Public Domain Computer Programs for the Aeronautical Engineer

For many years the Air Force, Navy, NASA and educational institutions have sponsored the development of computer software for the use of aeronautical engineers and aviation technicians. Public Domain Aeronautical Software's purpose is to make this treasure house available to the aeronautical community at an affordable price for current desktop computers. Most PDAS programs are ready to execute (Windows, Linux, Macintosh) and come with complete source code, descriptions, and sample cases (both input and output). For many programs, there is graphical output formatted for gnuplot or PostScript. You may use the source code in whole or in part in any of your aeronautical studies. If the original references are available in portable document format (pdf), they are included on the disc. All of this is available on the CD-ROM *Public Domain Computer Programs for the Aeronautical Engineer.*

CONTENTS OF CURRENT VERSION (Last updated 3 September 2009)
The bold name following the slash at the end of each description is the name of the folder on the disc holding the files for this program.

1. D2500 - Wave Drag by Area Rule. This is the famous Harris Wave Drag Program from NASA Langley. D2500 calculates the supersonic zero-lift wave drag of complex aircraft configurations by use of the supersonic area rule. This an extension of the transonic area rule that states that the zero-lift drag of an airplane configuration is the same as that of a body of revolution having the same cross-sectional area distribution. Instead of using a single equivalent body, D2500 calculates a series of bodies, one for each roll angle. The total aircraft configuration wave drag is the integrated average of the equivalent body wave drags through the full roll range of 360 degrees. There are program options that permit the calculation of best fuselage shaping for drag reduction. Copies of the original papers on area rule are included on the CD-ROM. **/WAVEDRAG**
2. WingBody - Subsonic/Supersonic Panel Code. This is the Woodward panel code popularly known as the NASA-Ames WingBody Program. This program estimates the aerodynamics of a simple wing-body-tail combination in subsonic or supersonic flow, as well as calculating wing shape for minimum drag in supersonic cruise. The body is represented by line sources and doublets and the lifting surfaces are represented by source panels and constant pressure panels. **/WINGBODY**
3. PanAir - This program computes subsonic and supersonic flow about general aircraft configurations using a higher order panel method. In contrast to the low order codes such as WingBody, the source and doublet strengths are variable over the individual panels. This leads to a solution with continuous doublet strength over the surface of the vehicle, thereby eliminating the flow singularities associated with jumps in doublet strength.This is necessitated by the more stringent requirements of supersonic problem. The potential for numerical error is greatly reduced in the PanAir program by requiring the singularity strength to be continuous. It is also this higher order attribute which

allows PanAir to be used to analyze flow about arbitrary configurations. To perform an analysis, the aircraft surface is partitioned into several networks of surface grid points. The user also supplies information concerning the freestream onset flow, the angle of attack, and the angle of sideslip. Numerous flow quantities are computed at points on the vehicle surface and at points in space. These include pressure coefficients, total and perturbation values of velocity and mass flux components, total and perturbation potential, local Mach number, and vacuum pressure coefficient. The pressure coefficients on individual panels are fitted with two-dimensional quadratic splines and integrated to obtain the six components of force and the moment coefficients. These coefficients may be output for each panel, for columns of panels, for each network, or for any combination of networks. The user has extensive control over the type and quantity of data that is output during a PanAir Analysis. (By Boeing, under contract to NASA Ames and Langley, USAF and USN). The Panair users manual and many references are on the disc. **/PANAIR**

4. Coordinates of NACA Airfoils - computes the ordinates of 4-digit, 4-digit-modified, 5-digit, 6-series, and 16-series airfoils. This is a complete revision of the original NASA Langley programs based on AIAA-2001-5235. The results are shown in various densities, from coarse to very fine. Numerous sample cases are included to help a user to become familiar with the input data. In fact, input files for all of the airfoils shown in the appendices to Abbott and von Doenhoff, *Theory of Airfoil Sections* are provided. Coding is provided to show how all of the appendices to Abbott and von Doenhoff have been recomputed to correct numerous typographic errors in the published book. These corrected appendices are posted on the PDAS web site. All of the relevant NACA, NASA, and AIAA reports are on the disc. A copy of the NASA program released in 1996 is also included for reference. **/NACA456**
5. Digital Datcom - The USAF Data Compendium is a large document describing methods for computing aircraft stability and control characteristics. Many methods are included so as to compute the characteristics of a wide variety of airplane and missile configurations. The Digital Datcom program was developed to automate the process of extracting variables from the hundreds of empirical charts in the printed document. The Digital Datcom users manual, AFFDL-TR-79-3032, vol.I and the complete USAF Datcom report are on the disc. **/DATCOM**
6. Characteristics of the Standard Atmosphere. - Atmosphere is a program that computes pressure, density, temperature, speed of sound, and viscosity from sea level to 1000 km, using the equations of the 1976 Standard Atmosphere. A copy of the official document from the Government Printing Office is included on the CD-ROM. Separate versions are available in Basic, C, Fortran77, Pascal (Delphi), Python, C++, and Fortran. Sample programs in each language allow printing an atmosphere table. The routines from 86 to 1000 km are a contribution of Steve Pietrobon. In addition to the standard atmosphere, routines are provided for both hot and cold days as well as the MIL-standard arctic and tropical days. **/ATMOS**
7. GetMAC - solves for the mean aerodynamic chord of a wing made up of several segments. This is a straightforward coding of the standard equations combined with a user interface that should prove easy to use. The output defines the length of the mean

aerodynamic chord as well as its x- and y-positions and the location of the quarter-chord point. **/GETMAC**

8. VuCalc - Interactive Compressible Flow Solver. This program was originally written by Tom Benson of the NASA Lewis Research Center for a SGI workstation. It is now converted for use with Microsoft Windows. VuCalc permits one to compute compressible flow quantities. In addition to direct solutions, VuCalc also performs inverse calculations. VuCalc calculates isentropic flow, normal shock, oblique shock and flight in the standard atmosphere. VuCalc has now been updated to compute Rayleigh and Fanno flows. A copy of NACA Report 1135 is included on the CD-ROM. **/VUCALC**
9. PanAir Input Preprocessor - Panin allows the user to write a script file in free format that reads a geometry file in LaWGS format and produces a properly formatted input file for PanAir. The column formatted file that is the native input for PanAir is quite efficient, but error prone. The PanAir Input Preprocessor will help you get a correct input file for PanAir. **/PANIN**
10. Wing and Fuselage Geometry Generator - The program MakeWgs creates wireframe models of wings or bodies that are then used with the PanAir preprocessor to create input files for PanAir, or for HiddenLine or ThreeView. The wings can have NACA 4-digit airfoils as well as several supersonic airfoils. Bodies that have been programmed include parabolic, Sears-Haack, von Karman Ogive, ellipsoid, etc. A copy of NASA Memorandum 85767, which is the formal description of LaWGS, is on the disc. **/MAKEWGS**
11. Potential Flow About Airfoils with Boundary-Layer Coupled One-Way. This program, PABLO, solves for potential flow about airfoils and computes the boundary layer, thereby giving the solution for flow over the combined airfoil and boundary layer. PABLO has a very nice graphical interface displaying geometry, pressures, and boundary-layer characteristics. This program is from KTH in Sweden, compliments of Christian Wauquiez and Art Rizzi. Pablo is written with Matlab and requires that a version of Matlab (student edition OK) be installed on the user's machine. **/PABLO**
12. Quiz Program - This program drills the student for simple facts. There are currently quizzes for the aviation phonetic alphabet, Morse code, dimensionless numbers of fluid mechanics and 3-letter airport codes. **/QUIZ**
13. Flow Field in Supersonic Inlet - based on 2D or axisymmetric method of characteristics. This is a NASA Ames program by Virginia Sorensen. **/INLET**
14. Arrow Wing Wave Drag and Lift. This module encodes the closed form solution for the wave drag of an arrow or delta wing with sharp edges. It is based on a paper by Arthur Rogers that generalized the classic result of Puckett and Stewart. The tedious equations are coded in a module that should prove easy to use in various aerodynamic programs. **/ROGERS**
15. Gas Properties - Thermodynamic and transport properties of gases. GASP has been written to calculate the thermodynamic and transport properties of argon, carbon dioxide, carbon monoxide, fluorine, methane, neon, nitrogen, and oxygen. GASP accepts any two of pressure, temperature, or density as input. In addition, entropy and enthalpy are possible inputs. Outputs are temperature, density, pressure, entropy, enthalpy, specific heats, expansion coefficient, sonic velocity, viscosity, thermal

conductivity, and surface tension. A special technique is provided to estimate the thermal conductivity near the thermodynamic critical point. GASP is a group of Fortran subroutines. The user typically would write a main program that invoked GASP to provide only the described outputs. Subroutines are structured so that the user may call only those subroutines needed for his particular calculations. Allowable pressures range from 0.l atmosphere to 100 to l,000 atmospheres, depending on the fluid. Similarly, allowable pressures range from the triple point of each substance to 300 degrees K to 2000 degrees K, depending on the substance. The GASP package was developed to be used with heat transfer and fluid flow applications. It is particularly useful in applications of cryogenic fluids. Some problems associated with the liquefication, storage, and gasification of liquefied natural gas and liquefied petroleum gas can also be studied using GASP. A copy of the original document, NASA TN D-7808 from NASA Lewis is included on the CD-ROM. /**GASP**

