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AFFDL-TR-68-66
(Supplement 1)

A COMPILATION OF COMPUTER PROGRAMS IN FLIGHT VEHICLE TECHNOLOGY 1968-1969

AMBROSE B. NUTT

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TECHNICAL REPORT AFFDL-TR-68-66, SUP. 1

MARCH 1970

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AIR FORCE FLIGHT DYNAMICS LABORATORY
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A COMPILATION OF COMPUTER PROGRAMS IN FLIGHT VEHICLE TECHNOLOGY 1968-1969

AMBROSE B. NUTT

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Air Force Flight Dynamics Laboratory (FDO-3), Wright-Patterson AFB, Ohio.

FOREWORD

The Air Force Flight Dynamics Laboratory at Wright-Patterson Air Force Base, Ohio is one of the eight Laboratories under the Director of Laboratories, Air Force Systems Command. This Laboratory is the Air Force focal point for exploratory and advanced development (including simulation techniques) for the entire technology required (except for avionics and propulsion) to develop any type of flight vehicle.

It is the policy of the Director of Laboratories that Air Force Laboratories shall be responsible for informing the scientific community at large of significant accomplishments within the Laboratories' areas of cognizance.

One of the objectives of the Air Force Dynamics Laboratory's program is to develop techniques for simplifying and reducing the cost of design, development and test of future Air Force flight vehicles.

It is with the above policy and objective in mind that this compilation of computer programs, useful in the design of flight vehicles, is published.

Although some of the programs are similar to those available elsewhere, this collection should be useful to organizations with limited system libraries and particularly to those organizations involved in Flight Dynamics research and development leading to the acquisition of future flight vehicles.

This technical documentary report has been reviewed and is approved.

Joseph R. Myers

JOSEPH R. MYERS
Commander
Air Force Flight Dynamics Laboratory

ABSTRACT

A compilation of computer programs useful in the design of flight vehicles. Technical domains covered include the following:

Structures
Aerodynamics
Vehicle Dynamics
Flight Control
Crew Escape and Retardation
Landing Gear Subsystems

All programs were devised in-house in the Air Force Flight Dynamics Laboratory or were prepared as directed by them under R&D contracts.

This report supplements a previous report "A Compilation of Computer Programs in Flight Vehicle Technology - 1964-1967," Air Force Flight Dynamics Laboratory Technical Report TR-68-66, dated April 1968 (Defense Documentation Center Nr. AD 835 368), by the same author.

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INTRODUCTION

The compatibility of the computer programs described herein with any given Electronic Data Processing (EDP) equipment depends upon the programming language, the operating system used, as well as the type of computer available to the prospective user. Sufficient information is provided on each program to allow its usefulness to be assessed.

More detailed information on any given program may be obtained from the Air Force Flight Dynamics Laboratory (AFFDL) contact indicated for each program in this document by writing the Air Force Flight Dynamics Laboratory; Wright-Patterson Air Force Base, Ohio, 45433; Attention: (Name and office symbol of AFFDL contact).

Telephone contact may be made by calling Area Code 513-25- and the five digit extension indicated for the program AFFDL contact in this document.

Any program described herein is available to any of the Department of Defense Agencies or their contractors.

COMPUTER PROGRAMS IN

FLIGHT CONTROL TECHNOLOGY

Summary of Flight Control Technical Efforts in AFFDL

Exploratory and advanced development programs in the field of flight path control and motional behavior of aerospace vehicles; areas being investigated include: control display, aerodynamic stability, handling qualities, control equipment and instrumentations, portable ILS equipment, and use of pilot as control element.

Program Title: T-39 Weather Landing Minimums Investigation Plot Package

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: Terry Emerson, FDCS, 55496

Contractor: Bunker-Ramo Corporation

Date of Program Availability: 30 January 1970

Mathematical Technique Used: Algebra

Program Usage Description: Cal-Comp plot package of various aspects of the landing weather minimums investigation conducted by the USAF Instrument Pilot Instruction School at Randolph Air Force Base.

Program Title: T-39 Weather Landing Minimums Investigation File Maintenance

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: Terry Emerson, FDCS, 55496

Contractor: Bunker-Ramo Corporation

Date of Program Availability: October 1969

Mathematical Technique Used: Algebra

Program Usage Description: Stores the flight test data from the landing weather minimums investigation conducted by the USAF Instrument Pilot Instructors School at Randolph Air Force Base, on magnetic tape and produces an uninterpreted printout of the data base.

Program Title: Root Locus Calculation

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: F. George, FDCC, 52148

Contractor: In-House

Date of Program Availability: 1 October 1969

Mathematical Technique Used: Complex Arithmetic

Program Usage Description: Input transfer function in polynomial or factored form in terms of Laplace variable, and region of interest in complex plane. Output options are tabular printout or plot. Scales to be included in input.

Program Title: TRANF (Transfer Program)

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: A. J. Connors, FDCC, 52148

Contractor: In-House

Date of Program Availability: October 1969

Mathematical Technique Used: Matrix Algebra

Program Usage Description: The program computes the determinant of a 6x6 matrix that has elements which are in quadratic form. The characteristic polynomial is calculated, then the roots of the polynomial are extracted. Laplace's Theorem on complementary minors was applied. The program uses double precision arithmetic.

