

From AFFDL-TR-79-3032
THE USAF STABILITY AND CONTROL DIGITAL DATCOM
Volume I, Users Manual

SECTION 1

INTRODUCTION

In preliminary design operations, rapid and economical estimations of aerodynamic stability and control characteristics are frequently required. The extensive application of complex automated estimation procedures is often prohibitive in terms of time and computer cost in such an environment. Similar inefficiencies accompany hand-calculation procedures, which can require expenditures of significant man-hours, particularly if configuration trade studies are involved, or if estimates are desired over a range of flight conditions. The fundamental purpose of the USAF Stability and Control Datcom is to provide a systematic summary of methods for estimating stability and control characteristics in preliminary design applications. Consistent with this philosophy, the development of the Digital Datcom computer program is an approach to provide rapid and economical estimation of aerodynamic stability and control characteristics.

Digital Datcom calculates static stability, high-lift and control device, and dynamic-derivative characteristics using the methods contained in Sections 4 through 7 of Datcom. The computer program also offers a trim option that computes control deflections and aerodynamic data for vehicle trim at subsonic Mach numbers.

The program has been developed on a modular basis as illustrated in Figure 1. These modules correspond to the primary building blocks referenced in the program executive. The modular approach was used because it simplified program development, testing, and modification or expansion.

This report is the User's Manual for the USAF Stability and Control Digital Datcom. Potential users are directed to Section 2 for an overview of program capabilities. Section 3 provides input definitions, with basic configuration geometry modeling techniques presented in Section 4. Analyses of special configurations are treated in Section 5. Section 6 discusses the available output data. The appendices discuss namelist coding rules, airfoil section characteristic estimation methods with supplemental data, and a list of geometric and aerodynamic variables available as supplemental output. A self-contained user's kit is included to aid the user in setting up inputs to the program.

Even though the development of Digital Datcom was pursued with the sole

objective of translating the Datcom methods into an efficient, user-oriented computer program, differences between Datcom and Digital Datcom do exist. Such is the primary subject of Volume II, Implementation of Datcom Methods, which contains the correspondence between Datcom methods and program formulation. This volume also defines the program implementation requirements. The listing of the computer program is contained on microfiche as a supplement to this report. Modifications, extensions, and limitations of Datcom methods as incorporated in Digital Datcom are discussed throughout the report. Volume III discusses a separate plot module for Digital Datcom..

Users should refer to Datcom for the limitations of methods involved. However, potential users are forewarned that Datcom drag methods are not recommended for performance. Where more than one Datcom method exists, Volume II indicates which method or methods are employed in Digital Datcom.

The computer program is written in the Fortran IV language for the CDC CYBER 175. Through the use of overlay and data packing techniques, the core requirement is 67,000 octal words for execution on the CYBER 175 with the NOS operating system using the FTN compiler. Central processor time for a case executed on the NOS system depends on the type of configuration, number of flight conditions, and program options selected. Usual requirements are on the order of one to two seconds per Mach number.

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SECTION 2

PROGRAM CAPABILITIES

This section has been prepared to assist the potential user in his decision process concerning the applicability of the USAF Stability and Control Digital Datcom to his particular requirements. For specific questions dealing with method validity and limitations, the user is strongly encouraged to refer to the USAF Stability and Control Datcom document. Much of the flexibility inherent in the Datcom methods has been retained by allowing the user to substitute experimental or refined analytical data at intermediate computation levels. Extrapolations beyond the normal range of the Datcom methods are provided by the program; however, each time an extrapolation is employed, a message is printed which identifies the point at which the extrapolation is made and the results of the extrapolation. Supplemental output is available via the “dump” and “partial output” options which give the user access to key intermediate parameters to aid verification or adjustment of computations. The following paragraphs discuss primary program capabilities as well as selected qualifiers and limitations.

2.1 ADDRESSABLE CONFIGURATIONS

In general, Datcom treats the traditional body-wing-tail geometries including control effectiveness for a variety of high-lift /control devices. High-lift/control output is generally in terms of the incremental effects due to deflection. The user must integrate these incremental effects with the “basic” configuration output. Certain Datcom methods applicable to reentry type vehicles are also available. Therefore, the Digital Datcom addressable geometries include the “basic” traditional aircraft concepts (including canard configurations), and unique geometries which are identified as “special” configurations. Table 1 summarizes the addressable configurations accommodated by the program.

2.2 BASIC CONFIGURATION DATA

The capabilities discussed below apply to basic configurations, i.e., traditional body-wing-tail concepts. A detailed summary of output as a function of configuration and speed regime is presented in Table 2. Note that transonic output can be expanded through the use of data substitution (Sections 3.2 and 4.5). Typical output for these configurations are presented in section 6.

2.2.1 Static Stability Characteristics

The longitudinal and lateral-directional stability characteristics provided by the Datcom and the Digital Datcom are in the stability-axis system. Body-axis normal-force and axial-force coefficients are also included in the output for convenience of

the user. For those speed regimes and configurations where Datcom methods are available, the Digital Datcom output provides the longitudinal coefficients C_D , C_L , C_m , C_N , and C_A , and the derivatives

$$C_{L_\alpha}, C_{m_\alpha}, C_{Y_\beta}, C_{n_\beta}, C_{l_\beta}$$

Output for configurations with a wing and horizontal tail also includes downwash and the local dynamic-pressure ratio in the region of the tail. Subsonic data that include propeller power, jet power, or ground effects are also available. Power and ground effects are limited to the longitudinal aerodynamic characteristics.

Users are cautioned that the Datcom does not rigorously treat aerodynamics in the transonic speed regime, and a fairing between subsonic and supersonic solutions is often the recommended procedure. Digital Datcom uses linear and nonlinear fairings through specific points; however, the user may find another fairing more acceptable. The details of these fairing techniques are discussed in Volume II, Section 4. The partial output option, discussed in Section 3.5, permits the user to obtain the information necessary for transonic fairings. The experimental data input option allows the user to revise the transonic fairings on configuration components, perform parametric analyses on test configurations, and apply better method results (or data) for configuration build-up.

Datcom body aerodynamic characteristics can be obtained at all Mach numbers only for bodies of revolution. Digital Datcom can also provide subsonic longitudinal data for cambered bodies of arbitrary cross section as shown in Figure 6. The cambered body capability is restricted to subsonic longitudinal-stability solutions.

Straight-tapered and nonstraight-tapered wings including effects of sweep, taper, and incidence can be treated by the program. The effect of linear twist can be treated at subsonic Mach numbers. Dihedral influences are included in lateral-directional stability derivatives and wing

wake location used in the calculation of longitudinal data. Airfoil section characteristics or a required input, although most of these characteristics may be generated using the Airfoil Section Module (Appendix B). Users are advised to be mindful of section characteristics which are sensitive to Reynolds number, particularly in cases where very low Reynolds number estimates are of interest. A typical example would be pretest estimates for small, laminar flow wind tunnels where Reynolds numbers on the order of 100,000 are common.

Users should be aware that the Datcom and Digital Datcom employ turbulent skin friction methods in the computation of friction drag values. Estimates for cases involving significant wetted areas in laminar flow will require adjustment by the user.

Computations of wing-body longitudinal characteristics assume, in many cases, that the configuration is of the mid-wing type. Lateral-directional analyses do

account for other wing locations. Users should consult the Datcom for specific details.

Wing-body-tail configurations which may be addressed are shown in Table 2. These capabilities permit the user to analyze complete configurations, including canard and conventional aircraft arrangements. Component aerodynamic contributions and configuration build-up data are available through the use of the “BUILD” option described in Section 3.5. Using this option, the user can isolate component aerodynamic contributions in a similar fashion to break down data from a wind tunnel where such information is of value in obtaining an overall understanding of a specific configuration.

Twin vertical panels can be placed either on the wing or horizontal tail. Analysis can be performed with both twin vertical tail panels and a conventional vertical tail specified though interference effects between the three panels is not computed. The influence of twin vertical tails is included only in the lateral-directional stability characteristics at subsonic speeds.

2.2.2 Dynamic Stability Characteristics

The pitch, acceleration, roll and yaw derivatives of

$$C_{L_q}, C_{m_q}, C_{L_{\dot{\alpha}}}, C_{m_{\dot{\alpha}}}, C_{l_p}, C_{Y_p}, C_{n_p}, C_{n_r}, \text{ and } C_{l_r}$$

are computed for each component and the build-up configurations shown in Table 2. All limitations discussed in Section 7 of the USAF Stability and Control Datcom are applicable to digital Datcom as well. The experimental data option of the program (Section 4.5) permits the user to substitute experimental data for key parameters involved in dynamic derivative solutions, such as body $dC_L/d\alpha$ and wing-body $dC_L/d\alpha$. Any improvement in the accuracy of these key parameters will produce significant improvement in the dynamic stability estimates. Use of experimental data substitution for this purpose is strongly recommended.