16. FLUID - Thermodynamic and transport properties of fluids. The accurate computation of the thermodynamic and transport properties of fluids is a necessity for many engineering calculations. The FLUID program was developed to calculate the thermodynamic and transport properties of pure fluids in both the liquid and gas phases. Fluid properties are calculated using a simple gas model, empirical corrections, and an efficient numerical interpolation scheme. FLUID produces results that are in very good agreement with measured values, while being much faster than older more complex programs developed for the same purpose. A Van der Waals equation of state model is used to obtain approximate state values. These values are corrected for real gas effects by model correction factors obtained from tables based on experimental data. These tables also accurately compensate for the special circumstances which arise whenever phase conditions occur. Viscosity and thermal conductivity values are computed directly from tables. Interpolation within tables is based on Lagrange's three point formula. A set of tables must be generated for each fluid implemented. FLUID currently contains tables for nine fluids including dry air and steam. The user can add tables for any fluid for which adequate thermal property data is available. The FLUID routine is structured so that it may easily be incorporated into engineering programs. Also from NASA Lewis. A copy of the original document, NASA TM X-3572 is included on the CD-ROM. FLUID is a companion program to the gas properties program GASP. **/FLUID**
17. Three-Dimensional Surface Viewer. - Viewer is a package of Fortran subprograms to draw three-dimensional surfaces of the form z = f (x, y) over a rectangular domain. It uses a given recipe to generate views of the surface after arbitrary rotations about the three spatial axes.The function f and the bounding values for x and y are the inputs. The surface thus defined may be drawn after arbitrary rotations. Output is to gnuplot. The viewing algorithm is completely described and sample programs are included. Viewer was written by Bruce Canwright and Paul Swigert of NASA Lewis. A copy of the original document, NASA TM X-1598, is included on the CD-ROM. **/VIEWER**
18. Induced Drag from Span Load Distribution - Advanced aerodynamics textbooks show you how to compute induced drag by Fourier analysis of the span load function. They don't tell you what to do if you only know a few discrete points on the loading function. This procedure allows you to compute the induced drag from the spanwise load

distribution when only a few load values are known. Based on a note by Jerry Lundry. **/INDUCED**

19. Wing Shape for Minimum Induced Drag by Vortex Lattice - computes the optimum shape of a wing-tail or wing-canard using vortex lattice analysis, by John Lamar and Jeanne Peters of NASA Langley. This program is documented in NASA TN D-8090 and a copy of this document is on the disc. **/VLMD**
20. FairData - compute a smoothing spline for plotting wind tunnel data. This program is by Robert Smith and Lona Howser of NASA Langley. The program is documented in NASA TN D-7397 and a copy of this report is on the disc. **/FAIRDATA**
21. Hidden-Line Program - Draws perspective views with hidden line removal of an arbitrary configuration defined by wireframe meshes of gridpoints. This is the Silhouette program by David Hedgley of NASA Dryden. The configuration description is in the format known as the Langley Wire Frame Geometry Standard (LaWGS). Output is for gnuplot or PostScript. Includes copies of the original documents, NASA RP-1085, NASA TP 2695, and NASA TM 81369 . **/HLP**
22. ThreeView - produce plan, side, and rear views from the same input file as HiddenLine. **/3VIEW**
23. Conversion Programs - a set of three programs for converting input files for WingBody, WaveDrag, or PanAir into LaWGS format. The resulting file can be used as input for HiddenLine or for ThreeView. Includes a copy of NASA Memorandum 85767, describing the NASA wireframe geometry standard. A fourth program that converts input files from the S/HABP program into LaWGS is also included on the disc, but must be regarded as a work in progress. **/2WGS**
24. Turbulent Skin Friction - a simple subroutine and test program for encoding the reference temperature method of computing turbulent skin friction. A copy of NACA TN 3391 by Simon Sommer and Barbara Short is on the disc. **/TURBSF**
25. Design and Analysis of Low Speed Airfoils - This is the original version of the airfoil program by Richard Eppler of the University of Stuttgart and Dan Somer of NASA Langley. This is a classic program for the design of 2-D airfoils including the effects of the boundary layer. A copy of NASA TM 80210 by Eppler and Sommers is on the disc. **/EPPLER**
26. Solution of Quartic and Cubic Polynomials with Real Coefficients. Algorithms have been developed and coded to avoid overflow and roundoff errors in computing roots of polynomials with real coefficients, up to quartic order. These subroutines were carefully written by Alfred Morris and William Davis of the Naval Surface Weapons Center. **/QUARTIC**
27. Virtual Reality Model of Airplane Configuration - This program converts a wireframe model in LaWGS format into a VRML model. Use a VRML viewer to explore the three dimensional scene. There is a long dormant project to allow web browsers such as Internet Explorer or Firefox to display three-dimensional objects and visualize the object from various angles. I am trying to stay on top of this effort in order to be able visualize wireframes and surfaces if this ever comes to pass. **/VRML**
28. Contour Plotter - plot contours of a function defined at an arbitrary set of points in 2-D. The graphical presentation of experimentally or theoretically generated data sets frequently involves the construction of contour plots. A general computer algorithm has

been developed for the construction of contour plots. The algorithm provides for efficient and accurate contouring with a modular approach which allows flexibility in modifying the algorithm for special applications. The algorithm accepts as input data values at a set of points irregularly distributed over a plane. The algorithm is based on an interpolation scheme in which the points in the plane are connected by straight line segments to form a set of triangles. In general, the data is smoothed using a least-squares-error fit of the data to a bivariate polynomial. To construct the contours, interpolation along the edges of the triangles is performed, using the bivariable polynomial if data smoothing was performed. Once the contour points have been located, the contour may be drawn. (NASA Ames Research Center) **/CONPLOT**

29. Optimum Flight Trajectory - find the best climb, cruise and descent path using energy methods. (From NASA Ames). **/OPTTRAJ**
30. Orbiting solar array simulation model. - Solar arrays are becoming an increasingly important means of generating power for earth orbiting spacecraft. Currently, almost all unmanned earth satellites utilize solar array electrical power generation systems.Applications for solar arrays in the near future include providing power for space shuttle payloads and manned space stations. This computer program was developed to simulate the capabilities of earth orbiting arrays. The model used is based on an improved version of a finite-element radiation shape factor subprogram. The inherent simplicity and speed of the original subprogram has been augmented with an improved shadow evaluation technique to provide the user with an efficient array model. The program allows the characteristics of orbiting arrays to be evaluated with a minimum of user effort and computer cost. Input to the program consists of a brief description of the array and the orbital parameters. The orbital parameters are used to determine the direct solar radiation incident on the cells, incident solar radiation reflected to cells from the earth, and the shadowing of any cells. Once the amount of thermal radiation gained and lost by the array is known, the amount of power which can be generated and the temperature of the array is determined. **/SOLARARR**
31. Tidy. After a computer program has been under development for some time, the statement numbers and indentation patterns tend to get out of order and lack consistency. The Tidy program renumbers Fortran programs and indent loops consistently. Tidy can convert variables to upper or lower case. It can also convert Hollerith strings to quote-delimited. (From USAF Weapons Center (Kirtland)) **/TIDY**
32. LineInt and LinIntrp - solve for intersections of straight lines and compute interpolated points on a straight line. These programs are useful in making configuration layouts. /**LINEINT** and **/LININTRP**
33. Hypersonic Arbitrary Body - an all-new rewrite of the essential inviscid features of the famous program from Douglas for USAF. New version (Fortran 95) uses LaWGS geometry input. Includes a major contribution from Igor Polykov of an interactive version of the original Mark 4 program. A full copy of the Mark 4 program is on the disc. **/HYPER**
34. Computer Methods for Mathematical Computation - A translation into Fortran 95 of the procedures from the classic textbook *Computer Methods for Mathematical Computation* by Forsythe, Malcolm and Moler. **/FMM**

35. Analysis of aircraft motions. This program was developed by Ames Research Center, in cooperation with the National Transportation Safety Board, as a technique for deriving time histories of an aircraft's motion from Air Traffic Control (ATC) radar records. This technique uses the radar range and azimuth data, along with the downlinked altitude data, to derive an expanded set of data which includes airspeed, lift, attitude angles (pitch, roll, and heading), etc. This technique should prove useful as a source of data in the investigation of commercial airline accidents and in the analysis of accidents involving aircraft which do not have onboard data recorders (e.g., military, short-haul, and general aviation). The technique used to determine the aircraft motions involves smoothing of raw radar data. These smoothed results, in combination with other available information (wind profiles and aircraft performance data), are used to derive the expanded set of data. This program uses a cubic least-square fit to smooth the raw data. This moving-arc procedure provides a smoothed time history of the aircraft position, the inertial velocities, and accelerations. Using known winds, these inertial data are transformed to aircraft stability axes to provide true airspeed, thrust minus drag, lift, and roll angle. Further derivation, based on aircraft dependent performance data, can determine the aircraft angle of attack, pitch, and heading angle. Results of experimental tests indicate that values derived from ATC radar records using this technique agree favorably with airborne measurements. **/ATC**
36. Supersonic Airplane Design. The famous Carlson-Middleton program for analysis and design of supersonic wings. **/TEA201**
37. Modified strip analysis method for predicting wing flutter at subsonic to hypersonic speeds. - A modified strip analysis has been developed for rapidly predicting flutter of finite-span, swept or unswept wings at subsonic to hypersonic speeds. The method employs distributions of aerodynamic parameters which may be evaluated from any suitable linear or nonlinear steady-flow theory or from measured steady-flow load distributions for the undeformed wing. The method has been shown to give good flutter results for a broad range of wings at Mach number from 0 to as high as 15.3. The principles of the modified strip analysis may be summarized as follows:
    Variable section lift-curve slope and aerodynamic center are substituted respectively, for the two-dimensional incompressible-flow values of 2 pi and quarter chord which were employed by Barmby, Cunningham, and Garrick. Spanwise distributions of these steady-flow section aerodynamic parameters, which are pertinent to the desired planform and Mach number, are used. Appropriate values of Mach number-dependent circulation functionsare obtained from two-dimensional unsteady compressible-flow theory. Use of the modified strip analysis avoids the necessity of reevaluating a number of loading parameters for each value of reduced frequency, since only the modified circulation functions, and of course the reduced frequency itself, vary with frequency. It is therefore practical to include in the digital computing program a very brief logical subroutine, which automatically selects reduced-frequency values that converge on a flutter solution. The problem of guessing suitable reduced-frequency values is thus eliminated, so that a large number of flutter points can be completely determined in a single brief run on the computing machine. If necessary, it is also practical to perform the calculations manually. Flutter characteristics have been calculated by the modified strip analysis and compared with results of other calculations and with experiments for Mach numbers up