Program Title: Pilot Rating Prediction for VTOL Aircraft in Hover Mode

Computer Used: IBM 7090

Language: FORTRAN IV

FDL Contact: James D. Dillow, FDCC, 52148

Contractor: In-House

Date of Program Availability: 17 October 1969

Mathematical Technique Used: Gradient Technique

Program Usage Description: This program minimizes a functional of four variables using Fletcher Powell accelerated gradient techniques.

Program Title: Stoppable Rotor Aircraft Stability and Control Derivative Prediction Program

Computer Used: Being run initially on an IBM 360-65

Language: FORTRAN IV-H

FDL Contact: R. Nicholson, FDCC, 53047

Contractor: Bell Helicopter Company, Fort Worth, Texas

Date of Program Availability: Approximately February 1970

Mathematical Technique Used: Various numerical techniques are used in the program.

Program Usage Description: The program is designed to permit the calculation of the stability and control derivatives of stappable rotor aircraft during conversions between the helicopter and airplane flight regimes. The technical parameters can also be varied to permit parametric studies to be performed.

COMPUTER PROGRAMS IN

VEHICLE DYNAMICS TECHNOLOGY

Summary of Vehicle Dynamics Technical Effort in AFFDL

Exploratory and advanced development on methods to insure prevention of adverse effects of noise, sonic fatigue and pseudo noise in aerospace vehicles; also accomplishing of research to predict and prevent aerothermoelastic and vehicle dynamic problems such as flutter and vibration.

Program Title: HOFR (Dynamic Response of Honeycomb Panels to Acoustic Loading)

Computer Used: IBM 7040/7094 DCS

Language: FORTRAN IV

FDL Contact: R. C. W. van der Heyde, FDDA, 54279

Contractor: Northrop

Date of Program Availability: October 1969

Mathematical Technique Used: Ritz-Galekkin and Matrix Methods

Program Usage Description: HOFR program predicts stresses, strains, deflections, fatigue life, and natural frequencies of honeycomb panels loaded by harmonic or random acoustic excitation (Ref AIAA Journal Vol. 6, No. 8, Aug 1968).

Program Title: MAIN (Acoustical Response, Noise Transmission losses and interior Noise Levels of Aircraft Excited by Random Pressure Fields)

Computer Used: IBM 7040/7094 DCS

Language: FORTRAN IV

FDL Contact: R. C. W. van der Heyde, FDDA, 54279

Contractor: Wyle Laboratories, Huntsville, Alabama

Date of Program Availability: October 1969

Mathematical Technique Used: Structural Models, Normal Mode Studies

Program Usage Description: Solutions (PSD) for structural responses, noise reduction and internal acoustic fields of untreated and acoustically treated fuselage structures are given for random noise fields. (Ref AFFDL-TR-68-2)

Program Title: RANVIB (Random Vibration Analysis System for Complex Structures)

Computer Used: IBM 7040/7094 DCS

Language: FORTRAN IV, Map, Binary

FDL Contact: R. M. Shimovetz, FDDA, 52743

Contractor: Boeing, Renton, Washington

Date of Program Availability: October 1969

Mathematical Technique Used: Finite Element Matrix Methods

Program Usage Description: RANVIB program employs matrix method to calculate statistical measurements (cross PSD joint moments) of response (deflection and stress) for complex structures subjected to random noise fields. The random noise field models available at present are boundary layer noise and a laboratory source. (Ref AFFDL-TR-68-43)

Program Title: SOUND (Near Field Noise Prediction)

Computer Used: IBM 7040/7094 DCS

Language: FORTRAN IV

FDL Contact: R. M. Shimovetz, FDDA, 52743

Contractor: Lockheed Georgia Co.

Date of Program Availability: October 1969

Mathematical Technique Used: Polynomial curve fitting using experimentally determined parameters

Program Usage Description: The SOUND program calculates the near field noise in octave levels and overall level given temperatures and Mach Nr. of exhaust gas and plots the equal SPL contours on line. (Ref AFFDL-TR-67-43)

Program Title: TAXI Simulates a Vehicle Traversing a Runway Profile

Computer Used: IBM 7090/7094

Language: FORTRAN IV

FDL Contact: T. Gerardi, FDDS, 55584

Contractor: AFFDL In-House

Date of Program Availability: October 1969

Mathematical Technique Used: Runge-Kutta Method

Program Usage Description: "TAXI" simulates a 5-degree of freedom rigid body taxiing over any given runway profile. A curve fitting routine is incorporated to provide a continuous profile of the digitized runway input data. This runway input data must be runway elevations taken at 2-foot intervals. The program output is in the form of accelerations at the nose and main landing gear and at the vehicle c.g. A 1-cos type bump can also be used as the forcing function instead of an exact runway profile.

Program Title: Runway Power Spectral Densities (PSD)

Computer Used: IBM 7090/7094

Language: FORTRAN IV

FDL Contact: T. Gerardi, FDDS, 55584

Contractor: AFFDL In-House

Date of Program Availability: October 1969

Mathematical Technique Used: Fourier Transform

Program Usage Description: "RUNWAY" calculates the Power Spectral Density (PSD) of runway elevation data taken at 6 inch or 2 foot intervals. The PSD and reduced frequency values are punched onto cards in a format compatible to the program "PSDPLT", which plots the PSD curve on a Calcom plotter. (Ref. AFFDL-TR-68-66)

Program Title: Dynamic Shell Analysis Using Doubly Curved Finite Elements

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: R. F. Taylor, FDDS, 53297

Contractor: The Boeing Company

Date of Program Availability: December 1968

Mathematical Technique Used: Matrix Algebra, Lagrange Multipliers

Program Usage Description: This computer program provides for the static and dynamic analysis of stiffened doubly-curved shells. The algorithm is based on the direct stiffness method. In its present form, the geometry module is limited to shells of revolution, but the method can be extended to shells of general geometry. The elements available are a doubly-curved quadrilateral, apex, and curved stiffeners. (Ref. AFFDL-TR-69-15, Part III).