2.2.3 High-Lift and Control Characteristics

High-lift devices that can be analyzed by the Datcom methods include jet flaps, split, plain, single-slotted, double-slotted, fowler, and leading edge flaps and slats. Control devices, such as trailing-edge flap-type controls and spoilers, can also be treated. In general terms, the program provides the incremental effects of high lift or control device deflections at zero angle of attack.

The majority of the high-lift-device methods deal with subsonic lift, drag, and pitching-moment effects with flap deflection. General capabilities for jet flaps, symmetrically deflected high-lift devices, or trailing-edge control devices include lift, moment, and maximum-lift increments along with drag-polar increments and hinge-moment derivatives. For translating devices the lift-curve slope is also computed. Asymmetrical deflection of wing control devices can be analyzed for rolling and yawing effectiveness. Rolling effectiveness may be obtained for all-movable differentially-deflected horizontal stabilizers. The speed regimes where

these capabilities exist are shown in Table 3.

Control modes employing all-moving wing or tail surfaces can also be addressed with the program. This is accomplished by executing multiple cases with a variety of panel incidence angles.

2.2.4 Trim Option

Trim data can be calculated at subsonic speeds. Digital Datcom manipulates computed stability and control characteristics to provide trim output (static $C_m = 0.0$). The trim option is available in two modes. One mode treats configurations with a trim control device on the wing or horizontal tail. Output is presented as a function of angle of attack and consists of control deflection angles required to trim and the associated longitudinal aerodynamic characteristics shown in Table 3. The second mode treats conventional wing-body-tail configurations where the horizontal-tail is all-movable or “flying.” In this case, output as a function of angle of attack consists of horizontal-stabilizer deflection (or incidence) angle required to trim; untrimmed stabilizer C_L , C_D , C_m , and hinge-moment coefficients; trimmed stabilizer C_L , C_D , and hinge moment coefficients; and total wing-body-tail C_L and C_D . Body-canard-tail configurations may be trimmed by calculating the stability characteristics at a variety of canard incidence angles and manually calculating the trim data. Treatment of a canard configuration is addressed in Table 1.

2.3 SPECIAL CONFIGURATION DATA

The capabilities discussed below apply to the three special configurations illustrated in Figure 2.

2.3.1 Low-Aspect-Ratio Wings and Wing-Body Combinations

Datcom provides methods which apply to lifting reentry vehicles at subsonic speeds. Digital Datcom output provides longitudinal coefficients C_D , C_L , C_m , C_N , and C_A and the derivatives

$$C_{L_\alpha}, C_{m_\alpha}, C_{Y_\beta}, C_{n_\beta}, C_{l_\beta}$$

2.3.2 Aerodynamic Control at Hypersonic Speeds

The USAF Stability and Control Datcom contains some special control methods for high-speed vehicles. These include hypersonic flap methods which are incorporated into Digital Datcom. The flap methods are restricted to Mach numbers greater than 5, angles of attack between zero and 20 degrees and deflections into the wind. A two-dimensional flow field is determined and oblique shock relations are used to describe the flow field.

Data output from the hypersonic control-flap methods are incremental normal- and axial-force coefficients, associated hinge moments, and center-of-pressure location. These data are found from the local pressure distributions on the flap and in regions forward of the flap. The analysis includes the effects of flow separation due to windward flap deflection by providing estimates for separation induced-pressures

forward of the flap and reattachment on the flap, Users may specify laminar or turbulent boundary layers.

2.3.3 Transverse-jet Control Effectiveness

Datcom provides a procedure for preliminary sizing of a two-dimensional transverse-jet control system in hypersonic flow, assuming that the nozzle is located at the aft end of the surface. The method evaluates the interaction of the transverse jet with the local flow field. A favorable interaction will produce amplification forces that increase control effectiveness.

The Datcom method is restricted to control jets located on windward surfaces in a Mach number range of 2 to 20. In addition, the method is invalid for altitudes where mean free paths approach the jet-width dimension.

The transverse control jet method requires a user-specified time history of local flow parameters and control force required to trim or maneuver. With these data, the minimum jet plenum pressure is then employed to calculate the nozzle throat diameter and the jet plenum pressure and propellant weight requirements to trim or maneuver the vehicle.

2.4 OPERATIONAL CONSIDERATIONS

There are several operational considerations the user needs to understand in order to take maximum advantage of Digital Datcom.

2.4.1 Flight Condition Control

Digital Datcom requires Mach number and Reynolds number to define the flight conditions. This requirement can be satisfied by defining combinations of Mach number, velocity, Reynolds number, altitude, and pressure and temperature. The input options for speed reference and atmospheric conditions that satisfy the requirement are given in Figure 3, The speed reference is input as either Mach number or velocity, and the atmospheric conditions as either altitude or freestream pressure and temperature. The specific reference and atmospheric conditions are then used to calculate Reynolds number.

The program may loop on speed reference and atmospheric conditions three different ways, as given by the variable LOOP in Figure 3. In this discussion, and in Figure 3, the speed reference is referred to as Mach number, and atmospheric conditions as altitude. The three options for program looping on Mach number and altitude are listed and discussed below.

- LOOP = 1 - Vary Mach and altitude together. The program executes at the first Mach number and first altitude, the second Mach number and second altitude, and continues for all the flight conditions. In the input data, NMACH must equal NALT and NMACH flight conditions are executed. This option

should be selected when the Reynolds number is input, and must be selected when atmospheric conditions are not input.

- LOOP = 2 - Vary Mach number at fixed altitude. The program executes using the first altitude and cycles through each Mach number in the input list, the second altitude and cycles through each Mach number, and continues until each altitude has been selected. Atmospheric conditions must be input for this option and NMACH times NALT flight conditions are executed.
- LOOP = 3 - Vary altitude at fixed Mach number. The program executes using the first Mach number and cycles through each altitude in the input list, the second Mach number and cycles through each altitude. and continues until each Mach number has been selected. Atmospheric conditions must be input for this option and NMACH times NALT flight conditions are executed.

2.4.2 Mach Regimes

Aerodynamic stability methods are defined in Datcom as a function of vehicle configuration and Mach regime. Digital Datcom logic determines the configuration being analyzed by identifying the particular input namelists that are present within a case (see Section 3). The Mach regime is normally determined according to the following criteria:

<u>Mach Number (M)</u>	<u>Mach Regime</u>
$M < 0.6$	Subsonic
$0.6 < M < 1.4$	Transonic
$M > 1.4$	Supersonic
$M > 1.4$ and the hypersonic flag is set (see Figure 3)	Hypersonic

These limits were selected to conform with most Datcom methods. However, some methods are valid for a larger Mach number range. Some subsonic methods are valid up to a Mach number of 0.7 or 0.8. The user has the option to increase the subsonic Mach number limit using the variable STMACH described In Section 3.2. The program will permit this variable to be in the range: $0.6 \leq \text{STMACH} \leq 0.99$. In the same fashion, the supersonic Mach limit can be reduced using the variable TSMACH. The program will permit this value be in the range: $1.01 \leq \text{TSMACH} \leq 1.40$. The program will default to the limits of each variable if the range is exceeded. The Mach regimes are then defined as follows:

<u>Mach Number (M)</u>	<u>Mach Regime</u>
$M < \text{STMACH}$	Subsonic
$\text{STMACH} < M < \text{TSMACH}$	Transonic
$M > \text{TSMACH}$	Supersonic

M > TSMACH
and the hypersonic
flag is set

Hypersonic

2.4.3 Input Diagnostics

There is an input diagnostic analysis module in Digital Datcom which scans all of the input data cards prior to program execution. A listing of all input data is given and any errors are flagged. It checks all namelist cards for correct namelist name and variable name spelling, checks the numerical inputs for syntax errors, and checks for legal control cards. The namelist and control cards are described in Section 3.

This module does not “fix up” input errors. It will, however, insert a namelist termination if it is not found. Digital Datcom will attempt to execute all cases as input by the user even if errors are detected.

2.4.4 Airfoil Section Module

The airfoil section module can be used to calculate the required geometric and aerodynamic input parameters for virtually any user defined airfoil section. This module substantially simplifies the user's input preparation.

An airfoil section is defined by one of the following methods:

1. An airfoil section designation (for NACA, double wedge, circular arc, or hexagonal airfoils)
2. Section upper and lower cartesian coordinates, or
3. Section mean line and thickness distribution.

The airfoil section module uses Weber's method (References 2 to 4) to calculate the inviscid aerodynamic characteristics. A viscous correction is applied to the section lift curve slope, c_g . In addition a 5% correlation factor (suggested in Datcom, page 4.1.1.2-2) is applied to bring the results in line with experimental data. The airfoil section module methods are discussed in Appendix A.

The airfoil section is assumed to be parallel to the free stream. Skewed airfoils can be handled by supplying the section coordinates parallel to the free stream. The module will calculate the characteristics of any input airfoil, so the user must determine whether the results are applicable to his particular situation. Five general characteristics of the module should be noted.