to 15.3 and for wings with sweep angles from 0 degrees to 52.5 degrees, aspect ratios from 2.0 to 7.4, taper ratios from 0.2 to 1.0, and center-of-gravity positions between 34% chord and 59% chord. These ranges probably cover the great majority of wings that are of practical interest with the exception of very low-aspect-ratio surfaces such as delta wings and missile fins.(NASA Langley Research Center) **/FLUTTER**

38. GRAPE- Two-dimensional grids about airfoils and other shapes by the use of Poisson's equation. - The ability to treat arbitrary boundary shapes is one of the most desirable characteristics of a method for generating grids, including those about airfoils. In a grid used for computing aerodynamic flow over an airfoil, or any other body shape, the surface of the body is usually treated as an inner boundary and often cannot be easily represented as an analytic function. The GRAPE computer program was developed to incorporate a method for generating two-dimensional finite-difference grids about airfoils and other shapes by the use of the Poisson differential equation. GRAPE can be used with any boundary shape, even one specified by tabulated points and including a limited number of sharp corners. The GRAPE program has been developed to be numerically stable and computationally fast. GRAPE can provide the aerodynamic analyst with an efficient and consistent means of grid generation. The GRAPE procedure generates a grid between an inner and an outer boundary by utilizing an iterative procedure to solve the Poisson differential equationsubject to geometrical restraints. In this method, the inhomogeneous terms of the equation are automatically chosen such that two important effects are imposed on the grid. The first effect is control of the spacing between mesh points along mesh lines intersecting the boundaries. The second effect is control of the angles with which mesh lines intersect the boundaries. Along with the iterative solution to Poisson's equation, a technique of coarse-fine sequencing is employed to accelerate numerical convergence. GRAPE program control cards and input data are entered via the NAMELIST feature. Each variable has a default value such that user supplied data is kept to a minimum. Basic input data consists of the boundary specification, mesh point spacings on the boundaries, and mesh line angles at the boundaries. Output consists of a dataset containing the grid data and, if requested, a plot of the generated mesh. This program is by Reese Sorensen of NASA Ames Research Center. **/GRAPE**
39. Mass properties of a rigid structure. The computer program MASSPROP was developed to calculate the mass properties of complex rigid structural systems. This program's basic premise is that complex systems can be adequately described by a combination of basic elementary structural shapes. Thirteen widely used basic structural shapes are available in this program. They are as follows: Discrete Mass, Cylinder, Truncated Cone, Torus, Beam (arbitrary cross section), Circular Rod (arbitrary cross section), Spherical Segment, Sphere, Hemisphere, Parallelepiped, Swept Trapezoidal Panel, Symmetric Trapezoidal Panels, and a Curved Rectangular Panel. MASSPROP provides a designer with a simple technique that requires minimal input to calculate the mass properties of a complex rigid structure and should be useful in any situation where one needs to calculate the center of gravity and moments of inertia of a complex structure. Rigid body analysis is used to calculate mass properties. Mass properties are calculated about component axes that have been rotated to be parallel to the system coordinate axes. Then the system center of gravity is calculated and the mass properties are

transferred to axes through the system center of gravity by using the parallel axis theorem. System weight, moments of inertia about the system origin, and the products of inertia about the system center of mass are calculated and printed. From the information about the system center of mass the principal axes of the system and the moments of inertia about them are calculated and printed. The only input required is simple geometric data describing the size and location of each element and the respective material density or weight of each element. This program was written by Reid Hull, John Gilbert, and Phillip Klitch of NASA Langley. A copy of NASA TM 78681 by Hull, Gilbert, and Klitch is on the disc.

40. Steady and oscillatory kernel function method for interfering surfaces in subsonic, transonic and supersonic flow. - Interest has grown considerably in aircraft designed to operate efficiently in the high subsonic regime. This interest has increased the need for better unsteady transonic aerodynamic analysis techniques so that flutter and dynamic response characteristics can be accurately predicted in this flow regime. The characteristic of transonic flow which causes the greatest difficulty when attempting to apply uniform flow theory to such problems is the presence of shocks imbedded in the flow. Linear theory cannot account for this phenomenon and finite difference approaches often require extremely costly amounts of computer time. This computer program was developed to provide an analysis method based on a kernel function technique which uses assumed pressure functions with unknown coefficients. With this technique, generalized forces can be calculated in unsteady flow and pressure distributions can be obtained in both steady and unsteady flow. Once the aerodynamic matrices are computed and inverted, they may be saved and used on subsequent problems at very little cost as long as Mach number, reduced frequencies, and aerodynamic geometry remain unchanged. This method should be very useful for design applications where the structural mode shapes change continually due to structural changes and payload variations but the aerodynamic parameters remain constant. In this program, a wing over which the flow has mixed subsonic and supersonic components with imbedded shocks is treated as an array of general aerodynamic lifting surface elements. Each element is allowed to have mutual interference with the other elements. Each element is assigned the appropriate Mach number and its downwash modified accordingly. The Mach number distribution and shock geometry may be obtained either experimentally or by a finite difference technique. The solution proceeds in a manner identical to ordinary aerodynamic interference methods based on a collocation technique. The unknown pressure function is assumed to be composed of a series of polynomials weighted by a user selected weighting function that is characteristic of each lifting surface. The non-planar kernel function is computed using a Mach number and a reduced frequency determined from values at a downwash control point. To link subsonic and supersonic linear theory solutions, it is assumed that the appropriate Mach number for computing downwash at a point is the Mach number at that point and that the reduced frequency is modified according to the local velocity such that the physical frequency is held constant. Thus, the computation procedure becomes a problem of testing the Mach number of the downwash point. If the downwash point is supersonic, the self-induced downwash and all interference effects at that point are computed with the supersonic kernel function. Likewise, if the downwash point is subsonic, the subsonic kernel

function is used. The presence of a normal shock is simulated by a line doublet which represents the load induced by shock movement. The appropriate steady or unsteady normal shock boundary conditions are satisfied across the shock along the surface of the wing. The computed aerodynamic matrices may be saved on magnetic tape for use in subsequent analyses. (By Atlee Cunningham of General Dynamics under contract to NASA Langley). **/KERNEL**

41. MISLIFT- Aerodynamic lift on wing-body combinations at small angles of attack in supersonic flow. Two separate and distinct theories are incorporated in this computer program to estimate the lift-induced pressures existent on a wing-body combination. These are (1) the second-order shock-expansion theory, which is used to obtain the lifting pressures on the body alone at small angles of attack, and (2) the linear-theory integral equations, which is used to evaluate the lifting pressures induced by the wing. These equations relate the local surface slope at a point on the lifting surface to the pressure differential at the point and the influence of the pressures upstream of the point. The numerical solution of these equations is effected by treating the wing-planform as a composite of elemental rectangles and applying summation techniques to satisfy the necessary integral relations. Most of the input required by this program is involved with the description of the missile planform geometry. The output consists of the computed value of the lifting pressure slope (the differential pressure coefficient per degree angle of attack) for each of the elements in the planform array. A force and moment summary is presented for the configuration under consideration. (NASA Langley Research Center) **/MISLIFT**
42. ORACLS- Optimal regulator algorithms for the control of linear systems. - This control theory design package, called Optimal Regulator Algorithms for the Control of Linear Systems (ORACLS), was developed to aid in the design of controllers and optimal filters for systems which can be modeled by linear, time-invariant differential and difference equations. Optimal linear quadratic regulator theory, currently referred to as the Linear-Quadratic-Gaussian (LQG) problem, has become the most widely accepted method of determining optimal control policy. Within this theory, the infinite duration time-invariant problems, which lead to constant gain feedback control laws and constant Kalman-Bucy filter gains for reconstruction of the system state, exhibit high tractability and potential ease of implementation. A variety of new and efficient methods in the field of numerical linear algebra have been combined into the ORACLS program, which provides for the solution to time-invariant continuous or discrete LQG problems. The ORACLS package is particularly attractive to the control system designer because it provides a rigorous tool for dealing with multi-input and multi-output dynamic systems in both continuous and discrete form. The ORACLS programming system is a collection of subroutines which can be used to formulate, manipulate, and solve various LQG design problems. The ORACLS program is constructed in a manner which permits the user to maintain considerable flexibility at each operational state. This flexibility is accomplished by providing primary operations, analysis of linear time-invariant systems, and control synthesis based on LQG methodology. The input-output routines handle the reading and writing of numerical matrices, printing heading information, and accumulating output information. The basic vector-matrix operations include addition, subtraction, multiplication, equation, norm construction, tracing, transposition, scaling,