Program Title: Supersonic Unsteady Aerodynamics for Wings with Trailing Edge Control Surfaces and Folded Tips

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: S. J. Pollock, FDDS, 53297

Contractor: North American Rockwell/Columbus Division

Date of Program Availability: August 1968

Mathematical Technique Used: The Mach box method used follows the aerodynamic influence coefficient procedure of Zartarian and Hsu. Each surface and diaphragm is overlaid with a grid of rectangular boxes, the diagonals of which are parallel to the Mach lines.

Program Usage Description: For wing configurations including those with trailing edge control surfaces, folded tips, cranked leading and trailing edges, and supersonic or subsonic leading and trailing edges, steady and unsteady supersonic aerodynamic coefficients can be obtained for use in response and flutter analyses. At the option of the user, the program will also calculate steady or unsteady lifting pressure distributions, and if the generalized mass and stiffness matrices are provided, it will obtain solutions of flutter equations in one computer run. (Ref. AFFDL-TR-68-30).

Program Title: Transonic Unsteady Aerodynamics for Planar Wings with Trailing Edge Control Surfaces

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: North American Rockwell/Los Angeles Division

Date of Program Availability: August 1968

Mathematical Technique Used: This is an extension of the transonic box method of FDL-TDR-64-152, Part II, to include the effects of a swept trailing edge and a trailing edge flap. The method is based on the representation of the velocity potentials by a doublet distribution. Thickness effects are not included, and the free-stream Mach number is assumed to be 1.0.

Program Usage Description: The program provides for a swept trailing edge with two sections, and as many as three sweep angles on the leading edge. Provision is made for treating a trailing edge aileron. For a maximum of ten modes of oscillation, the program computes the oscillatory potentials and pressures and a generalized force matrix (Ref. AFFDL-TR-67-180).

COMPUTER PROGRAMS IN

VEHICLE EQUIPMENT TECHNOLOGY

Summary of Vehicle Equipment Technical Effort in AFFDL

Experimental and advanced development in vehicle equipment for future Air Force systems; advanced technology in areas of crew escape, retardation and recovery, internal environmental control and mechanical elements such as bearings, and alighting gear.

Program Title: Radial Carcass Aircraft Tire Inflation Program

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: H. K. Brewer, FDFM, 55558

Contractor: In-House

Date of Program Availability: October 1969

Mathematical Technique Used: Forward Integration

Program Usage Description: The program computes the stresses, strains and displacements of a pure radial carcass tire subject to inflation pressure. The tire is modeled as an orthotropic toroidal shell. Since the meridian profile of the shell is not a well defined mathematical curve, numerical techniques must be used to integrate the shell equations.

Program Title: Cross Bias Aircraft Tire Inflation Program

Computer Used: IBM 7094

Longuage: FORTRAN IV

FDL Contact: H. K. Brewer, FDFM, 55558

Contractor: In-House

Date of Program Availability: October 1969

Mathematical Technique Used: Forward Integration

Program Usage Description: The program computes the stresses, strains, and displacements of a cross-bias aircraft tire subject to inflation pressure. The tire is modeled as an orthotropic toroidal shell. The orthotropy varies with meridian position due to the changing cord angles. Because of this and the fact that the meridian profile is not a well defined mathematical curve, numerical techniques must be used to integrate the shell equations.

Program Title: Cross Bias Aircraft Tire Inflation Program (Coupled Solution)

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: H. K. Brewer, FDFM, 55558

Contractor: In-House

Date of Program Availability: November 1969

Mathematical Technique Used: Forward Integration

Program Usage Description: The program computes the stresses, strains, and displacements of a cross-bias aircraft tire subject to inflation pressure. The tire is modeled as a layered anisotropic toroidal shell with the coupling between bending and stretching taken into account. Because the tire meridian profile is not a well defined mathematical curve, numerical techniques must be used to integrate the shell equations.

Program Title: Curve Fitting of Tire Cross Sections

Computer Used: IBM 7094

Longuage: FORTRAN IV

FDL Contact: H. K, Brewer, FDFM, 55558

Contractor: In-House

Date of Program Availability: October 1969

Mathematical Technique Used: Least Squares Trigonometric Curve Fit

Program Usage Description: This program takes experimental x-y coordinate data of a tire meridian cross section and fits it with a 7 term cosine series in the least squares sense. It then computes the tangent angle and the radii of curvature at each point. This becomes input data for the tire stress analysis program.

Program Title: Elastic Constants of Rubber-Textile Cord Composites

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: H. K. Brewer, FDFM, 55558

Contractor: In-House

Date of Program Availability: October 1969

Mathematical Technique Used: Function Evaluation

Program Usage Description: The program computes the overall sheet moduli of a rubber-textile cord composite similar to that used in tire manufacture. The analysis is based on the self-consistent model of composite materials. The rubber is treated as perfectly elastic and the cord as transversely isotropic.