1. For subsonic Mach numbers, the module computes the airfoil subsonic section characteristics and the results can be considered accurate for Mach numbers less than the crest critical Mach number. Near crest critical Mach number, flow mixing due to the upper surface shock will make the boundary layer correction invalid. Compressibility corrections also become invalid. The module also computes the required geometric variables at all speeds, and for transonic and supersonic speeds these are the only required inputs. Mach

- equals zero data are always supplied.
2. Because of the nature of the solution, predictions for an airfoil whose maximum camber is greater than 6% of the chord will lose accuracy. Accuracy will also diminish when the maximum airfoil thickness exceeds approximately 12% of the chord, or large viscous interactions are present such as with supercritical airfoils.
 3. When section cartesian coordinates or mean line and thickness distribution coordinates are specified, the user must adequately define the leading edge region to prevent surface curve fits that have infinite slope. This can be accomplished by supplying section ordinates at non-dimensional chord stations (x/c of 0.0, 0.001, 0.002, and 0.003).
 4. If the leading edge radius is not specified in the airfoil section input, the user must insure that the first and second coordinate points lie on the leading edge radius. For sharp nosed airfoils the user must specify a zero leading edge radius.
 5. The computational algorithm can be sensitive to the “smoothness” of the input coordinates. Therefore, the user should insure that the input data contains no unintentional fluctuations. Considering that Datcom procedures are preliminary design methods, it is at least as important to provide smoothly varying coordinates. as it is to accurately define the airfoil geometry.

2.4.5 Operational Limitations

Several operational limitations exist in Digital Datcom. These limitations are listed below without extensive discussion or justification. Some pertinent operational techniques are also listed.

- The forward lifting surface is always input as the wing and the aft lifting surface as the horizontal tail. This convention is used regardless of the nature of the configuration.
- Twin vertical tail methods are only applicable to lateral stability parameters at subsonic speeds.
- Airfoil section characteristics are assumed to be constant across the airfoil span, or an average for the panel. Inboard and outboard panels of cranked or double-delta planforms can have their individual panel leading edge radii and maximum thickness ratios specified separately.
- If airfoil sections are simultaneously specified for the same aerodynamic surface by an NACA designation and by coordinates, the coordinate information will take precedence.
- Jet and propeller power effects are only applied to the longitudinal stability parameters at subsonic speeds. Jet and propeller power effects cannot be applied simultaneously.

- Ground effect methods are only applicable to longitudinal stability parameters at subsonic speeds.
- Only one high lift or control device can be analyzed at a time. The effect of high lift and control devices on downwash is not calculated. The effects of multiple devices can be calculated by using the experimental data input option to supply the effects of one device and allowing Digital Datcom to calculate the incremental effects of the second device.
- Jet flaps are considered to be symmetrical high lift and control devices. The methods are only applicable to the longitudinal stability parameters at subsonic speeds.
- The program uses the input namelist names to define the configuration components to be synthesized. For example, the presence of namelist HTPLNF causes Digital Datcom to assume that the configuration has a horizontal tail.

Should Digital Datcom not provide output for those configurations for which output is expected, as shown in Table 2, limitations on the use of a Datcom method has probably been exceeded. In all cases users should consult the Datcom for method limitations.

SECTION 3

DEFINITION OF INPUTS

The Digital Datcom basic input data unit is the “case.” A “case” is a set of input data that defines a configuration and its flight conditions. The case consists of inputs from up to four data groups.

- Group I inputs define the flight conditions and reference dimensions.
- Group II inputs specify the basic configuration geometry for conventional configurations, defining the body, wing and tail surfaces and their relative locations.
- Group III inputs specify additional configuration definition, such as engines, flaps, control tabs, ground effects or twin vertical panels. This input group also defines those “special” configurations that cannot be described using Group II inputs and include low aspect ratio wing and wing-body configurations, transverse jet control and hypersonic flaps.
- Group IV inputs control the execution of the case, or job for multiple cases, and allow the user to choose some of the special options, or to obtain extra output.

3.1 INPUT TECHNIQUE

Two techniques are generally available for introducing input data into a Fortran computer program: namelist and fixed format. Digital Datcom employs the namelist input technique for input Groups I, II and III since it is the most convenient and flexible for this application. Its use reduces the possibility of input errors and increases the utility of the program as follows:

- Variables within a namelist may be input in any order;
- Namelist variables are not restricted to particular card columns;
- Only required input variables need be included; and
- A variable may be included more than once within a namelist, but the last value to appear will be used.

Namelist rules used in the program and applicable to CDC and IBM systems are presented in Appendix A. The user should adhere to them when preparing inputs for Digital Datcom. To aid the user in complying with the general namelist rules, examples of both correct and incorrect namelist coding are included in Appendix A.

All namelist input variables (and program data blocks) are initialized “UNUSED” (1.0E-60 on CDC systems) prior to case execution. Therefore, omission of pertinent input variables may result in the “UNUSED” value to be used in

calculations. However, the “UNUSED” value is often used as a switch for program control, so the user should not indiscriminately use dummy inputs.

All Digital Datcom numeric constants require a decimal point. The Fortran variable names that are implied INTEGERS (name begins with I, J, K, L, M, or N) are declared REAL and must be specified in either “E” or “F” format (X.XXXEYY or X.XXX).

Group IV inputs are the “case control cards.” Though they are input in a fixed format, their use has the characteristic of a namelist. since (with the exception of the case termination card) they can be placed in any order or location in the input data. Descriptions and limitations of each of the available control cards are discussed in Section 3.5.

Table 4 defines the namelists and control cards that can be input to the program. Since not all namelist inputs are required to define a particular problem or configuration, those namelists required for various analyses are summarized in Tables 5 through 7. Use of these tables will save time in preparing namelist inputs for a specific problem.

The user has the option to specify the system of units to be used, English or Metric. Table 8 summarizes the systems available, and defines the case control card required to invoke each option. For clarity, the namelist variable description charts which follow have a column titled “Units” using the following nomenclature:

l denotes units of length: feet, inches, meters, or centimeters

A denotes units of area: ft², in², m², or cm²

Deg denotes angular measure in degrees, or temperature in degrees Rankine or degrees Kelvin

F denotes units of force; pounds or Newtons

t denotes units of time; seconds.

Specific input parameters, geometric illustrations, and supporting data are provided throughout the report. To aid the user in reading these figures, the character ‘0’ defines the number zero and the character ‘O’ the fifteenth letter in the alphabet.

3.2 GROUP I INPUT DATA

Namelist input data to define the case flight conditions and reference dimensions are shown in Figures 3 and 4.

Namelist FLTCON, Figure 3, defines the case flight conditions. The user may opt to provide Mach number and Reynolds number per unit length for each case to be

computed. In this case, input preparation requires that the user compute Reynolds number for each Mach number, and altitude combination he desires to run.

However, the program has a standard atmosphere model, which accurately simulates the 1962 Standard Atmosphere for geometric altitudes from -16,404 feet to 2,296,588 feet, that can be used to eliminate the Reynolds number input requirement and provides the user the option to employ Mach number or velocity as the flight speed reference. The user may specify Mach numbers (or velocities) and altitudes for each case and program computations will employ the atmosphere model to determine pressure, temperature, Reynolds number and other required parameters to support method applications.

Also incorporated is the provision for optional inputs of pressure and temperature by the user. The program will override the standard atmosphere and compute flow condition parameters consistent with the pressure and temperature inputs. This option will permit Digital Datcom applications such as wind tunnel model analyses at test section conditions.

The five input combinations which will satisfy the Mach number and Reynolds number requirements are summarized in Figure 3. If the NACA control card is used, the Reynolds number and Mach number must be defined using the variables RNNUB and MACH.

Other optional inputs include vehicle weight and flight path angle (“WT” and “GAMMA”). These parameters are of particular interest when using the Trim Option (Section 3.5). The trim flight conditions are output as an additional line of output with the trim data and the steady flight lift coefficient is output with the untrimmed data.

Use of the variable LOOP enables the user to run cases at fixed altitude with varying Mach number (or velocity), at fixed Mach number (or velocity) at varying altitudes, or varying speed and altitude together.

Nondimensional aerodynamic coefficients generated by Digital Datcom may be based on user-specified reference area and lengths. These reference parameters are input via namelist OPTINS, Figure 4. If the reference area is not specified, it is set equal to the theoretical planform area of the wing. This wing area includes the fuselage area subtended by the extension of the wing leading and trailing edges to the body center line. The longitudinal reference length, if not specified in OPTINS, is set equal to the theoretical wing mean aerodynamic chord. The lateral reference length is set equal to the wing span when it is not user specified.

