td>5/month</td>
</tr>
<tr>
<td>Engineering Rate</td>
<td>19.55 '74 $/hr</td>
</tr>
<tr>
<td>Tooling Rate</td>
<td>14.00 '74 $/hr</td>
</tr>
<tr>
<td>Labor Rate</td>
<td>10.90 '74 $/hr</td>
</tr>
<tr>
<td>Engines for Test Aircraft</td>
<td>3</td>
</tr>
<tr>
<td>Ratio of Manufacturer's Airframe Weight to Take-Off Wt.</td>
<td>.75</td>
</tr>
</tbody>
</table>

**MISCELLANEOUS:**

| Maximum Dynamic Pressure | 5.13 N/m² |
| Pressurized Volume | 178.2 m³ |
| Number of Pilots | 3 |
| Number of Attendants | 8 |
| Air Conditioning Flow Rate | 200 kg/min |
| Autopilot Channels (w/MUX) | 5 |
| General Capacity | 750 kilovolt-amperes |
| Maintenance Complexity Factor | 1.6 |
| Hydraulics Volume Flow Rate | 300 liters/min |
| Number of Inertial Platform Systems | 1 |
| Ratio of APU-on Time to Engine on Time | .1 |
| Curved Windshield | .15 |
| Ratio of First Class to Economy Seating | 483 knots |
| Maximum Speed | .5 |
| Supercritical Airfoil Technology | CF-6 |
| Airfoil Design Lift Coefficient | .1 sec |
| Some Nonlinear Aerodynamics Terms | Baseline Engine |
| Elevator Servo Time Constant |
Figure 1.- Generalized flow diagram for OPDOT.
Figure 2.— Schematic showing primary calling sequence of subroutines used to evaluate the performance index and constraint functions.
Figure 3.- Mission profile used in OPDOT.
Figure 4. - Aircraft "picture" as drawn by the method of reference 28. Aircraft pictured was optimized from data in Appendix II.
Figure 4.— Concluded.
A description of a computer program, OPDOT, for the optimal preliminary design of transport aircraft is given. OPDOT utilizes constrained parameter optimization to minimize a performance index (e.g. direct operating cost per block hour) while satisfying operating constraints. The approach in OPDOT uses geometric descriptors as independent design variables. The independent design variables are systematically iterated to find the optimum design. The technical development of the program is provided and a program listing with sample input and output are utilized to illustrate its use in preliminary design. This is not meant to be a user's guide, but rather a description of a useful design tool developed for studying the application of new technologies to transport airplanes.