Program Title: Heat Transfer Analysis of Skid Brakes

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: H. K. Brewer, FDFM, 55558

Contractor: In-House

Date of Program Availability: October 1969

Mathematical Technique Used: Modal Analysis

Program Usage Description: This program computes the temperature distribution through the thickness of a skid pad brake during landing of an aircraft. The problem is characterized by the one dimensional Laplace equation. However, the temperature gradient at the ground-brake interface is variable with time, since the aircraft is slowing down. Thus the problem is one of time dependent boundary conditions.

Program Title: Expansion of Spherical Membrane made of Non-Linear Elastomeric Material

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: H. K. Brewer, FDFM, 55558

Contractor: In-House

Date of Program Availability: October 1969

Mathematical Technique Used: Root Finding, Interpolation

Program Usage Description: This program computes the equilibrium radius of a highly deformable elastic spherical membrane with a non-linear stress-strain curve. The final pressure and membrane stress are also computed assuming adiabatic expansion of the pressurizing gas.

Program Title: Performance Analysis of Crew Escape Techniques (PACET)

Computer Used: IBM 7090/7094

Language: FORTRAN IV

FDL Contact: J. M. Peters, FDFR, 53305

Contractor: North American-Rockwell Company
Los Angeles Division

Date of Program Availability: 15 January 1968

Mathematical Technique Used: The program uses the Fourth Order Runge-Kutta Integration Method

Program Usage Description: The program is used for trajectory analysis for open and encapsulated ejection seat escape systems, with or without DART (Directional Automatic Realignment of Trajectory) or STAPAC (Gyro Controlled Vernier Rockets) Stability Subsystems. The program is a six-degree of freedom computer program that calculates the attitude and position-time history of a rigid body moving through three-dimensional space in accordance with the physical laws of motion. The program considers the forces produced by propulsive thrust, friction, aerodynamic characteristics, gravity and retardation devices. The program accommodates the escape concepts and related aerodynamic tables, rocket inpulse curves, and parachute data. Two unique escape system stabilization systems (DART and STAPAC) are available as subroutines. DART (Directional Automatic Realignment of Trajectory) and STAPAC (Gyro-Controlled Vernier Rocket Stabilization) are utilized to stabilize an ejection seat against conditions of c.g.-man rocket thrust misalignment and aerodynamically induced pitching moments. The program provides for four methods of producing output: (1) Numerical Printout (2) SC-4020 (Cathode-Ray Tube) and (3) Benson-Lehner Graphical (4) CALCOMP Plotter. There are 45 output parameters for 6 DOF. (Ref. AFFDL-TR-68-66)

Program Title: Six Degree of Freedom Drop Test Vehicle Trajectory (Crew Escape Systems)

Computer Used: IBM 7090/7094 & CDC 6600

Longuage: FORTRAN IV

FDL Contact: M. C. Whitney, FDFR, 53305

Contractor: Weber Aircraft, Burbank, Calif.

Date of Program Availability: 1 May 1968

Mothematical Technique Used: Runge-Kutta Method

Program Usage Description: The program is a six degree of freedom trajectory analysis program designed for the evaluation of a sink test vehicle capable of testing crew escape systems under adverse attitude and high sink rate flight conditions. This program is comprised chiefly of four sections: (1) The input section, which allows a flexible choice of vehicle configuration, stabilizer chute sizing and launching conditions, (2) the compilation of vehicle wind tunnel testing data, (3) the numerical integration (Runge-Kutta Method) solution of the dynamic equations, and (4) computer trajectory runs. The output, aside from its detailed listing of hardware geometry, launching conditions, and the conventional trajectory printout, also features interim diagnostic comments. These comments pertain to parachute snatch loads, fill-out and snatch interval and vehicle conditions at pertinent regions of its flight path.

Program Title: Forebody/Decelerator Supersonic Flow Field

Computer Used: WPAFB-IBM 7094 and Univ. of Minn. CDC-6600

Language: FORTRAN IV

FDL Contact: C. A. Babish III, FDFR, 54008

Contractor: Regents of the University of Minnesota

Date of Program Availability: January 1970

Mathematical Technique Used: Algebra, Geometry, Calculus

Program Usage Description: This program calculates the flow field properties around and on the surface of a two-body system consisting of an axisymmetric forebody immersed in supersonic free-stream and a trailing conical decelerator. A significant output of the program is the description of the middle wake region of the forebody which is used as the starting point for the trailing decelerator flow field calculations.

Program Title: External Vision Plotting Program

Computer Used: IBM 7090/7094

Language: FORTRAN IV

FDL Contact: E. O. Roberts, FDFR, 54926

Contractor: In-House

Date of Program Availability: May 1968

Mathematical Technique Used: Geometry, Trigonometry, Algebra

Program Usage Description: The computer program is used as a working tool to provide various external vision plots from inside any particular aircraft system. Given specified planar windows of any configuration made up of straight lines and circles, the program will (1) calculate and print out the points of the window edges in relation to the eye point, (2) make a perspective plot and print out the coordinates of the horizon and runway pattern, and (3) plot the visibility angles of the window configuration. The program is designed to plot on an 18" CALCOMP plotting machine.

COMPUTER PROGRAMS IN

FLIGHT MECHANICS TECHNOLOGY

Summary of Flight Mechanics Technical Effort in AFFDL

Exploratory and advanced development (including simulation) in aerodynamics, aerothermodynamics, gasdynamics and flight performance to establish configuration and mission profiles for aerospace vehicles.