juxtaposition, and construction of null and identity matrices. The analysis routines provide for the following computations: the eigenvalues and eigenvectors of real matrices; the relative stability of a given matrix; matrix factorization; the solution of linear constant coefficient vector-matrix algebraic equations; the controllability properties of a linear time-invariant system; the steady-state covariance matrix of an open-loop stable system forced by white noise; and the transient response of continuous linear time-invariant systems. The control law design routines of ORACLS implement some of the more common techniques of time-invariant LQG methodology. For the finite-duration optimal linear regulator problem with noise-free measurements, continuous dynamics, and integral performance index, a routine is provided which implements the negative exponential method for finding both the transient and steady-state solutions to the matrix Riccati equation. For the discrete version of this problem, the method of backwards differencing is applied to find the solutions to the discrete Riccati equation. A routineis also included to solve the steady-state Riccati equation by the Newton algorithms described by Klein, for continuous problems, and by Hewer, for discrete problems. Another routine calculates the prefilter gain to eliminate control state cross-product terms in the quadratic performance index and the weighting matrices for the sampled data optimal linear regulator problem. For cases with measurement noise, duality theory and optimal regulator algorithms are used to calculate solutions to the continuous and discrete Kalman-Bucy filter problems. Finally, routines are included to implement the continuous and discrete forms of the explicit (model-in-the-system) and implicit (model-in-the-performance-index) model following theory. These routines generate linear control laws which cause the output of a dynamic time-invariant system to track the output of a prescribed model. In order to apply ORACLS, the user must write an executive (driver) program which inputs the problem coefficients, formulates and selects the routines to be used to solve the problem, and specifies the desired output. This software was written by Ernest Armstrong of NASA Langley. A copy of NASA TP 1106 is included on the disc. **/ORACLS**

43. VASP- Variable dimension automatic synthesis program. - VASP is a variable dimension Fortran version of the Automatic Synthesis Program, ASP. The program is used to implement Kalman filtering and control theory. Basically, it consists of 31 subprograms for solving most modern control problems in linear, time-variant (or time-invariant) control systems. These subprograms include operations of matrix algebra, computation of the exponential of a matrix and its convolution integral, and the solution of the matrix Riccati equation. The user calls these subprograms by means of a Fortran main program, and so can easily obtain solutions to most general problems of extremization of a quadratic functional of the state of the linear dynamical system. Particularly, these problems include the synthesis of the Kalman filter gains and the optimal feedback gains for minimization of a quadratic performance index. VASP, as an outgrowth of the Automatic Synthesis Program, has the following improvements: more versatile programming language; more convenient input/output format; some new subprograms which consolidate certain groups of statements that are often repeated; and variable dimensioning. The pertinent difference between the two programs is that VASP has variable dimensioning and more efficient storage. The documentation for the VASP program contains a VASP dictionary and example problems. The dictionary contains a

description of each subroutine and instructions on its use. The example problems include dynamic response, optimal control gain, solution of the sampled data matrix Riccati equation, matrix decomposition, and a pseudo-inverse of a matrix. This subroutine library was written by John White and Homer Lee of NASA Ames. **/VASP**

44. Variable metric algorithm for constrained optimization. VMACO is a non-linear program developed to calculate the least value of a function of N variables subject to general constraints (both equality and inequality). Generally, the first set of constraints is an equality (the target) and the remaining constraints are inequalities (boundaries). The VMACO program utilizes an iterative method in seeking the optimal solution. It can be "hooked" into a driver program (examples are provided) which can calculate the values for the real function, constraints, and their first order partials with respect to the controls. The algorithm is based upon a variable metric method presented by M.J.D. Powell and a quadratic programming method by R. Fletcher. This implementation requires more overhead in calculating each new control variable, but fewer iterations are required for convergence. In comparison with other algorithms, it has been found that VMACO handles test cases withconstraints particularly well, and that less execution time is necessary for convergence. VMACO was written by J. D. Frick of McDonnell Douglas Corp./Houston for NASA Marshall. **/VMACO**

45. W12SC3 - Supersonic wing design and analysis using source and vortex panel singularity distributions, based on the USSAERO program by Woodward. W12SC3 combines source and vortex panel singularity distributions forcalculating the linear theory estimate of the configuration aerodynamics. The user can specify Woodward II calculations for arbitrary body models or Woodward I calculations for an interference shell that approximates actual body shape. The Carlson correction for supersonic linear theory wing calculations is applied at wing control points. If desired, COREL will produce conical panel pressure data for further processing by W12SC3. W12SC3 can perform the following aerodynamic functions:
    1) full analysis,
    2) full design,
    3) full optimization,
    4) mixed design-analysis, and
    5) mixed design-optimization.

    Results from W12SC3 include wing camber distribution, surface velocities, pressure coefficients and drag. **/W12SC3**

46. Rational spline subroutines. - Scientific data often contains random errors that make plotting and curve-fitting difficult. The Rational-Spline Approximation with Automatic Tension Adjustment algorithm lead to a flexible, smooth representation of experimental data. The user sets the conditions for each consecutive pair of knots: (knots are user-defined divisions in the data set) to apply no tension; to apply fixed tension; or to determine tension with a tension adjustment algorithm. The user also selects the number of knots, the knot abscissas, and the allowed maximum deviations from line segments. The selection of these quantities depends on the actual data and on the requirements of a particular application. This program differs from the usual spline under tension in that it allows the user to specify different tension values between each adjacent pair of knots rather than a constant tension over the entire data range. The subroutines use an

automatic adjustment scheme that varies the tension parameter for each interval until the maximum deviation of the spline from the line joining the knots is less than or equal to a user-specified amount. This procedure frees the user from the drudgery of adjusting individual tension parameters while still giving control over the local behavior of the spline. This software was developed and coded by James R. Schiess and Patricia A. Kerr of NASA Langley. A copy of NASA Technical Paper 2366 is included on the CD-ROM. **/RSPLINE**

47. Transient response of ablating axisymmetric bodies including the effects of shape change (ABAXI). Some of the features of the analysis and the associated program are (1) the ablation material is considered to be orthotropic with temperature-dependent thermal properties; (2) the thermal response of the entire body is considered simultaneously; (3) the heat transfer and pressure distribution over the body are adjusted to the new geometry as ablation occurs; (4) the governing equations and several boundary-condition options are formulated in terms of generalized orthogonal coordinates for fixed points in a moving coordinate system; (5) the finite-difference equations are solved implicitly; and (6) other instantaneous body shapes can be displayed with a user-supplied plotting routine. NASA Langley program by Lona Howser. Copies of NASA reports TM X-2375 and TN D-6220 are on the disc. **/ABAXI**

WORKS IN PROGRESS

I have a number of programs that are incomplete or lacking in documentation. Many of these are full of interesting source code and might prove useful to the aeronautical engineer interested in computational methods. I will continue to attempt to bring these programs up to the full standard for release, but others may wish to examine the inner workings of the code and perhaps discover some of the missing documents and test cases. These works-in-progress will be included on the CD-ROM, beginning in January 2009.

1. Analytical comparisons of ablative nozzle materials. This program is designed to predict the ablation performance of rocket nozzle heat protection materials. The program is based on the use of nonsymmetrical difference equations that are employed to solve systems of complex partial differential equations.The program can be used to predict the thermal degradation of a wide variety of materials exposed to an external source of heat. It can be generally adapted to the simulation of processes involving heat and mass transfer by substituting specific parameters into the basic equations. The program also includes the effects of mass addition on heat transfer, the calculation of internal gas pressure and internal material stresses, and a number of other options for surface or char removal. The program has previously been used to compare performance of phenolic nylon, phenolic graphite, and phenolic refrasil as rocket nozzle heat protection materials.NASA Lewis program under contract to General Electric. **/ABLATE**
2. Velocity gradient method for calculating velocities in an asymmetric annular duct. (ANDUCT).
   Turbomachinery components are often connected by ducts, which are usually annular. The configurations and aerodynamic characteristics of these ducts are crucial to the optimum performance of the turbomachinery blade rows. The ANDUCT computer program was developed to calculate the velocity distribution along an arbitrary line

between the inner and outer walls of an annular duct with axisymmetric swirling flow. Although other programs are available for duct analysis, the use of the velocity gradient method makes the ANDUCT program fast and convenient while requiring only modest computer resources. A fast and easy method of analyzing the flow through a duct with axisymmetric flow is the velocity gradient method, also known as the stream filament or streamline curvature method. This method has been used extensively for blade passages but has not been widely used for ducts, except for the radial equilibrium equation. In ANDUCT, a velocity gradient equation derived from the momentum equation is used to determine the velocity variation along an arbitrary straight line between the inner and outer wall of an annular duct. The velocity gradient equation is used with an assumed variation of meridional streamline curvature. Upstream flow conditions may vary between the inner and outer walls, and an assumed total pressure distribution may be specified. ANDUCT works best for well-guided passages and where the curvature of the walls is small as compared to the width of the passage. **/ANDUCT**