Reference parameters contained in OPTINS must be specified for body-alone configurations since the default reference parameters are based on wing geometry. It is suggested that values near the magnitude of body maximum cross-sectional area be used for the reference area and body maximum diameter for the longitudinal and lateral reference lengths.

The output format generally provides at least three significant digits in the solution

when user specified reference parameters are of the same order of magnitude as the default reference parameters. If the user specifies reference parameters that are orders of magnitude different from the wing area or aerodynamic chord, some output data can overflow the output format or print only zeros. This may happen in rare instances and would require readjustment of the reference parameters.

3.3 GROUP II INPUT DATA

Namelist data to define basic configuration geometry is shown in Figures 5 through 8. Those “special” configurations (Figure 2) are defined using Group III namelists. The namelist SYNTHS defines the basic configuration synthesis parameters. The user has the option to apply a scale factor to his geometry which permits full scale configuration dimensions to be input for an analysis of a wind tunnel model. The program will use the scale factor to scale the input data to model dimensions. The variable used is “SCALE.”

The body configuration is defined using the namelist BODY (Figure 6). The variable METHOD enables the user to select either the traditional Datcom methods for body C_L , C_m and C_D at low angles of attack (default), or Jorgensen’s method, which is applicable from zero to 180 degrees angle of attack. Jorgensen’s method can be used by selecting “METHOD=2” subsonically or supersonically. Users are encouraged to consult the Datcom for details concerning these methods. Digital Datcom will accept an arbitrary origin for the body coordinate system, i.e., body station “zero” is or required to be at the fuselage nose.

The planform geometry of each of the aerodynamic surfaces are input using the namelist WGPLNF, HTPLNF, VTPLNF and VFPLNF shown in Figure 7. The section aerodynamic characteristics for these surfaces are input using either the section characteristics namelists WGSCHR, HTSCHR, VTSCHR and VFSCHR (Figure 4) and/or the NACA control card discussed in Section 3.5. Airfoil characteristics are assumed constant for each panel of the planform.

The USAF Datcom contains three methods for the computation of forward lifting surface downwash field effects on aft lifting surface aerodynamics. They are given in detail in Section 4.4 of Datcom, and their regimes of primary applicability are summarized in Figure 9. The user is cautioned not to apply the empirically based subsonic Method 2 outside the bounds listed in Figure 9. Method 1 is recommended as an optional approach for the b_w/b_h regime of 1.0 to 1.5. By default, Digital Datcom selects Method 3 for b_w/b_h less than 0.5 and Method 1 for span ratios greater than or equal to 1.5.

Using the variable DWASH in namelist WGSCHR, the user has the option of applying Method 1 or 2. Method 2 is applicable at subsonic Mach numbers and span ratios of 1.25 to 3.6.

Aspect ratio classification is required to employ the Datcom straight tapered wing solutions for wing or tail lift in the subsonic and transonic Mach regimes.

Classification of lifting surface aspect ratio as either high or low results in the selection of appropriate methods for computation. The USAF Datcom uses a classification parameter, which depends upon planform taper ratio and leading edge sweep (Table 9). It also notes an overlap regime where the user may employ either the low or high aspect ratio methods. Digital Datcom allows the user to specify the aspect ratio method to be used in this overlap regime using the parameter ARCL in the section namelists. High aspect ratio methods are automatically selected for unswept, untapered wings with aspect ratios of 3.5 or more if ARCL is not input. Transonically, several parameters need to be defined to obtain the panel lift characteristics. Those required variables are summarized in Figures 10 and 11 and are input using the experimental data substitution namelist EXPRnn. Additionally, intermediate data may be available, for example CXXXXX, which requires experimental data to complete. By use of the experimental data input namelist EXPRnn, data can be made available to complete these second-level computations, as shown in Figure 10.

The namelist EXPRnn can also be used to substitute selected configuration data with known test results for some Datcom method output and build a new configuration based on existing data. This option is most useful for theoretically expanding a wind tunnel test data base for analysis of non-tested configurations.

3.4 GROUP III INPUT DATA

The namelists required for additional or “special” configuration definition are presented in Figures 12 through 22, and Tables 10 through 12. Specifically, the namelists PROPWR, JETPWR, GRNDEF, TVTPAN, ASYFLP and CONTAB enable the user to “build upon” the configuration defined through Group II inputs. The remaining namelists LARWB, TRNJET and HYPEFF define “stand alone” configurations whose namelists are not used with Group II inputs.

The inputs for propellor power or jet power effects are made through namelists PROPWR and JETPWE, respectively. The number of engines allowable is one or two and the engines may be located anywhere on the configuration. The configuration must have a body and a wing defined and, optionally, a horizontal tail and a vertical tail. Since the Datcom method accounts for incremental aerodynamic effects due to power, configuration changes required to account for proper placement of the engine(s) on the configuration (e.g., pylons) are not taken into account.

Twin vertical panels, defined by namelist TVTPAN, can be defined on either the wing or horizontal tail. Since the method only computes the incremental lateral stability results, “end-plate” effects on the longitudinal characteristics are not calculated. If the twin vertical panels are present on the horizontal tail, and a vertical tail or ventral fin is specified, the mutual interference among the panels is not computed.

Inputs for the high lift and control devices are made with the namelists SYMFLP, ASYFLP and CONTAB. In general, the eight flap types defined using SYMFLP (variable FTYPE) are assumed to be located on the most aft lifting surface, either horizontal tail or wing if a horizontal tail is not defined. Jet flaps, also defined using SYMFLP, will always be located on the wing, even with the presence of a horizontal tail. Control tabs (namelist CONTAB) are assumed to be mounted on a plain trailing edge flap (FTYPE=1); therefore, for a control tab analysis namelists CONTAB and SYMFLP (with FTYPE=1) must both be input. For ASYFLP namelist inputs, the spoiler and aileron devices (STYPE of 1., 2., 3. or 4.) are defined for the wing, even with the presence of a horizontal tail, whereas the all-moveable horizontal tail (STYPE=5.0) is, of course, a horizontal tail device.

3.5 GROUP IV INPUT DATA

Case control cards are provided to give the user case control and optional input/output flexibility.

All Datcom control cards must start in card Column 1. The control card name cannot contain any embedded blanks unless the name consists of two words; they are then separated by a single blank. All but the case termination card (NEXT CASE) may be inserted anywhere within a case (including the middle of any namelist). Each control card is defined below and examples of their usage are illustrated in the example problems of Section 7.

3.5.1 Case Control

NAMELIST - When this card is encountered, the content of each applicable namelist is dumped for the case in the input system of units. This option is recommended if there is doubt about the input values being used, especially when the SAVE option has been used.

SAVE - When this control card is present in a case, input data for the case are preserved for use in following case. Thus, data encountered in the following case will update the saved data. Values not input in the new case will remain unchanged. Use of the SAVE card also allows minimum inputs for multiple case jobs. The total number of appearances of all namelists in consecutive SAVE cases cannot exceed 300; this includes multiple appearances of the same namelist. An error message is printed and the case is terminated if the 300 namelist limit is exceeded. Note, if both SAVE and NEXT CASE cards appear in the last input case, the last case will be executed twice.

The NACA, DERIV and DIM control cards are the only control cards affected by the SAVE card; i.e., no other control cards can be saved from case to case.

DIM FT, DIM IN, DIM M, DIM CM

When any of these cards are encountered, the input and output data are specified in

the stated system of units. (See Table 8.) DIM FT is the default.

NEXT CASE - When this card is encountered, the program terminates the reading of input data and begins execution of the case. Case data are destroyed following execution of a case unless a SAVE card is present. The presence of this card behind last input case is optional.

3.5.2 Execution Control

TRIM - If this card is included in the case input, trim calculations will be performed for each subsonic Mach number within the case. A vehicle may be trimmed by deflecting a control device on the wing or horizontal tail or by deflecting an all-movable horizontal stabilizer.

DAMP - The presence of this card in a case will provide dynamic derivative results (for addressable configurations) In addition to the standard static-derivative output (see Figure 25).

NACA - This card provides in NACA airfoil section. designation (or supersonic airfoil definition) for use in the airfoil section module. It is used in conjunction with, or in place of, the airfoil section characteristics namelists, Figure 8. The airfoil section module calculates the airfoil section characteristics designated in Figure 8, and is executed if either a NACA control card is present or the variable TYPEIN is defined in the appropriate section characteristic namelist (WGSCHR, HTSCHR, VTSCHR or VFSCHR). Note that if airfoil coordinates and the NACA card are specified for the same aerodynamic surface, the airfoil coordinate specification will be used. Therefore, if coordinates have been specified in a previous case and the SAVE option is in effect, "TYPEIN" must be set equal to "UNUSED" for the presence of an NACA card to be recognized for that aerodynamic surface. The airfoil designated with card will be used for both panels of cranked or double-delta planforms.

The form of this control card and the required parameters are given below.