Program Title: ISENEX (ISENTROPIC NOZZLE EXPANSION)

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: W. H. DeMent, FDME, 55919

Contractor: In-House

Date of Program Availability: October 1969

Mathematical Technique Used: Iterative Method

Program Usage Description: Computes one-dimensional real gas flow expansion through a supersonic/hypersonic conical nozzle. Calculates bulk thermodynamic and aerodynamic flow properties at the exit of a supersonic or hypersonic conical nozzle from selected reservoir conditions and nozzle geometry. Uses real gas properties from AEDC Mower Tables (AEDC TDR 63-138), flow freezing criteria from Pearce. Samet and Whalen (WADD TR 60-341), and an emperical boundary layer displacement thickness calculation as developed by Burke and Bird (CAL Rpt 112). A simplified approximation to a non-uniform enthalpy profile is available by dividing the 808A nozzle flow into a "HOT" central core flow with a surrounding "COOL" shroud flow (a characteristic of high pressure arc heater operation). Fay and Riddell heat transfer calculations to a hemispherical nose are included.

Program Title: Finite Difference Hypersonic Blunt Body Solution

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: W. H. DeMent, FDME, 55919

Contractor: General Dynamics/Convair

Date of Program Availability: October 1969

Mathematical Technique Used: Finite difference method to achieve the complete solution of the Navier-Stokes equations.

Program Usage Description: This program was developed to calculate the aerothermodynamic conditions surrounding a blunted cone in hypersonic flow, so that the results could be compared with wind tunnel data. The model may have either a hemispheric or elliptically blunted nose. The nozzle exit conditions or free stream conditions ahead of the model, along with model geometry data, are the primary inputs to the program. The finite difference method is used to develop the complete solution to the Navier-Stokes equations as applied to the flow over the model. (Ref. AFFDL TR 68-66)

Program Title: SONIC (Sonic Boom Calculation)

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: T. M. Weeks, FDME, 55043

Contractor: In-House

Date of Program Availability: October 1969

Mathematical Technique Used: Method of Characteristics

Program Usage Description: Determines near and intermediate field shock strength for a non-uniform two-dimensional supersonic flow field consisting of a slit jet impinging on a lifting surface. The jet Mach number is equal to or greater than the flight Mach number.

Program Title: Automated Procedures for Evaluating Powered Hypersonic Vehicles from Subsonic through Hypersonic Speeds

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: Duane R. Burnett, FDMS, 55006

Contractor: Republic Aviation, Division of Fairchild Hiller

Date of Program Availability: January 1969

Mathematical Technique Used: As stated in AFFDL-TR-68-25, Vol. I, Part I & II

Program Usage Description: This computer program was designed to make rapid and comprehensive evaluations of hypersonic vehicle designs. The major emphasis is directed towards vehicle designs having scramjet engines as the primary propulsion system with ramjets, turbo-accelerators, and rocket engines as intermediate acceleration propulsion systems. In addition, the program handles engine-vehicle systems using the latter engines as primary propulsion systems. The program computes engine performance and the aerodynamic, weight, and heat transfer characteristics of a given vehicle design. This information, in turn, is then used in the program to analyze the vehicle performance over its particular mission profile. The program can handle generalized mission profiles consisting of take-off, climb-acceleration ascent, cruise, glide, and landing flight segments. The program can also be used to conduct studies of parametric variations of vehicle and scramjet components, and to determine the effect of various system trade-offs on the performance of hypersonic cruise aircraft, recoverable launch vehicles, upper stage boosters (non-recoverable), and scramjet powered missiles.

COMPUTER PROGRAMS IN

STRUCTURES TECHNOLOGY

Summary of Structures Technical Effort in AFFDL

Exploratory and advanced development in flight loads, atmospheric turbulence, analysis methods, statistical procedures, simulation techniques, flight load sensors, structural design concepts and materials utilization; work in these areas encompasses the entire flight regime of aerospace vehicles.

Program Title: Laminate Optimization Program Procedure V87 or RC7

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: Cecil Wallace, FDTC, 55548

Contractor: General Dynamics/Ft Worth

Date of Program Availability: 1968

Mathematical Technique Used: Matrix Algebra

Program Usage Description: This program finds an efficient combination of layer orientations at a point for a laminated composite with given properties for each lamina (principal moduli, thickness, and allowables) and a combined membrane loading. The program can handle up to six independent layer orientations and up to ten independent membrane load conditions. A positive margin of safety is assured for each load contion. Design limit envelope is determined according to either the maximum strain or the Hill's yield criteria, assuming a linear stress-strain relationship up to the limiting stress values.

Program Title: Laminate Properties Program U-65

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: Cecil Wallace, FDTC, 55548

Contractor: General Dynamics/Ft Worth

Date of Program Availability: 1967

Mathematical Technique Used: Matrix Algebra

Program Usage Description: This program computes the engineering moduli of the gross laminate, the coefficients (A_{ij}, D^*_{ij}, D_{ij}) of the laminate constitutive equation (which relates the stress resultants and couples to membrane strains and curvatures), and the yield surfaces according to either the maximum strain or the Hill's yield criteria, from the given orthotropic lamina properties (principal moduli, fiber orientation, and thickness).

It also calculates stresses or stress resultants and strains in each layer due to a given laminate membrane loading (stresses or strains). This is restricted to laminates symmetric about their middle surfaces.

The program computes allowable stresses for the gross laminate from the individual lamina properties and limit strains, against which the computed actual strains may be compared.

Linear stress-strain behavior is assumed.