3. Three-dimensional supersonic flow (AOFA). This program determines the complete viscous and inviscid flow around a body of revolution at a given angle of attack and traveling at supersonic speeds. The viscous calculations from this program agree with experimental values for surface and pitot pressures and with surface heating rates. At high speeds, lee-side flows are important because the local heating is difficult to correlate and because the shed vortices can interact with vehicle components such as a canopy or a vertical tail. This program should find application in the design analysis of any high speed vehicle. Lee-side flows are difficult to calculate because thin-boundary-layer theory is not applicable and the concept of matching inviscid and viscous flow is questionable. This program uses the parabolic approximation to the compressible Navier-Stokes equations and solves for the complete inviscid and viscous regions of flow, including the pressure. The parabolic approximation results from the assumption that the stress derivatives in the streamwise direction are small in comparison with derivatives in the normal and circumferential directions. This assumption permits the equation to be solved by an implicit finite difference marching technique which proceeds downstream from the initial data point, provided the inviscid portion of flow is supersonic. The viscous cross-flow separation is also determined as part of the solution. To use this method it is necessary to first determine an initial data point in a region where the inviscid portion of the flow is supersonic. NASA Ames program by John Rakich. **/AOFA**
4. Aircraft roll-out iterative energy simulation program (ARIES)
   This program analyzes aircraft brake performance during rollout. The program simulates a three degree of freedom rollout after nose gear touchdown. The amount of brake energy dissipated during landing determines the life expectancy of brake pads. ARIES incorporates brake pressure, actual flight data, crosswinds, and runway characteristics to calculate the following:
   1) brake energy used during rollout for up to four independent brake systems,
   2) time profiles of rollout distance, velocity, deceleration, and lateral runway position, and
   3) all aerodynamic moments on the vehicle.
   ARIES can be adapted for modeling most landing aircraft during unpowered rollout.

Optimum braking procedures can be developed with ARIES to minimize brake deterioration while staying within specified lengths of runway. ARIES has been used to evaluate several Shuttle Orbiter brake pad failures. After the input of initial runway and landing conditions, ARIES utilizes three simulation models to evaluate the rollout at given time intervals. The brake force simulation requires tire and brake information along with actual flight data. The equations of motion allow force and moment balances to be calculated. The aerodynamic effects are computed, including lift, drag, axial and normal forces, and roll, pitch, and yaw moments. The various aerosurface effects are obtained from interpolation of the Rockwell Aero Sciences Group Design Data Book tables. The output is inboth printed and plotted form. ARIES iterates the calculations until the computed forward velocity is below three knots. Rockwell International. **/ARIES**

5. Non-rotating blade-to blade, steady, potential transonic cascade flow analysis code (CAS2D)
   An exact, full-potential-equation model for the steady, irrotational, homoentropic, and homoenergetic flow of a compressible, inviscid fluid through a two-dimensional planar cascade together with its appropriate boundary conditions has been derived. The CAS2D computer program numerically solves an artificially time-dependent form of the actual full-potential-equation, providing a nonrotating blade-to-blade, steady, potential transonic cascade flow analysis code.In CAS2D, the governing equation is discretized by using type-dependent, rotated finite differencing and the finite area technique. The flow field is discretized by providing a boundary-fitted, nonuniform computational mesh. This mesh is generated by using a sequence of conformal mapping, nonorthogonal coordinate stretching, and local, isoparametric, bilinear mapping functions. The discretized form of the full-potential equation is solved iteratively by using successive line over relaxation. Possible isentropic shocks are captured by the explicit addition of an artificial viscosity in a conservative form. In addition, a four-level, consecutive, mesh refinement feature makes CAS2D a reliable and fast algorithm for the analysis of transonic, two-dimensional cascade flows. The results from CAS2D are not directly applicable to three-dimensional, potential, rotating flows through a cascade of blades because CAS2D does not consider the effects of the Coriolis force that would be present in the three-dimensional case. (NASA Lewis Research Center) **/CAS2D**
6. Transformation of coordinates in Celestial Coordinates **/CELEST**
7. Dissociated air flow effects during plasma arc testing (COLDARC)
   The COLDARC program was developed as part of an effort to predict the heating rate and surface friction effects on the Thermal Protection System of the Space Shuttle Orbiter during re-entry environments. COLDARC enables the user to predict the heating rate and surface friction on a test article during plasma arc testing. This program takes into account the effects of dissociated air flow over the specimen and the associated heat flux and surface temperatures. Normally, plasma arc testing involves air flow over a test specimen having a relatively smooth surface. Since the orbiter Thermal Protection System does not constitute a smooth mold line surface, the COLDARC program was necessary to assess the impact of this surface roughness and the dissociated air flow. COLDARC uses a simplified frozen flow model to represent the dissociated air flow and to predict the heat flux and surface friction, including the effects or retarded atomic

recombination, from test facility data. (ROCKWELL INTERNATIONAL CORP.) **/COLDARC**

8. Conical Relaxation for supersonic wing design and analysis (COREL)
COREL is useful in the aerodynamic design and analysis of wings for supersonic maneuvering. It uses the Super Critical Conical Camber (SC3) concept, in which high supersonic lift coefficients are obtained by controlling cross flow development. COREL solves the nonlinear full potential equation for a spanwise section of a wing in the crossflow plane and corrects the result for any nonconical geometry. COREL computes the mixed subsonic/supersonic crossflow that develops on supersonic wings with high lift coefficients at Mach numbers normal to shock waves of 1.3 or less. The bow and crossflow shocks are captured as part of the solution. The initial aerodynamic solution is produced on a crude grid and is then reiterated. A finer mesh is then mapped, keeping the bow shock within the boundary of the new computed crossflow. The input geometry can be specifically defined or calculated in COREL using Craidon bicubic spline patches. (GRUMMAN AEROSPACE CORP.) **/COREL**
9. Aeroelastic divergence characteristics of unguided, slender body, multi-stage launch vehicles (DIVERGE).
The primary function of this computer program is the calculation of the divergence dynamic pressure and associated divergence modal characteristics of unguided, slender-body, multistage launch vehicles. The divergence dynamic pressure is obtained as the non-trivial solution to a homogenous stability equation using matrix recurrence techniques. Provision is made for modulating the distributed lift curve coefficient slope function and the stiffness function. The program also includes an option for calculating a generalized static margin which approximates the degeneration in rigid-body static margin due to aeroelasticity effects. Evaluated equations are also programmed to allow for the exclusion of the effect of aerodynamic crossflow resulting from vehicle angular velocities if desired. Other physical and aerodynamic properties calculated include total mass, center of mass, moments of inertia in pitch about the reference station, total aerodynamic lift curve slope, static aerodynamic center of pressure, rigid body static margin, and short period frequency. Input to the program is via the Fortran NAMELIST option with output printed. (NASA Langley Research Center) **/DIVERGE**
10. University of Kansas static aeroelasticity program (ELASTIC)
This software package contains three programs which compute geometric, mass, aerodynamic, and structural characteristics of fighter type aircraft. The programs were developed for computational support of a parametric study of planform and aeroelastic effects on aerodynamic center and stability derivatives. They calculate alpha- and q-stability derivatives and induced drag for thin elastic aeroplanes at subsonic and supersonic speeds. The programs are applicable to studies of steady state aeroelastic effects on stability characteristics of airplanes, but results are limited in validity to wings of typical fighter airplanes with a weight of 40,000 pounds (178,000 Newtons) and wing structures designed to withstand a limit load of 7.33 g's. The programs represent the airplane at subsonic and supersonic speeds as thin surface(s) (without dihedral) composed of discrete panels of constant pressure for the aerodynamic effects, and as slender beam(s) for the structural effects. They compute the static aeroelastic angle-of-

attack and pitch rate stability derivatives for a twisted and cambered thin airplane configuration at various flight conditions. (U. Kansas for NASA Langley). **/ELASTIC**

11. Analysis of three-dimensional supersonic nozzle exhaust flow fields (EXHAUST).
A second order numerical method employing reference plane characteristics has been developed for the calculation of geometrically complex three dimensional nozzle-exhaust flow fields, heretofore uncalculable by existing methods. The nozzles may have irregular cross sections with swept throats and may be stacked in modules using the vehicle undersurface for additional expansion. The nozzles may have highly nonuniform entrance conditions, the medium considered being an equilibrium hydrogen-air mixture. The program calculates and carries along the underexpansion shock and contact as discrete discontinuity surfaces, for a nonuniform vehicle external flow. Additionally, shock formation due to coalescence is detected. A wide variety of geometric problems may be considered since the reference plane method has been developed for three separate coordinate systems, all incorporated into a single program. (Advances Technology Labs. for NASA Lewis) **/EXHAUST**