Card	Column(s)	input(s)	Purpose
	1 thru 4	NACA	The unique letters NACA designate that at airfoil is to be defined
5		Any delimiter	
6		W, H, V, or F	Planforms for which the airfoil designation applies Wing(W), Horizontal tail (H), Vertical Tail (V), or ventral Fin (F)
7		Any delimiter	
8		1, 4, 5, 6, S	Type of airfoil section; 1-series (1), 4-digit (4),

		5-digit (5), 6-series (6). or supersonic (S)
9	Any delimiter	
10 thru 80	Designation	Input designation; columns are free-field (blanks are ignored)

Only fifteen (15) characters are accepted in the airfoil designation. The vocabulary consists of the numbers zero (0) through nine (9), the letter “A”, and the special characters comma, period, hyphen and equal sign. Any characters input that are not in the vocabulary list will be interpreted as the number zero (0).

Section designation input restrictions inherent to the Airfoil Section Module are presented in Table 13.

3.5.3 Output Control

CASEID - This card provides a case identification that is printed as part of the output headings. This identification can be any user defined case title, and must appear in card columns 7 through 80.

DUMP NAME1, NAME2, ... - This card is used to print the contents of the named arrays in the foot-pound-second system of units. The arrays that can be listed and definition of their contents are given in Appendix C. For example, if the control card read was “DUMP FLC, A” the flight conditions array FLC and the wing array A would be printed prior to the conventional output. If more names are desired than can fit in the available space on one card, additional dump cards may be included.

DUMP CASE - This card is similar to the “DUMP NAME1, ...” control card. When this card is present in a case, all the arrays (defined in Appendix C) that are used during case execution are printed prior to the conventional output. The values in the arrays are in the foot-pound-second system of units.

DUMP INPUT - This card is similar to the “DUMP CASE” card except that it forces a dump of all input data blocks used for the case.

DUMP IOM - This card is similar to the “DUMP CASE” card except that all the output arrays for the case are dumped.

DUMP ALL - This card is similar to the “DUMP CASE” card. Its use dumps all program arrays, even if not used for the case.

DERIV RAD - This card causes the static and dynamic stability derivatives to be output in radian measure. The output will be in degree measure unless this flag is set. The flag remains set until a DERIV DEG control card is encountered, even if “NEXT CASE” cards are subsequently encountered.

DERIV DEG - This card causes the static and dynamic stability derivatives to be output in degree measure. The remaining characteristics of this control card are the same as the DERIV RAD card. DERIV DEG is the default.

PART - This card provides auxiliary and partial outputs at each Mach number in the

case (see Section 6.1.8). These outputs are automatically provided for all cases at transonic Mach numbers.

BUILD - This control card provides configuration build-up data. Conventional static and dynamic stability data are output for all of the applicable basic configuration combinations shown in Table 2.

PLOT - This control card causes data generated by the program to be written to logical unit 13, which can be retained for input to the Plot Module (described in Volume III). The format of this plot file is described in Section 5 of Volume III.

3.4. REPRESENTATIVE CASE SETUP

Figures 23 and 24 illustrate a typical case setup utilizing the namelists and control cards described. Though namelists (and control cards) may appear in any order (except for NEXT CASE), users are encouraged to provide inputs in the data groups outlined in this section in order to avoid one of the most common input errors - neglecting an important namelist input. The user's kit (Appendix D) has been assigned to assist the user in eliminating many common input errors, and its use is encouraged.

[end of section 3]

SECTION 4

BASIC CONFIGURATION MODELING TECHNIQUES

4.1 COMPONENT CONFIGURATION MODELING

Use of the Datcom methods requires engineering judgement and experience to properly model a configuration and interpret results. The same holds true in the use of the Digital Datcom program. As a convenience to the user, the program performs intermediate geometric computations (e.g., area and aspect ratio) required in method applications. The user can retrieve the values used for key geometric parameters by means of the PART and/or DUMP options, Section 3.5. The geometric inputs to the Digital Datcom program are relatively simple except for the judgement required in best representing a particular configuration. This section describes some geometry modeling techniques to appropriately model a configuration.

4.1.1 Body Modeling

The basic body geometry parameters required (regardless of speed regime) consist of the longitudinal coordinates with corresponding planform half widths, peripheries, and/or cross-sectional areas. These values are usually used in a linear sense (e.g., the trapezoidal rule is used to integrate for planform area). This implies that body-shape parameters are linearly connected. However, geometric derivatives, such as $(dS/dx)_i$, are obtained from quadratic interpolations. Proper modeling techniques which reflect a knowledge of method implementation, when used in conjunction with the PART and DUMP options, greatly enhance the program capability and accuracy.

Body methods for lift-curve slope, pitching-moment slope and drag coefficient in the transonic, supersonic, and hypersonic speed regimes require the body to be synthesized from a combination of body segments. The body segments consist of a nose segment, an afterbody segment, and a tail segment. However, in these speed regimes, lift and pitching-moment coefficients versus angle of attack are defined as functions of the body planform characteristics, and therefore are not necessarily a function of the body-segment parameters.

The program performs the configuration synthesis computations as described below. The body input parameters R, P, and S (defined in Figure 6) can reflect actual body contours. Digital Datcom will interpolate the R array at $x=l_N$, $x=l_N+l_A$, and the last input x for d_N , d_1 , and d_2 , respectively. Using the shape parameters B_{nose} and B_{tail} it will synthesize an "equivalent" body from the various possibilities shown in Figure 6. For example, in the center body $X = l_N$ to $X = l_N + l_A$, will be treated as a cylinder with a fineness ratio of $2l_A/(d_N+d_1)$, the nose will be the shape specified by B_{nose} with a fineness ratio of l_N/d_N , etc. Thus, it is up to the user to choose l_N , l_A , B_{nose} , and B_{tail} to derive a reasonable approximation of the actual body. Digital Datcom requires synthesized body configurations to be either nose-alone, nose-afterbody, nose-afterbody-tail, or nose-tail (see Figure 6). The shape of the

body segments is restricted as follows: nose and tail shapes must be either an ogive or cone, afterbodies must be cylindrical while tails may be either boat-tailed or flared. Additional body namelist inputs are required to define these body segments and consist of nose- and tail-shape parameters BNOSE and BTAIL and nose and afterbody length parameters BLN and BLA. In the hypersonic speed regime, the effects of nose bluntness may be obtained by specifying DS, the nose bluntness diameter.

For an example of inputs for BLN (l_N) and BLA (l_A) as required in speed regimes other than subsonic, the reader is directed to Figure 6. Body diameters at the various segment intersections, l_N dN, l_N d1, and l_N d2, are obtained from linear interpolation. The tail length, l_{BT} , is obtained by subtracting segments LN l_N and tA l_N from the total body length.

Most Digital Datcom analyses assume bodies are axisymmetric. Users may obtain limited results for cambered bodies of arbitrary cross section by specifying the BODY namelist optional inputs Z_U and Z_L . This option is restricted to the longitudinal stability results in the subsonic speed regime. At speeds other than subsonic, Z_U and Z_L values are ignored and axisymmetric body results are provided. It is recommended that the reference plane for Z_U and Z_L inputs be chosen near the base area centroid.

The body modeling example problem (Section 7. problem 1) was selected specifically to illustrate modeling techniques and relevant program operations. They include:

- Choice of longitudinal coordinates that reflect body curvature and critical body intersections, i.e.. wing-body intersection, and body segmentation, if required.
- Subsonic cambered body modeling.
- Use of the DUMP option so that key parameters can be obtained with the aid of Appendix C.

4.1.2 Wing-Tail Modeling

Input data for wings, horizontal tails, vertical tails and ventral fins have been classified as either planform data or as section characteristic data, as shown in Figures 7 and 8 of Section 3. Twin-vertical panel planform input data is shown in Figure 15.

Classification of nonstraight-tapered wings and horizontal tails as either cranked (aspect ratio > 3) or double delta (aspect ratio < 3) is relevant to only the subsonic speed regime. In this speed regime, the appropriate lift and drag prediction methods depend on the classification of the lifting surface. Digital Datcom executes subsonic analyses according to the user-specified classification regardless of the surface aspect ratio. However, if the surface is inappropriately designated, a warning message is printed.

Dihedral angle inputs are used primarily in the lateral stability methods. The longitudinal stability methods reflect only the effects of dihedral in the downwash and ground effect calculations. The direct effects of dihedral on the primary lift of horizontal surfaces are not defined in Datcom and are therefore not included in Digital Datcom.

Digital Datcom wing or horizontal tail alone analysis requires the exposed semispan and the theoretical semispan to be set to the same value in namelist WGPLNF and HTPLNF. The input wing root chord should be consistent with the chosen semispan. The reference parameters in namelist OPTINS should be used to specify reference parameters corresponding to other than the theoretical wing planform. If the reference parameters are not specified, they are evaluated using the theoretical wing inputs and the reference area is set as the wing theoretical area, the longitudinal reference length as the wing mean aerodynamic chord, and the lateral reference length is set as the wing span.