Program Title: Stability Analysis of Laminated Composite Plates and Honeycomb Sandwich Panels, "Panbuck"

Computer Used: IBM 360/IBM 7094

Language: FORTRAN IV

FDL Contact: Cecil Wallace, FDTC, 55548

Contractor: Grumman Aircraft Engineering Corp., Bethpage, NY

Date of Program Availability: 1969

Mathematical Technique Used: Matrix Algebra

Program Usage Description: This program predicts the critical elastic buckling loads and modes for rectangular laminated composite plates with midplane symmetry and for honeycomb sandwich panels, both of uniform thickness, subjected to a combination of in-plane biaxial compression and shear loads applied parallel to the panel's axes of orthotropy. Edge conditions may be fully clamped, simply supported or a combination of these. The effect of normal shear deformation is included. However, the in-plane stiffness of the honeycomb core is neglected. Honeycomb panel facings must have equal moduli of elasticity. The critical elastic shear buckling stress is not computed.

Program Title: Ultimate Strength of Laminated Composites, RD5

Computer Used: IBM 7094

Language: FORTRAN IV

FDL Contact: Cecil Wallace, FDTC, 55548

Contractor: General Dynamics/Ft Worth

Date of Program Availability: 1968

Mathematical Technique Used: Matrix Algebra, Gauss-Jordon Elimination Method

Program Usage Description: This program predicts the ultimate strength of laminated composites consisting of orthotropic lamina which may have nonlinear stress-strain behavior. The program determines incrementally the average stress-strain response to ultimate failure of plane anisotropic composites with midplane symmetry subjected to biaxial membrane loads. An increment of the membrane stress is applied to the laminate while assuming a linear stress-strain response of the laminate over the applied stress increment. The given stress-strain behavior in the principal directions and the major Poisson's ratio of the individual lamina are used. It is assumed that any degradation due to yielding or failure of an individual lamina is restricted to that lamina and is not transmitted to adjacent lamina.

The program is restricted to a maximum of 20 stress increments and 15 lamina.

Program Title: Anisotropic Plate Analysis Program RA5

Computer Used: IBM 7094

Longuage: FORTRAN IV

FDL Contact: Cecil Wallace, FDTC, 55548

Contractor: General Dynamics/Ft Worth

Date of Program Availability: 1967

Mothematical Technique Used: Ritz method, matrix algebra, iteration

Program Usage Description: This program determines critical elastic buckling loads and buckled shapes, natural frequencies and mode shapes, and deflections, moments and shears due to transverse loadings of laminated anisotropic skewed plates. Full fixity, simple support, or free edges may be assumed for any edge. Also elastic point support anywhere on plate and elastic line supports parallel to edges may be assigned. Variations in plate stiffness and loadings over the plate may be included.

Linear (small deflection) theory and energy principles are used to formulate the problems and Ritz method of solution is applied to the energy equations using a series of up to 49 terms in the assumed deflection expression. The deflected shape is approximated with beam characteristic functions.

Program Title: Digital Computer Program for the Analysis of Aerospace Structures by the Matrix Displacement Method

Computer Used: IBM 7044/7094 II DCS

Longuage: FORTRAN IV

FDL Contact: L. Berke, FDTR, 53413

Contractor: In-House

Date of Program Availability: 1964

Mothematical Technique Used: Matrix Algebra

Program Usage Description: This report presents a detailed development of the Matrix Displacement Method and describes and available computer program, which can be used for the stress and deflection analysis of arbitrary structures idealized into an assembly of axial load members (bars), triangular panels, rectangular panels with linearly varying edge displacements, and rectangular panels with an assumed (Turner) stress distribution. Only the translation degrees of freedom are considered in this program. Five different loading conditions may be analyzed simultaneously, and for each condition a separate temperature distribution may be specified. A description of the digital analysis, instructions for the use of the program, and an illustrative analysis problem are presented. (Ref. AFFDL-TR-64-18)

Program Title: Automated Method for the Large Deflection and Instability Analysis of Three-Dimensional Truss and Frame Assemblies

Computer Used: IBM 7044/7094 II DCS

Longuage: FORTRAN IV

FDL Contact: L. Berke, FDTR, 53418

Contractor: Case Western Reserve

Date of Program Availability: 1967

Mothematical Technique Used: Function Minimization

Program Usage Description: The computer program can be used for the large displacement (moderate rotations) analysis of three dimensional structural assemblies constructed of truss and frame members. Both generalized displacements and forces can be prescribed at node points as loading. Load incrementation options facilitate the tracing of load-displacement curves so that maximum loads or bifurcation type instabilities can be detected. The method solution is the direct minimization of the Total Potential as a function of the generalized nodal displacements. This computer program was found especially useful for investigating bifurcation and snap-through types of instabilities of relatively simple truss and frame structures. (Ref. AFFDL-TR-66-102)

Program Title: Finite Element Displacement Method for Elastic-Plastic Problems

Computer Used: IBM 7044/7094 II DCS

Language: FORTRAN IV

FDL Contact: L. Berke, FDTR, 53418

Contractor: In-House and Illinois Institute of Technology Research Institute

Date of Program Availability: 1969

Mathematical Technique Used: Iterative Finite Element Matrix Method

Program Usage Description: A computer program is presented for the small strain analysis of plane structures in the strain hardening elastic-plastic range. The finite element displacement method is used to perform the linear analyses in the iterative scheme. Bar and constant strain isotropic plane stress triangular elements are available to construct structural idealizations. The use of ten different sets of material properties, three different material laws, and incremental proportional loading are available as options. Good correlation is shown with available test data and theoretical solutions. (Ref. AFFDL-TR-68-39)