12. Flexible spacecraft dynamics (FSD)
The Flexible Spacecraft Dynamics and Control program (FSD) was developed to aid in the simulation of a large class of flexible and rigid spacecraft. FSD is extremely versatile and can be used in attitude dynamics and control analysis as well as in-orbit support of deployment and control of spacecraft. FSD has been used to analyze the in-orbit attitude performance and antenna deployment of the RAE and IMP class satellites, and the HAWKEYE, SCATHA, EXOS-B, and Dynamics Explorer flight programs. FSD is applicable to inertially-oriented spinning, earth oriented, or gravity gradient stabilized spacecraft. The spacecraft flexibility is treated in a continuous manner (instead of finite element) by employing a series of shape functions for the flexible elements. Torsion, bending, and three flexible modes can be simulated for every flexible element. FSD can handle up to ten tubular elements in an arbitrary orientation. FSD is appropriate for studies involving the active control of pointed instruments, with options for digital PID (proportional, integral, derivative) error feedback controllers and control actuators such as thrusters and momentum wheels. The input to FSD is in four parts: 1) Orbit Construction FSD calculates a Keplerian orbit with environmental effects such as drag, magnetic torque, solar pressure, thermal effects, and thruster adjustments; or the user can supply a GTDS format orbit tape for a particular satellite/timespan; 2) Control words - for options such as gravity gradient effects, control torques, and integration ranges; 3) Mathematical descriptions of spacecraft, appendages, and control systems- including element geometry, properties, attitudes, libration damping, tip mass inertia, thermal expansion, magnetic tracking, and gimbal simulation options; and 4) Desired state variables to output, i.e., geometries, bending moments, fast Fourier transform plots, gimbal rotation, filter vectors, etc. All FSD input is of free format, namelist construction. (NASA Goddard Space Flight Center) **/FSD**

13. A general optical systems evaluation program (GENOPTICS)
The General Optical Systems Evaluation Program, GENOPTICS, was developed as an aid for the analysis and evaluation of optical systems that employ lenses, mirrors, diffraction gratings, and other geometrical surfaces. The GENOPTICS evaluation is performed by means of geometrical ray tracing based upon Snell's law. The

GENOPTICS program can provide for the exact ray tracing of as many as 800 rays through as many as 40 surfaces. These surfaces may be planar, conic, toric, or polynomial shaped lenses, mirrors, and diffraction gratings. Each surface may be tilted about as many as three axes and may be decentered. Surfaces having bilateral symmetry may also be analyzed. GENOPTICS provides for user-oriented input and for a wide range of output for the evaluation of the optical system being analyzed.

GENOPTICS provides a wide range of features for the optical system analyst. GENOPTICS performs paraxial ray tracing and computation of the third order aberrations including aspheric contribution. Graphical output can be generated for spot diagrams, radial energy distributions, and modulation transfer functions, for each object point and each color. Sag tables may be generated for any rotationally symmetric surface, with options to obtain the sag differences from a reference sphere in units of lengths or wavelengths. Statistics and plots of ray intercepts with any surface in the system may be obtained for use in vignetting analysis and beam distribution analysis. Afocal systems can be examined with image statistics generated in terms of tangents of angles with respect to the optical axis. For exact ray tracing, a ray pattern at the entrance pupil can be specified as a rectangular or polar grid, where each ray samples an equal amount of area, or as a pattern where each ray samples an equal amount of solid angle for a finite object. This latter pattern is useful in radiometric work.

Input to GENOPTICS includes program control statements, system definition data, surface data, and task data. Multiple cases may be examined in a single run. Output includes printed and graphical results. The user can specify which portions of an analysis are to be printed. Optional printout includes system data, surface-to-surface printout of each ray, modulation transfer function values, radial energy distribution values, and paraxial ray data including aberrations. (NASA Goddard Space Flight Center) **/GOPTICS**

14. Improved price estimation guidelines (IPEG)
The Improved Price Estimation Guidelines, IPEG, program provides a simple yet accurate estimate of the price of a manufactured product. IPEG facilitates sensitivity studies of price estimates at considerably less expense than would be incurred by using the Standard Assembly-line Manufacturing Industry Simulation, SAMIS, program (COSMIC program NPO-16032). A difference of less than one percent between the IPEG and SAMIS price estimates has been observed with realistic test cases. However, the IPEG simplification of SAMIS allows the analyst with limited time and computing resources to perform a greater number of sensitivity studies than with SAMIS. Although IPEG was developed for the photovoltaics industry, it is readily adaptable to any standard assembly line type of manufacturing industry. IPEG estimates the annual production price per unit. The input data includes cost of equipment, space, labor, materials, supplies, and utilities. Production on an industry wide basis or a process wide basis can be simulated. Once the IPEG input file is prepared, the original price is estimated and sensitivity studies may be performed. The IPEG user selects a sensitivity variable and a set of values. IPEG will compute a price estimate and a variety of other cost parameters for every specified value of the sensitivity variable. IPEG is designed as an interactive system and prompts the user for all required information and offers a variety of output options. (Cal Tech/Jet Propulsion Lab.) **/IPEG**

15. LONGLIB - a graphics library.
This library is a set of subroutines designed for vector plotting to CRT's, plotters, dot matrix, and laser printers. LONGLIB subroutines are invoked by program calls similar to standard CALCOMP routines. In addition to the basic plotting routines, LONGLIB contains an extensive set of routines to allow viewport clipping, extended character sets, graphic input, shading, polar plots, and 3-D plotting with or without hidden line removal.LONGLIB capabilities include surface plots, contours, histograms, logarithm axes, world maps, and seismic plots. LONGLIB includes master subroutines, which are self-contained series of commonly used individual subroutines. When invoked, the master routine will initialize the plotting package, and will plot multiple curves, scatter plots, log plots, 3-D plots, etc. and then close the plot package, all with a single call. The latest version, 5.0, is significantly enhanced and has been made more portable. (Cal Tech/Jet Propulsion Lab.) **/LONGLIB**
16. Mistuning effects on turbofan cascades (MISER2)
In the development of modern aircraft turbofan engines, the aeroelastic stability and response of bladed-disk assemblies have been among the most difficult problems encountered. The study of stability and response in these assemblies is complicated by the presence of small differences between the individual blades, known as mistuning. The Mistuning Effects on Turbofan Cascades program, MISER2, was developed to improve the basic understanding of the effects of mistuning on aeroelastic stability and response. The MISER2 program calculates the flutter boundaries and aeroelastic response of a cascade of arbitrarily mistuned airfoils. It is based on a formulation incorporating incompressible subsonic and supersonic, unsteady, two-dimensional aerodynamic theories. Each blade is modeled as a two degree-of-freedom oscillator having inertial coupling between the bending and torsional motions. It is possible to consider any type of uncoupled bending and torsional frequencies, damping ratios, mass ratios, and elastic axis and center of gravity positions. Special cases which can be treated by MISER2 include: tuned and mistuned cases; uncoupled bending and uncoupled torsion cases; and the tuned coupled bending-torsion case. (NASA Lewis Research Center) **/MISER2**
17. Monte Carlo investigation of trajectory operations and requirements (MONITOR).
The Monte Carlo Investigation of Trajectory Operations and Requirements (MONITOR) program was developed to perform spacecraft mission maneuver simulations for geosynchronous, single maneuver, and comet encounter type trajectories. MONITOR is a multifaceted program which enables the modeling of various orbital sequences and missions, the generation of Monte Carlo simulation statistics, and the parametric scanning of user requested variables over specified intervals. The MONITOR program has been used primarily to study geosynchronous missions and has the capability to model Space Shuttle deployed satellite trajectories. The ability to perform a Monte Carlo error analysis of user specified orbital parameters using predicted maneuver execution errors can make MONITOR a significant part of any mission planning and analysis system.

The MONITOR program can be executed in four operational modes. In the first mode, analytic state covariance matrix propagation is performed using state transition matrices for the coasting and powered burn phases of the trajectory. A two-body central force field is assumed throughout the analysis. Histograms of the final orbital elements and other state dependent variables may be evaluated by a Monte Carlo analysis. In the second mode, geosynchronous missions can be simulated from parking orbit injection through station acquisition. A two-body central force field is assumed throughout the simulation. Nominal mission studies can be conducted; however, the main use of this mode lies in evaluating the behavior of pertinent orbital trajectory parameters by making use of a Monte Carlo analysis. In the third mode, MONITOR performs parametric scans of user-requested variables for a nominal mission. Various orbital sequences may be specified; however, primary use is devoted to geosynchronous missions. A maximum of five variables may be scanned at a time. The fourth mode simulates a mission from orbit injection through comet encounter with optional Monte Carlo analysis. Midcourse maneuvers may be made to correct for burn errors and comet movements. (NASA Goddard Space Flight Center) **/MONITOR**

18. Nastran plotting post processor (NASTPLT)
The NASTRAN Plotting Post Processor was developed to read NASTRAN generated NASTPLT plot files, to check the file contents for validity, and to translate the NASTPLT plot commands into appropriate calls to plotting routines for either CalComp, Tektronix PLOT10, or Versatec plotting systems. This program was originally written to generate a summary of the contents of a NASTPLT plot file for the purposes of debugging and checking the validity and characteristics of the file contents. The summary information generated includes the following information for each plot on the NASTPLT file: plot number, draw-lines summary, draw-axis summary, draw-character summary, maximum and minimum values in the x-range and y-range, and pen change information. The summary information also includes the following information for the NASTPLT file as a whole: the number of records read, the number of commands, and the number of plots. The summary generation program was extended to include the plot routine calls for the CalComp, Tektronix PLOT10, and Versatec plotting systems. The Post Processor is run interactively and prompts the user for all of the required input. The user may request the summary information and then use that information to determine which plots on the file are to be output. The Post Processor is compatible with either VAX or IBM NASTRAN generated NASTPLT files. (Computer Sciences Corp. for NASA Langley) **/NASTPLT**