Horizontal tail input parameters SVWB, WVB, and SVHB, as well as vertical tail input parameters SHB, SEXT, and RLPH, are required only for the supersonic and hypersonic speed regimes. They are used in calculation of lateral-stability derivatives. If these data are not input, the program will calculate them, but will fail if any part of the exposed root chord lies off of the body; lateral stability calculations are not performed if this occurs.

Two-dimensional airfoil section characteristic data for wings and tails are input via namelists WGSCHR, HTSCHR, VTSCHR, and VFSCHR, or may be calculated using the airfoil section module. On occasion, the section characteristics cannot be explicitly defined because airfoil sections either vary with span (an average airfoil section may be specified), or the planform is not straight tapered and has different airfoil sections between the panels. In such circumstances, inputs should be estimated after reviewing existing airfoil test data. Sensitivity of program results to the estimated section characteristics can be readily evaluated by performing parametric studies utilizing the SAVE and NEXT CASE options defined in Section 3.5. Users are warned that airfoil sensitivities do exist for low Reynolds numbers, i.e., on the order of 100,000. These namelists can also be used to specify the aspect ratio criteria using "ARCL" (Table 9).

Planform geometry, section characteristic parameters, and synthesis dimensions for twin vertical panels are input via namelist TVTPAN. The effects of such panels are reflected in only the subsonic lateral-stability output. The panels may be located either on the wing or on the horizontal tail.

4.2 MULTIPLE COMPONENT MODELING

Combinations of aerodynamic components must be synthesized in namelist SYNTHS. However, the program makes no cross checks in assembly of components for configuration analysis. The user must confirm the geometry inputs to assure consistency of dimensions and component locations in total configuration

representation.

4.2.1 Wing-Body-Tail-body Modeling

Body values employed in wing-body computations are not the same as body-alone results but are obtained by performing body-alone analysis for that portion of the body forward of the exposed root chord of the wing. User supplied body data, input via the namelist EXPRnn, will be used in lieu of the “nose segment” data calculated. Carryover factors are a function of the ratio of body diameter to wing span, as obtained from the wing input data, i.e., the body diameter is taken as twice the difference of the exposed semispan and the theoretical semispan. Hence, the body radius input in namelist BODY does not affect the interference parameters.

4.2.2 Wing-Body-Tail Modeling

A conventional “aircraft” configuration is modeled using the body, wing, horizontal tail, and vertical tail modeling techniques previously described. Wing downwash data are required to complete analysis of configurations with a wing and horizontal tail. Subsonic and supersonic downwash data are calculated for straight-tapered wings. For other wing planforms, or at transonic Mach numbers, the downwash data (q_H/q_∞ , ϵ , and $d\epsilon/d\alpha$) must be supplied using the experimental data substitution option, though two alternatives are suggested:

6. Actual data, or from a wing-body-tail configuration which has an “equivalent” straight tapered wing, or
7. Defining an “equivalent” straight tapered wing and substituting the wing-body results obtained from the previous Digital Datcom run to obtain the best analytical estimate of the configuration.
- 8.

Body-canard-wing configurations are simulated using the standard body-wing-tail inputs. The forward surface (canard) is input as the wing, and the aft lifting surface as the horizontal tail. Digital Datcom checks the relative span of the wing and horizontal tail to determine if the configuration is a conventional wing-body-tail or a canard configuration.

4.2.3 Configuration Build-up Considerations

Section 3.5 describes multiple case control cards which simplify inputs for parametric and configuration build-ups. There are a few items to keep in mind. The effect of omitting an input variable or setting its value to zero may not be the same, since all inputs are initialized to “UNUSED”, 1.0E-60 for CDC computers.

However, the “UNUSED” value may be used to give the effect of an input variable being omitted. For example, If “KSHARP” in namelist WGSCHR was specified in a previous SAVE case, a subsequent case could specify “KSHARP = 1.0E-60” (for CDC computers) which would result in KSHARP being omitted in the subsequent case. In many places Digital Datcom uses the presence of a namelist for program

control. For example, the program assumes a body has been input if the namelist BODY exists in a case. The effects of a presence of a namelist, through case input or a SAVE card, cannot be eliminated even if all input volume are set to "UNUSED." The only exception to this rule involves high-lift and control input. Either namelist SYMFLP or ASYFLP way be specified in a case, but not both. In a case sequence involving namelist SYMFLP and a SAVE card, followed by another case where ASYFLP is specified, the ASYFLP analysis will be performed and the previous SYMFLP input ignored.

4.3 DYNAMIC DERIVATIVES

Digital Datcom computes dynamic derivatives for body, wing, wing-body, end wing-body-tail configurations for subsonic, transonic, and supersonic speeds. In addition, body-alone derivatives are available at hypersonic speeds. There is no special namelist input associated with dynamic derivatives. Use of the DUMP control card discussed in Section 3.5 will initiate computation. If experimental data are input, the dynamic derivative methods will employ the relevant experimental data. Dynamic derivative solutions are provided for basic geometry only. and the effects of high-lift and control devices are not recognized.

The experimental data option of the program permits the user to substitute experimental data for key static stability parameters involved in dynamic derivative solutions such as body C_L , wing-body C_L , etc. Any improvement in the accuracy of these parameters will produce significant improvement in the dynamic stability estimates. Use of experimental data substitution for this purpose is strongly recommended.

4.4 TRIM OPTION

Digital Datcom provides a trim option allows users to obtain longitudinal trim data. Two types of capability are provided: control device on wing or tail (Section 3.4) and the all-movable horizontal stabilizer. Trim with a control device on the wing or tail is activated by the presence of the namelist SYMFLP (Section 3.4) and TRIM control card (Section 3.5) In the same case. Output consists of aerodynamic increments associated with each flap deflection; similar output is provided at trim deflection angles. The trim output is generated as follows the undeflected total configuration moment at each angle of attack is compared with the incremental moments generated from SYMFLP input. Once the incremental moment is reached, the corresponding deflection angle is the trim deflection angle. The trim deflection is then used as the independent variable in table look-ups for the remaining increments, such as C_L and C_D . The user should specify a liberal range of flap deflection angles when using the control device trim option.

4.5 SUBSTITUTION OF EXPERIMENTAL DATA

Users have the option of substituting certain experimental data that will be used in

lieu of Digital Datcom results. The experimental data are used in subsequent configuration analysis, e.g., body data are used in the wing-body and wing-body-tail calculations. Experimental data are input via namelist EXPRnn, Figure 11. All specified parameters must be based on the same reference area and length used by Digital Datcom.

In the transonic Mach regime, some Datcom methods are available that require user supplied data to complete the calculations. For example, Datcom methods are given that define wing C_t/CL and CDL/CL^2 although methods are not available for C_L . If the wing lift coefficient is supplied using experiential data substitution, C_L and C_D can be calculated at each angle of attack for which C_L is given. The additional transonic data that can be calculated, and the “experimental” data required, are defined in Figure 10.

SECTION 5

ADDITIONAL CONFIGURATION MODELING TECHNIQUES

5.1 HIGH-LIFT AND CONTROL CONFIGURATIONS

Control-device input data for symmetrical and asymmetrical deflections are contained in namelist SYMFLP and ASYFLP respectively. Analysis is limited to either symmetrical or asymmetrical results in any one case. Multiple case runs involving SAVE cards, may interchange symmetrical and asymmetrical analyses from case to case. Only one control device, on either the wing or horizontal tail, may be analyzed per case. If a wing or wing-body case is run, flap input automatically refers to the wing geometry. However, if a wing-body-horizontal-tail case is input, flap input data refer to the horizontal tail. Multiple-device analysis must be performed manually by using the experimental-data input option.

Symmetrical and asymmetrical flap analysis (namelists SYMFLP and ASYFLP) are not performed in the hypersonic speed regime (hypersonic flap effectiveness inputs are made via namelist HYPEFF). No distinction is made between high lift devices and control devices within the program. For instance, trim data may be obtained with any device for which the pitching moment increment is output, with the exception of leading edge flaps. Jet flap analysis assume the flaps are on the wing and the increments are for a wing-body configuration.

5.2 POWER AND GROUND EFFECTS

Input parameters required to calculate the effects of propeller power, jet power, and ground proximity on the subsonic longitudinal-stability results are input via namelists PKOPWR, JETPWR, and GRNDEF. The effects of power or ground proximity on the static longitudinal stability results may be obtained for any wing-

body or wing-body-horizontal. tail-and/or vertical tail configuration. Output consists of lift, drag, and pitching moment coefficients that include the effects of power or ground proximity. Ground effect output may be obtained at a maximum of ten different ground heights. It should be noted that the of ground height usually become negligible when the ground height exceeds the wing span.

The effects of ground proximity on a wing-body configuration with symmetrical flaps can be calculated for as many as nine flap deflections at each ground height. The required data are input via namelists GRNDEF and SYMFLP.