Program Title: Arbitrary Shells of Revolution - Static Stress Analysis Program

Computer Used: IBM 7044/7094 II DCS

Language: FORTRAN IV

FDL Contact: T. Bernstein, FDTR, 55689

Contractor: Lehigh University

Date of Program Availability: 1967

Mathematical Technique Used: Numerical Integration

Program Usage Description: This program calculates the stresses and displacements in thin-walled elastic shells of revolution, when subjected to static edge, surface and/or temperature loads, by means of the method of analysis published by A. Kalnins in the Journal of Applied Mechanics, September 1964, pp. 467-476 and December 1965, pp. 941-943. The program is applicable to rotationally symmetric shells to which a number of axisymmetric branches can be attached. The only restriction on the shell is that its geometry, boundaries, and material properties are symmetric about one axis; that is, each section of the shell perpendicular to the axis must be circular. However, the geometry, and elastic parameters may vary in an arbitrary manner along the meridian of the shell.

The surface loads and temperature loads may vary arbitrarily over the surface of the shell. Through a simple input code number, the program automatically calculates the stresses and displacements of a shell of revolution spinning about its axis of symmetry. (Ref. AFFDL-TR-68-144)

Program Title: Nonsymmetric Eigenvalue Program (Arbitrary Shell of Revolution)

Computer Used: IBM 7044/7094 II DCS

Language: FORTRAN IV

FDL Contact: T. Bernstein, FDTR, 55689

Contractor: Lehigh University

Date of Program Availability: 1968

Mathematical Technique Used: Numerical Integration

Program Usage Description: This program calculates the linearized buckling load in thin-walled elastic shells (nonsymmetrically distributed prestress) using the method of analysis published by A. Kalnins in AFFDL-TR-68-144. The program is applicable to axially symmetric shells to which a number of axisymmetric branches can be attached. The only restriction on the shell is that is geometry, boundaries, and material properties are symmetric about one axis; that is, each section of the shell perpendicular to the axis of symmetry must be circular. However, the geometry and elastic parameters may vary in an arbitrary manner along the meridian of the shell. (Ref. AFFDL-TR-68-144)

Program Title: Axisymmetric Eigenvalue Program (Arbitrary Shell of Revolution)

Computer Used: IBM 7044/7094 II DCS

Language: FORTRAN IV

FDL Contact: T. Bernstein, FDTR, 55689

Contractor: Lehigh University

Date of Program Availability: 1967

Mathematical Technique Used: Numerical Integration

Program Usage Description: This program calculates the linearized buckling load in thin-walled elastic shells or the natural frequencies and mode shapes (stresses as well as displacements) of symmetric free vibration of rotationally symmetric elastic shells (symmetrically distributed prestress) using the method of analysis published by A. Kalnins in the Journal of the Acoustical Society, Vol. 36, July 1964, pp 1355-1365 and the Journal of Applied Mechanics, December 1965, pp 941 - 943. The program is applicable to axially symmetric shells to which a number of axisymmetric branches can be attached. The only restriction on the shell is that its geometry, boundaries, and material properties are symmetric about one axis; that is, each section of the shell perpendicular to the axis of symmetry must be circular. However, the geometry and elastic parameters may vary in an arbitrary manner along the meridian of the shell.

The program automatically finds either all natural frequencies within a prescribed frequency interval or a specified number of consecutive natural frequencies above a given frequency. The mode shapes of all displacements and stresses (or stress-resultants) are calculated within a specified accuracy and printed out at any desired number of points. (Ref. AFFDL-TR-68-144)

Program Title: Analytic Design Methods for Aircraft Structural Joints

Computer Used: IBM 7044/7094 II DCS

Longuage: FORTRAN IV

FDL Contact: Howard A. Wood, FDTR, 55689

Contractor: Ling Temco Vought Aerospace Corp.

Date of Program Availability: 1967

Mothematical Technique Used: Iteration

Program Usage Description: This report includes an engineering procedure for determining the distribution of loads in the mechanically fastened joints of splice and doubler installations. The methods are generally limited to the case of a single lap arrangement and a single sandwich arrangement, but the case of multiple (stacked) members is discussed. The members may have any form of taper or steps and the effects of fastener-hole clearance or "slop" and plasticity can be accounted for. The particular primary data that must be supplied but which are not generally available in the literature are the spring constants of the fastener sheet combinations.

The basic computer routines are limited to 100 elements or rows, of fasteners. For the case of single jap slices and doublers, the routines have been extended to include the effect of fastener (joint) plasticity and to present the residual loads existing after an excursion into the plastic range. The weight of the doubler is also calculated.

The stacked doubler and splice programs consider one additional member, are for elastic problems only and do not consider "slop".

The basic technique involved in the determination of fastener loads is essentially one of successive trails using the principles of static equilibrium and strain compatability. (Ref. AFFDL-TR-67-134)

Program Title: Digital Computer Program for the Analysis of Crack Propagation in Cyclic Loaded Structures

Computer Used: IBM 7044/7094 II DCS

Language: MIMIC

FDL Contact: Howard A. Wood, FDTR, 55651

Contractor: In-House

Date of Program Availability: 1967

Mathematical Technique Used: Digital Analog Simulation Program (MIMIC)

Program Usage Description: The program is useful in solving numerous problems occurring in aircraft type structures, such as fatigue crack propagation and crack growth emanating from projectile impact damage.