19. A segmented mission analysis program for low and high speed aircraft (NSEG)
NSEG was developed to perform rapid aircraft mission analyses. It is based upon the use of approximate equations of motion whose form varies with the type of flight segment. Flight segments considered are takeoff, accelerations, climbs, cruises, descents, decelerations, and landings. Layered atmosphere options are available. The program can also be used for flight envelope mapping. NSEG provides the capability to analyze aircraft missions from low to hypersonic speeds. Realistic and detailed vehicle characteristics are input to NSEG to permit accurate mission analysis. NSEG allows engine scaling so as to fit the design under analysis. NSEG contains several approximate flight path optimization capabilities based on Rutowski energy-like criteria for considering minimum time or fuel flight segments and maximum range segments during climb or descent. Takeoff and landing analysis is based on the Air Force Flight Dynamics Laboratory DATCOM method of high lift aerodynamic modelling. There are

three main atmosphere options available; the 1962 U.S. Standard atmosphere, a stratified atmosphere model, and an external atmosphere model supplied by the user. The stratified atmosphere model requires the input of the number of layers (maximum 25), altitudes, temperatures, and pressures. The mission specification is open-ended in that the upper limit on the number of flight segments to be included in a mission profile can be increased with a simple program change. Input consists of vehicle characteristic data, data to specify details of the mission, and selection of program options. (Aerophysics Research Corp. for NASA Langley) **/NSEG**

20. A vertical profile which minimizes aircraft fuel burn or direct operating cost (OPTIM)

    The OPTIM computer program was developed to generate optimum vertical profiles for turbojet powered aircraft. Specifically, OPTIM generates a profile of altitude, airspeed, and flight path angle as a function of range between a given set of origin and destination points for particular models of transport aircraft. The profile may be optimized in the sense of minimizing fuel or time or in minimizing the direct operating cost expressed as a combination of fuel and time. Inputs to the program include the vertical wind profile, the aircraft takeoff weight, and the aircraft engine and aerodynamic characteristics. The optimum vertical flight profile is generated by calculating the airspeed and thrust required to minimize the Hamiltonian at specific energy increments. (Analytical Mechanics Associates for NASA Langley) **/OPTIM**

21. Parameterized investigation of launch opportunities and trajectories (PILOT).

    The launch window for an earth satellite mission defines the dates and the times of day that a satellite can be launched and satisfy the mission constraints. The Parameterized Investigation of Launch Opportunities and Trajectories (PILOT) program was developed to perform mission simulation computations that yield data for use in delimiting optimum launch windows. The PILOT program performs parametric scans of a user specified trajectory over launch date and initial right ascension of the ascending node. During each scan various mission parameters are generated and output to a data file. The CoPILOT utility program is used to read and format the PILOT generated data file. The user specifies acceptable limits on the various PILOT generated parameters, CoPILOT checks the data, and generates an output table with notations of any constraint violations. Any time that no contraints are violated, an acceptable launch time exists. For each date, the acceptable launch times are printed. A printer plot may also be generated to visually display the launch window. (Computer Sciences Corp. for NASA Goddard) **/PILOT**

22. Design of two-dimensional supersonic turbine rotor blades with boundary layer correction (RBLADE).

    A computer program has been developed for the design of supersonic rotor blades where losses are accounted for by correcting the ideal blade geometry for boundary layer displacement thickness. The ideal blade passage is designed by the method of characteristics and is based on establishing vortex flow within the passage. Boundary-layer parameters (displacement and momentum thicknesses) are calculated for the ideal passage, and the final blade geometry is obtained by adding the displacement thicknesses to the ideal nozzle coordinates. The boundary-layer parameters are also used to calculate the aftermixing conditions downstream of the rotor blades assuming the flow mixes to a uniform state.

The computer program input consists essentially of the rotor inlet and outlet Mach numbers, upper- and lower-surface Mach numbers, inlet flow angle, specific heat ratio, and total flow conditions. The program gas properties are set up for air. Additional gases require changes to be made to the program. The computer output consists of the corrected rotor blade coordinates, the principal boundary-layer parameters, and the aftermixing conditions. (NASA Lewis Research Center) **/RBLADE**

23. Fast Mars relay communication link (RELAY)
This program evaluates the communications link between the Viking Orbiter and Lander vehicles. The program calculates the trajectory of the Orbiter and Lander simultaneously. Using data from both vehicles, this program calculates communication geometry. (Martin Marietta Corp.) **/RELAY**

24. Aeroelastic analysis for rotorcraft in flight or in a wind tunnel (ROTOR)
The testing of rotorcraft, either in flight or in a wind tunnel, requires a consideration of the coupled aeroelastic stability of the rotor and airframe, or the rotor and support system. Even if the primary purpose of a test is to measure rotor performance, ignoring the question of dynamic stability introduces the risk of catastrophic failure of the aircraft. This computer program was developed to incorporate an analytical model of the aeroelastic behavior of a wide range of rotorcraft. Such an analytical model is desirable for both pre-test predictions and post-test correlations. The program is also applicable in investigations of isolated rotor aeroelasticity and helicopter flight dynamics and could be employed as a basis for more extensive investigations of aeroelastic behavior, such as automatic control system design.
The program incorporates an analytical model which is applicable to a wide range of rotors, helicopters, and operating conditions. The equations of motion used in the model were derived using an integral Newtonian method, which provides considerable insight into the blade inertial and aerodynamic forces. The rotor model includes coupled flap-lag bending and blade torsion degrees of freedom, and is applicable to articulated, hingeless, gimballed, and teetering rotors with an arbitrary number of blades. The aerodynamic model is valid for both high and low inflow, and for both axial and nonaxial flight. Rotor rotational speed dynamics, including engine inertia and damping, and perturbation inflow dynamics are included in the aerodynamic model.
For a rotor on a wind-tunnel support, a normal mode representation of the test module, strut, and balance is used. The aeroelastic analysis for rotorcraft in flight is applicable to a general two-rotor aircraft, including single main-rotor and tandem helicopter configurations, and side-by-side or tilting proprotor aircraft configurations. The rotor model includes rotor-rotor aerodynamic interference and ground effect. The aircraft model includes rotor-fuselage-tail aerodynamic interference, engine dynamics, and control dynamics. A constant-coefficient approximation is used for nonaxial flow and a quasistatic approximation is used for the low frequency dynamics. The coupled system dynamics results is a set of linear differential equations which are used to determine the stability and aeroelastic response of the system. (NASA Ames Research Center) **/ROTOR**

25. Super/Hypersonic inviscid flow around real configurations (SHIFARC)
This package was developed to compute the inviscid super/hypersonic flow field about complex vehicle geometries accurately and efficiently. A second-order accurate finite

difference scheme is used to integrate the three-dimensional Euler equations in regions of continuous flow, while all shock waves are computed as discontinuities via the Rankine-Hugoniot jump conditions. This package has the ability to compute blunt nose entropy layers in detail. Real gas effects for equilibrium air are included using curve fits of Mollier charts. This package can be a very useful tool in the design and analysis of high speed vehicles such as supersonic aircraft, hypersonic transports, and re-entry spacecraft (shuttle orbiter).

This package consists of three separate computer programs. STEIN is the program that solves the Euler equations for the flow field. This solution is obtained by following these basic guidelines:

1) An accurate second order finite difference marching technique is used to numericallly integrate the governing partial differential equations;

2) Shock waves in the flow field are followed and the Rankine-Hugoniot conditions are satisfied across them;

3) The intersection of two shocks of the same family is computed explicitly;

4) Conformal mappings are used to develop a computational grid;

5) Body boundary conditions are satisfied by recasting the equations according to the concept of characteristics;

6) The edge of the entropy layer on blunt nose vehicles is followed from its origin and the derivatives across the layer formed;

7) Real gas effects are included when appropriate, by using fits of Mollier charts; and

8) Sharp leading edge wings are computed using a local two-dimensional solution.

The only limitation to this solution technique is that the Mach number in the marching direction (nose to tail) must be supersonic at every point in the flow field. The region around the nose of blunt nosed vehicles must be computed by another technique (see description of BLUNT below) and once the flow becomes supersonic, STEIN can proceed with its calculations. This program has been used extensively to compute external flow fields and has been found to yield accurate results for a wide variety of vehicle configurations flying at Mach numbers between 2 and 26 and having angles of attack to plus/minus 30 degrees.

The program BLUNT is used to find flow fields about blunt nosed portions of the vehicle. BLUNT uses a time dependent computational technique to asymptote to a steady transonic solution. Output from this program can be used by STEIN to define the flow field points where supersonic flow begins. The program QUICK provides the user with a geometry system to model a complex vehicle geometry in a quick, straight-forward fashion. QUICK consists of an initial defining and logical checkout group of routines, which actually set up the mathematical model, and a second group of routines which are used to interrogate the model for cross sectional information. QUICK supplies all geometrical information about the vehicle to STEIN. (Grumman Aerospace Corp.)