5.3 LOW-ASPECT-RATIO WING OR WING-BODY

The Datcom provides special methods to analyze low aspect ratio wing and wing-body combinations (lifting-body vehicles) in the subsonic speed regime. Parameters required to calculate the subsonic longitudinal and lateral results for lifting bodies are input via namelist LARWB. Digital Datcom output provides longitudinal coefficients C_L , C_D , C_N , C_A , and C_m and the derivatives

$$C_{L_\alpha}, C_{m_\alpha}, C_{Y_\beta}, \text{ and } C_{l_\beta}$$

5.4 TRANSVERSE-JET CONTROL EFFECTIVENESS

A flat plate equipped with a transverse-jet control system and corresponding input data requirements for namelist TRNJET is shown in Figure 21. The free stream Mach number, Reynolds number, and pressure are defined via namelist FLTCON, Figure 3. Estimates for the required control force can be made on the assumption that the center of pressure is at the nozzle. The predicted center of pressure location is calculated by the program and obtained by dumping the JET array. If the calculated center of pressure location disagrees with the assumption, a refinement of input data may be necessary

5.5 FLAP CONTROL EFFECTIVENESS AT HYPERSONIC SPEEDS

A flat plate with a flap control is shown in Figure 22 along with input namelist HYPFLP. Force and moment data are predicted assuming a two-dimensional flow field. Oblique shock relations are used in describing the flow field.

SECTION 6

DEFINITION OF OUTPUT

Digital Datcom results are output at the Mach numbers specified in namelist FLTCON. At each Mach number, output consists of a general heading, reference parameters, input error messages, array dumps, and specific aerodynamic characteristics as a function of angle of attack and/or flap deflection angle. Separate output formats are provided for the following sets of related aerodynamic data: static longitudinal and lateral stability, dynamic derivatives, high lift and control, trim option, transverse-jet effectiveness, and control effectiveness at hypersonic speeds. Since computer output is limited symbolically, definitions for the output symbols used within the related output sets are given. The Datcom engineering symbol follows the output symbol notation when appropriate, Unless otherwise noted, all results are presented in the stability axis coordinate system.

6.1 STATIC AND DYNAMIC STABILITY OUTPUT

The primary outputs of Digital Datcom are the static and dynamic stability data for a configuration. An example of this output is shown in Figure 25. Definitions of the output notations are given below.

6.1.1 General headings

Case identification information is contained in the output heading and consists of the following: the version of Datcom from which the program methodologies are derived, the type of vehicle configuration (e.g. body alone or wing-body) for which aerodynamic characteristics are output, and supplemental user-specified case identification information if the CASEID control card is used.

6.1.2 Reference Parameters

Reference parameters and flight-condition output are defined as follows:

- **MACH NUMBER** - Mach at which output was calculated. This parameter is user-specified in namelist FLTCON, or calculated from the altitude and velocity inputs.
- **ALTITUDE** - Altitude (if user input) at which Reynolds number was calculated. This optional parameter is user specified in namelist FLTCON.
- **VELOCITY** - Freestream velocity (if user input) at which Mach number and Reynolds number was calculated. This optional parameter is user specified in namelist FLTCON.
- **PRESSURE** - Freestream atmospheric pressure at which output was calculated (function of altitude). This parameter can also be user specified in namelist FLTCON.
- **TEMPERATURE** - Freestream atmospheric temperature at which output was calculated (function of altitude). This parameter can also be user specified in namelist FLTCON.
- **REYNOLDS NO.** - This flight condition parameter is the Reynolds number per unit length and is user-specified (or input) in namelist FLTCON.
- **REFERENCE AREA** - Digital Datcom aerodynamic characteristics are based on this reference area. It is either user-specified in namelist OPTINS or is

- equal to the planform area of the theoretical wing.
- **REFERENCE LENGTH - LONGITUDINAL** - The Digital Datcom pitching moment coefficient is based on this reference length. It is either user-specified in namelist OPTINS or is equal to the mean aerodynamic chord of the theoretical wing.
- **REFERENCE LENGTH - LATERAL** - The Digital Datcom yawing-moment and rolling-moment derivatives are based on this reference length. It is either user-specified in namelist OPTINS or is set equal to the wing span.
- **MOMENT REFERENCE CENTER** - The moment reference center location for vehicle moments (and rotations). It is user-specified in namelist SYNTHS and output as $X_{CG}(\text{HORIZ})$ and $Z_{CG}(\text{VERT})$.
- **ALPHA** - This is the angle-of-attack array that is user specified in namelist FLTCON. The angles are expressed in degrees.

6.1.3 Static Longitudinal and Lateral Stability

Not all of the static aerodynamic- characteristics shown in Figure 25 are calculated for each combination of vehicle configuration and speed regime, Digital Datcom methods are not always available. Aerodynamic characteristics that are available as output from Digital Datcom are presented in Table 2 as a function of vehicle configuration and speed regime. Additional constraints are imposed on some derivatives; the user should consult the Methods Summary in Section 1 of the USAF Stability and Control Datcom Handbook. The stability derivatives are expressed per degree or per radian at the users option (see Section 3.5).

- **CD** - Vehicle drag coefficient based on the reference area and presented as a function of angle of attack. If Datcom methods are available to calculate zero-lift drag but not to calculate CD versus alpha, the value of CD is printed as output at the first alpha. CD is positive when the drag is an aft acting load.
- **CL** - Vehicle lift coefficient based on the reference area and presented as a function of angle of attack. CL is positive when the lift is an up acting load.
- **CM** - Vehicle pitching-moment coefficient based on the reference area and longitudinal reference length and presented as a function of angle of attack. Positive pitching moment causes a nose-up vehicle rotation.
- **CN** - Vehicle (body axis) normal-force coefficient based on the reference area and presented as a function of angle of attack. CN is positive when the normal force is in the +Z direction. Refer to Figure 5 for Z-axis definition.
- **CA** - Vehicle (body axis) axial-force coefficient based on the reference area and presented as a function of angle of attack. CA is positive when the axial force is in the +X direction. Refer to Figure 5 for X-axis definition.
- **XCP** - The distance between the vehicle moment reference center and the center of pressure divided by the longitudinal reference length. Positive is a location forward of the center of gravity. If output is given only for the first

angle of attack, or for those cases where pitching moment (CM) is not computed, the value(s) define the aerodynamic-center location; i.e., $XCP = dCm/dCL - (XCG - Xac) / c$

- CLA - Derivative of lift coefficient with respect to alpha. If CLA is output versus angle of attack, these values correspond to numerical derivatives of the lift curve. When a single value of CLA is output at the first angle of attack, this output is the linear-lift-region derivative. CLA is based on the reference area.
- CMA - Derivative of the pitching-moment coefficient with respect to alpha. If CMA is output versus angle of attack, the values correspond to numerical derivatives of the pitching-moment curve. When a single value of CMA is output at the first angle of attack, this output is the linear-lift-region derivative. CMA is based on the reference area and longitudinal reference length.
- CYB - Derivative of side-force coefficient with respect to sideslip angle. When CYB is defined independent of the angle of attack, output is printed at the first angle of attack. CYB is based on the reference area.
- CNB - Derivative of yawing-moment coefficient with respect to sideslip angle. When CNB is defined independent of angle of attack, output is printed at the first angle of attack. CNB is based on the reference area and lateral reference length.
- CLB - Derivative of rolling-moment coefficient with respect to sideslip angle presented as a function of angle of attack. CLB is based on the reference area and lateral reference length.
- • Q/QINF - Ratio of dynamic pressure at the horizontal tail to the freestream value presented as a function of angle of attack. When a single value of Q/QINF is output at the first angle of attack, this output is the linear-lift-region value.
- EPSILON - Downwash angle at horizontal tail expressed in degrees. Downwash angle has the same algebraic sign as the lift coefficient. Positive downwash implies that the local angle of attack of the horizontal tail is less than the free-stream angle of attack.
- D(EPSILON)/D(ALPHA) - Derivative of downwash angle with respect to angle of attack. When a single value of D(EPSILON)/ D(ALPHA) is output at the first angle of attack, it corresponds to the linear-lift-region derivative.

6.1.4 Dynamic Derivatives

Not all of the dynamic derivatives shown in Figure 25 are calculated for each combination of vehicle configuration and speed regime because of Datcom limitations. Aerodynamic characteristics that are available as output from Digital Datcom are presented in Table 2 as a function of vehicle configuration and speed

regime. See the Datcom Handbook, Section 1, for additional restrictions. Dynamic stability derivatives are expressed per degree or per radian at the users option (see Section 3.5).