/SHIFARC

26. Circuit Analysis (SNEAK)

Input to this program consists of data representing the circuit to be analyzed. The data is prepared by converting the schematic of the circuit into a "wire list". In this wire list all switches are assumed closed with special circumstances, e.g. double throw switches, being noted as switchable continuity. The output consists of any paths that meet the criteria for sneak circuits. These areas of suspicion must then be submitted to manual analysis, but the number of paths to be analyzed is greatly reduced by the criterion of opposing power and ground. Post-analysis consists of checking switch logic to sift out paths that cannot be switched on and then determining any systems effects of the remaining possible sneak circuits. The computer output is designed to present the path tracing information in a format that readily assists manual analysis of the suspected sneak circuits. The automated sneak circuit analysis is accomplished in three processing phases. The first phase is the data reduction phase. In this phase the "wire list" is generated. Input may be in several different formats and even segmented such that separate groups or contractors may prepare "wire lists" covering subsystems with discontinuities at interfaces. The "wire list" is merged with an in-line disconnect table establishing continuity at the interface between any subsystems. This "wire list" is then reduced to an ISAM file containing a branch cross-reference table, in which each to-node/from-node branch is uniquely identified and stored with its associated characteristics. The second phase is the path derivation phase. In this process the data in the branch cross-reference table is used to examine all possible paths to see which meet the above mentioned two-fold criteria for a possible sneak circuit. The third phase is the path regeneration phase. The paths flagged are listed in branch sequence number and then in to-from connector sequence. The output report generated is in a highly useable format that allows the engineer to verify the suspected sneak circuit path by locating the wire segments on the circuit schematic drawings. (Boeing Co.) **/SNEAK**

27. Space Shuttle Synthesis Program (SSSP). The Space Shuttle Synthesis Program (SSSP) automates the trajectory, weights and performance computations essential to predesign of the Space Shuttle system for earth-to-orbit operations. The two-stage Space Shuttle system is a completely reusable space transportation system consisting of a booster and an orbiter element. The SSSP'S major parts are a detailed weight/volume routine, a precision three-dimensional trajectory simulation, and the iteration and synthesis logic necessary to satisfy the hardware and trajectory constraints. The SSSP is a highly useful tool in conceptual design studies where the effects of various trajectory configuration and shuttle subsystem parameters must be evaluated relatively rapidly and economically. The program furnishes sensitivity and tradeoff data for proper selection of configuration and trajectory predesign parameters. Emphasis is placed upon pre-design simplicity and minimum input preparation. Characteristic equations for describing aerodynamic and propulsion models and for computing weights and volumes are kept relatively simple. The synthesis program is designed for a relatively large number of two-stage Space Shuttle configurations and mission types, but avoids the complexity of a completely generalized computer program that would be unwieldy to use and/or modify. **/SSSP**

28. Velocities and streamlines on a blade-to-blade stream surface of a tandem blade turbomachine (TANDEM).
    This computer program gives the blade-to-blade solution of the two-dimensional, subsonic, compressible (or incompressible), nonviscous flow problem for a circular or straight infinite cascade of tandem or slotted turbomachine blades. The blades may be fixed or rotating. The flow may be axial, radial , or mixed. The method of solution is

based on the stream function using an iterative solution of nonlinear finite-difference equations. These equations are solved using two major levels of iteration. The inner iteration consists of the solution of simultaneous linear equations by successive over-relaxation, using an estimated optimum over-relaxation factor. The outer iteration then changes the coefficients of the simultaneous equations to correct for compressibility. The program input consists of the basic blade geometry, the meridional stream channel coordinates, fluid stagnation conditions, weight flow and flow split through the slot, and inlet and outlet flow angles. The output includes blade surface velocities, velocity magnitude and direction throughout the passage, and the streamline coordinates. (NASA Lewis Research Center) **/TANDEM**

29. One-dimensional numerical analysis of the transient thermal response of multilayer insulative systems (THERM1D)
This program performs a one-dimensional numerical analysis of the transient thermal response of multi-layer insulative systems. The analysis can determine the temperature distribution through a system consisting of from one to four layers, one of which can be an air gap. Concentrated heat sinks at any interface can be included. The computer program based on the analysis will determine the thickness of a specified layer that will satisfy a temperature limit criterion at any point in the insulative system. The program will also automatically calculate the thickness at several points on a system and determine the total system mass. This program was developed as a tool for designing thermal protection systems for high speed aerospace vehicles but could be adapted to many areas of industry involved in thermal insulation systems. In this package, the equations describing the transient thermal response of a system are developed. The governing differential equation for each layer and boundary condition are put in finite-difference form using a Taylor's series expansion. These equations yield an essentially tridiagonal matrix of unknown temperatures. A procedure based on Gauss' elimination method is used to solve the matrix. (NASA Langley Research Center). **/THERM1D**
30. Takeoff and landing performance capabilities of transport category aircraft (TOL)
One of the most important considerations in the design of a commercial transport aircraft is the aircraft's performance during takeoff and landing operations. The aircraft must be designed to meet field length constraints in accordance with airworthiness standards specified in the Federal Aviation Regulations. In addition, the noise levels generated during these operations must be within acceptable limits. This computer program provides for the detailed analysis of the takeoff and landing performance capabilities of transport category aircraft. The program calculates aircraft performance in accordance with the airworthiness standards of the Federal Aviation Regulations. The aircraft and flight constraints are represented in sufficient detail to permit realistic sensitivity studies in terms of either configuration modifications or changes in operational procedures.This program provides for the detailed performance analysis of the takeoff and landing capabilities of specific aircraft designs and allows for sensitivity studies. The program is not designed to synthesize configurations or to generate aerodynamic, propulsion, or structural characteristics. This type of information must be generated externally to the program and then input as data. The program's representation of the aircraft data is extensive and includes realistic limits on engine and aircraft operational boundaries and maximum attainable lift coefficients. The takeoff and climbout flight-path is generated

by a stepwise integration of the equation of motion. Special features include options for nonstandard-day operation, for balanced field length, for derated throttle to meet a given field length for off-loaded aircraft, and for throttle cutback during climbout for community noise alleviation. Advanced takeoff procedures for noise alleviation such as programmed throttle and control flaps may beinvestigated with the program. Approach profiles may incorporate advanced procedures such as two segment approaches and decelerating approaches. The landing performance considers the application of wheel brakes, spoilers, and thrust reversers. (NASA Langley Research Center) **/TOL**

31. TOMARS - A rapid, flexible, preliminary Earth-Mars mission-analysis computer program has been developed. The program computes a conic interplanetary trajectory approximation, a noncoplanar impulsive deboost maneuver into a closed orbit about the target planet, and many mission-dependent and mission-independent parameters to allow examination of the entire flight profile. The input data to the program allows the mission planner to select launch and arrival dates as well as a specific landing point located in a scientifically interesting area with proper lighting for any onboard optical equipment. The orbit about the planet must satisfy constraints such as communication requirements with the Earth and the necessity for solar cells to be exposed to sunlight for the greater part of each orbit. The many different problems involved in preliminary mission analyses present a real task for the flight planner. The program is written for Mars missions where the spacecraft is placed in an orbit about Mars followed by the separation of a landing module, but could be adapted for other interplanetary journeys. Examples of program input and output and sample data analyses are presented for an Earth-Mars mission during the 1973 launch opportunity. The accuracy of the program is limited by the use of Keplerian mechanics and impulsive-burn maneuvers rather than finite burn integrating schemes. However, it is felt that for preliminary mission design, the order-of-magnitude accuracy involved in the approximations, as compared with an integrating program, is far outweighed by the several orders of magnitude gained in computational speed and program flexibility. **/TOMARS**

32. Thermal Protection System multidimensional heat conduction program (TPS)
The Thermal Protection System (TPS) for the Space Shuttle consists of an outer layer of rigid surface insulation tiles. It is important that an accurate understanding of the thermal behavior of this system be obtainedprior to usage. This computer program was developed to compute the transient temperature history and the steady-state temperatures of complex body geometries in three dimensions. Emphasis has been placed on the type of problems associated with the TPS, but the program could be used in the thermal analysis of most three-dimensional systems.
The thermal model is subdivided into sections, or nodes, to a level of approximation which yields the desired level of accuracy. Input to the program consists of a geometrical description of the physical system, the material properties, and selected boundary conditions. The boundary conditions are used to account for heat flux, reradiation, radiation interchange, convection, fixed temperatures, and phase changes. The program will accomodate a thermal model with as many as 500 nodes, 4000 conductors, 3600 radiation interchange conductors, and 75 of each type of boundary condition. The program solves the differential equations describing the transient and steady state behavior of the model using finite difference techniques. For the transient

analysis, the user may select either a forward difference method, a midpoint difference (Crank-Nicolson) method, a backward difference method, or an alternating direction method to numerically solve the governing equations. For the steady-state analysis, a modified backward difference method is available. Program output is in the form of temperature versus time histories for each section of the thermal model. (Rockwell International Corp.) **/TPS**

33. V/STOL aircraft sizing and performance (VASCOMP II)
The VASCOMP2 computer program was developed to aid in the comparative design study of V/STOL aircraft systems by rapidly providing aircraft size and mission performance data. VASCOMP2 can be used to define design requirements such as weight breakdown, required propulsive power, and physical dimensions of aircraft which are to meet specified mission requirements. The program is also useful in sensitivity studies involving both design trade-offs and performance trade-offs. Generality and flexibilitywere maintained during formulation of the program in order to permit an accurate simulation of virtually any V/STOL configuration. VASCOMP2 is capable of approximating the design process involved in the layout and sizing of a wide variety of V/STOL aircraft and synthesizing the performance of these aircraft. The program is intended for use in the study of V/STOL aircraft which use fixed wing lift for primary cruise flight. The program is not suited for the study of aircraft which employ rotary wing lift for forward flight. (Boeing Vertol Co.) **/VASCOMP**

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