- CLQ - Vehicle pitching derivative based on the product of reference area and longitudinal reference length.
- CMQ - Vehicle pitching derivative based on the product of reference area and the square of the longitudinal reference length.
- CLAD - Vehicle acceleration derivative based on the product of reference area and longitudinal reference length.
- CMAD - Vehicle acceleration derivative based on the product of reference area and the square of the longitudinal reference length.
- CLP - Vehicle rolling derivative based on the product of reference area and the square of the lateral reference length.
- CYP - Vehicle rolling derivative based an the product of reference area and lateral reference length.
- CNP - Vehicle rolling derivative based on the product of reference area and the square of the lateral reference length.
- CNR - Vehicle yawing derivative based on the product of reference area and the square of the lateral reference length.
- CLR - Vehicle rolling derivative based on the product of reference area and the square of the lateral reference length.

6.1.5 High Lift and Control

This output consists of two basic categories: symmetrical deflection of high lift and/or control devices, and asymmetrical control surfaces. The high lift/control data follow the same sign convention an the static aerodynamic coefficients. Available output is presented in Table 3 as a function of speed regime and control type. Users are urged to consult the Datcom for limitations and constraints imposed upon these characteristics. Output obtained from symmetrical flap analysis are as follows.

- DELTA - Control-surface streamwise deflection angle. Positive trailing edge down. Values of this array are user-specified in namelist SYMFLP.
- D(CL) - Incremental lift coefficient in the linear-lift angle-of-attack range due to deflection of control surface. Based on reference area and presented as a function of deflection angle.
- D(CM) - Incremental pitching-moment coefficient due to control surface deflection valid in the linear lift angle-of-attack range. Based on the product of reference area and longitudinal reference length. Output is a function of deflection angle.
- D(CL MAX) - Incremental maximum-lift coefficient. Based on reference area and presented as a function of deflection angle.

- D(CD MIN) - Incremental minimum drag coefficient due to control or flap deflection. Based on reference area and presented as a function of deflection angle.
- D(CDI) - Incremental induced-drag coefficient due to flap deflection based on reference area and presented as a function of angle-of-attack and deflection angle.
- (CLA)D - Lift-curve slope of the deflected, translated surface based on reference area and presented as a function of deflection angle.
- (CH)A - Control-surface hinge-moment derivative due to angle of attack based on the product of the control surface area and the control surface chord, $S_c C_c$. A positive hinge moment will tend to rotate the flap trailing edge down.
- (CH)D - Control-surface hinge-moment derivative due to control deflection based on the product of the control surface area and the control surface chord. A positive hinge moment will tend to rotate the flap trailing edge down.

Output obtained from asymmetrical control surfaces are given below. Left and right are related to a forward facing observer:

- DELTAL - Left lifting surface streamwise control deflection angle. Positive trailing edge down. Values in this array are user-specified in namelist ASYFLP.
- DELTAR - Right lifting-surface streamwise control deflection angle . Positive trailing edge down. Values in this array are user-specified in namelist ASYFLP.
- XS/C - Streamwise distance from wing leading edge to spoiler lip. Values in this array are input via namelist ASYFLP, Figure 19.
- HS/C - Projected height of spoiler measured from and normal to airfoil mean line. Values in this array are input via namelist ASYFLP.
- DD/C - Projected height of deflector for spoiler-slot-deflector control. Values in this array are input via namelist ASYFLP.
- DS/C - Projected height of spoiler control. Values in this array are input via namelist ASYFLP.
- (CL) ROLL - Incremental rolling moment coefficient due to asymmetrical deflection of control surface based on the product of reference area and lateral reference length. Positive rolling moment is right wing down.
- CN - Incremental yawing-moment coefficient due to asymmetrical deflection of control surface based on the product of reference area and lateral reference length. Positive yawing moment is nose right.

6.1.6 Trim Option

The Digital Datcom trim option provides subsonic longitudinal characteristics at the

calculated trim deflection angle of the control device. The trim calculations assume unaccelerated flight; i.e., the static pitching moment is set to zero without accounting for any contribution from a non-zero pitch rate. Trim output is also provided for an all-movable horizontal stabilizer at subsonic speeds. These data include untrimmed stabilizer coefficients C_D , C_L , C_m , and the hinge moment coefficients, stabilizer trim incidence and trimmed stabilizer coefficients C_D , C_m , and the hinge-moment coefficient; wing-body-tail C_D and C_L with stabilizer at trim deflection angle. Additional Digital Datcom symbols used in output are as follows:

- HM - Stabilizer hinge-moment coefficient based on the product of reference area and longitudinal reference length. Positive hinge moment will tend to rotate the stabilizer leading edge up and trailing edge down.
- ALIHT - Stabilizer incidence required to trim expressed in degrees. Positive incidence, or deflection, is trailing edge down.

The all-movable horizontal stabilizer trim output is presented as a function of angle of attack

6.1.7 Control at Hypersonic Speeds

Two types of control analyses are available at hypersonic speeds. They are transverse-jet control and flap effectiveness.

Data output from the hypersonic flap methods are incremental normal- and axial-force coefficients, associated hinge moments, and center-of-pressure location. These data are found from the local pressure distributions on the flap and in regions forward of the flap. The analysis includes the effects of flow separation due to windward flap deflection. This is done by providing estimates for separation induced pressures forward of the flap and reattachment on the flap. The users may specify laminar or turbulent boundary layers.

The transverse control jet method requires a user-specified time history of local flow parameters and control force required to trim or maneuver. With these data, the minimum jet plenum pressure necessary to induce separation is calculated. This minimum jet plenum pressure is then employed to calculate the nozzle throat diameter and the jet plenum pressure and propellant weight requirements to trim or maneuver the vehicle. Typical output can be seen in example problem 10.

6.1.8 Auxiliary and Partial Output

Auxiliary outputs consist of drag breakdown data, and basic configuration geometric properties. Partial outputs consist of component and vortex interference factors, effect of geometric parameters (e.g., dihedral and wing twist) on static and dynamic characteristics, canard effective-downwash data for transonic fairings and intermediate data that require user supplied data to complete. Typical output is

shown in Figure 2b.

6.1.9 Effective Downwash

Datcom methods for configurations where the forward lifting-surface span is less than 1.5 times the aft lifting-surface span do not explicitly provide estimates for either the downwash angle or gradient. However., Digital Datcom provides “effective-values” for those quantities. The canard effective downwash angle and gradient are defined as downwash data required to produce the correct wing-body-tail lift characteristics when applied to conventional configuration equations. The effective downwash gradient, $d\epsilon/d\alpha$, is found by equating the right hand sides of Datcom equations 4.5.1.1-a and 4.5-1.1-b. The effective downwash angle, ϵ , is found by equating the right hand sides of Datcom equations 4.5.1.2-a and 4.5.1.2-b.

6.2 DIGITAL DATCOM SYSTEM OUTPUT

Execution of Digital Datcom will produce a series of messages and data in addition to the results previously discussed. This information falls into three categories: input diagnostics and error analysis, extrapolation warning messages, and Airfoil Section Module output. In addition to those outputs, an optional listing of the case input namelist data is available by using the NAMELIST control card (see Section 3.5). Additional output may be obtained by using the DUMP and PART control cards. When the DUMP option is exercised, the contents of user specified data blocks are output prior to the conventional aerodynamic characteristics output. A list of the arrays and variables stored in each data block is presented in Appendix C.

6.2.1 Input Error Analysis

An input diagnostic module (CONERR) checks all data in the input stream prior to execution of any other Digital Datcom module. This module checks all namelist and control cards and flags any errors. CONERR headings and error messages are designed to be self explanatory. All input cards are listed and any cards containing errors have the appropriate message written immediately to the right of the card. An explanation of the seven messages that can be generated by CONERR are given in Table V. CONERR will not correct any errors and the program will attempt to execute each case using the data as input by the user.

Prior to case execution, additional input error analysis is conducted to insure that all namelists essential to the case are present. This analysis will abort only those cases missing an essential namelist. The messages that can be produced by this analysis are given in Table 15.

6.2.2 Extrapolation Messages

Extrapolation messages are produced when the independent variable range of the Datcom figures (nomographs/design charts) have been exceeded. Those messages identify the number of the figure involved, the independent variable values currently being used, the resultant value of the dependent variable, the type of extrapolation that was used to generate the dependent variables and the name of the table lookup

routine and the subroutines that contains the figure. They are printed primarily to alert users when the normal limit of Datcom figures has been exceeded so that the user can determine the credibility of the results. The messages are listed at the end of the case output. Extrapolation message interpretation is illustrated in Figure 27. The extrapolation messages are written to a computer system “scratch tape” as they are generated. At the conclusion of the case they are read and sorted by figure number within each program overlay. In this way all, extrapolations for a single figure produced in a method module are output together for convenience. Note that these extrapolation messages are not necessarily output in their order of occurrence in the program.

6.2.3 Airfoil Section Module

The Airfoil Section Module is executed whenever airfoil section characteristics are to be calculated. Output consists of section coordinates and a listing of the calculated section characteristics.