The program calculates the crack propagation behavior of cyclic loaded structrues by means of the theory and equation developed by Forman. The program was specifically written to take into account complex crack geometries and cyclic loads of nonuniform character. Crack description and loading is input in terms of the stress intensity factor range Δ K. In addition to providing crack length after a prescribed number of cycles, the solution determines the number of cycles required for crack instability or rapid growth to failure. (Ref: AFFDL-TR-67-5)

Program Title: Matrix Analysis via Generative and Interpretative Computations (MAGIC)

Computer Used: IBM 7044/7094 II DCS

Language: FORTRAN IV

FDL Contact: G. E. Maddux, FDTR, 55639

Contractor: Bell Aerosystems Co.

Date of Program Availability: 1 Junuary 1969

Mothematical Technique Used: Matrix abstraction and manipulation is used to minimize the potential energy in a structural system.

Program Usage Description: An automated general purpose system for analysis is presented. This system, identified by the acronym "MAGIC" for "Matrix Analysis via Generative and Interpretative Computations", provides a flexible framework for implementation of the finite element analysis technology. Powerful capabilities for displacement, stress and stability analyses are included in the subject MAGIC System for structural analysis.

The matrix displacement method of analysis based upon finite element idealization is employed throughout. Six versatile finite elements are incorporated in the finite element library. These are; frame, shear panel, triangular cross section ring, toroidal thin shell ring, quadrilateral thin shell and triangular thin shell elements. These finite element representations include matrices for stiffness, incremental stiffness, prestrain load, thermal load, distributed mechanical load and stress.

The MAGIC System for structural analysis is presented as an integral part of the overall design cycle. Considerations in this regard include, among other things, preprinted input data forms, automated data generation, data confirmation features, restart options, automated output data reduction and readable output displays.

Documentation of the MAGIC System is presented in three parts; namely, Volume I: Engineer's Manual, Volume II: User's Manual and Volume III: Programmer's Manual. (Ref. AFFDL-TR-68-56)

Program Title: Point Matching Solutions of Boundary Value Problems

Computer Used: IBM 7044/7094 II DCS

Language: FORTRAN II

FDL Contact: G. E. Maddux, FDTR, 55689

Contractor: Ohio State University

Date of Program Availability: 1964

Mathematical Technique Used: The method of undetermined parameters is employed.

Program Usage Description: This report describes work undertaken to develop further the point-matching technique for application to thermally and transversely loaded plates and associated boundary value problems; to develop computer programs, based upon the method, which are capable of universal usage to solve plate problems involving arbitrary shape and loading; to demonstrate the use of the computer programs on practical problems; and to investigate the mathematical convergence properties of the method.

The equations of linear, thin, elastic plate theory, including thermal effects, are presented. Solutions to the governing differential equation require complementary and particular parts. Various forms of complementary and particular solutions suitable for handling arbitrary boundary shape and loading are presented, along with the resulting form of the slope, moment, and shear equations. Two forms of complementary solution are presented: the Michell solution, in polar coordinates, and the Levy solution, in rectangular coordinates. Three forms of particular solution are described: trigonometric and power series in rectangular coordinates, and concentrated load functions. The application of these solutions by the point matching method to the problems of thermally and transversely loaded plates are demonstrated by several examples.

Application of the point matching method to other boundary value problems solvable in terms of harmonic and biharmonic functions is described; e.g., torsion, conductive heat transfer, plane elasticity, slow motion of a viscous fluid, membrane deflection, and electromagnetics.

A method of analyzing plates having both transverse and in-plate loads is presented. This method uses an iterative application of the point matching technique.

Some limitations and considerations when using the point matching technique are described in a separate chapter. (REF. AFFDL-TR-64-159)

Program Title: Thermal Response in Sandwich Panels

Computer Used: IBM 7044/7094 II DCS

Language: FORTRAN II

FDL Contact: G. E. Maddux, FDTR, 55689

Contractor: Martin Marietta Aerospace Corp.

Date of Program Availability: 1964

Mathematical Technique Used: A forward finite difference form of the heat balance equation is solved to give temperature versus time results.

Program Usage Description: An analytical model is presented for predicting thermal response in honeycomb sandwich panels. The model considers a variety of configurations involving single or stacked panels. Consideration is given to all three modes of heat transfer and to temperature dependent thermophysical properties of the materials of fabrication. The heat balance equations are of the finite difference form and employ the forward difference technique for solution. A stability criterion is presented for the heat balance equations. The entire system of equations is programmed for solution on the IBM 7094 digital computer. Validity of a portion of the analytical model is established by comparing predicted results to existing experimental data for single honeycomb panels. (REF. AFFDL-TDR-64-135)

Program Title: Fortran Matrix Abstraction Technique

Computer Used: IBM 7044/7094 II DCS

Language: FORTRAN IV

FDL Contact: J. R. Johnson, FDTR, 55689

Contractor: McDonnel Douglas Corp.

Date of Program Availability: 1968

Mathematical Technique Used: Matrix Algebra, Linear Equations

Program Usage Description: FORMAT (Fortran Matrix Abstraction Technique) is a digital computer system consisting of three distinct programs written entirely in Fortran IV. The system provides for generating, manipulating, printing, and plotting of large order (i.e.,2000) matrices commonly used in state-of-the-art structural analysis technique. The capability of maintaining and automatic editing of case data has also been provided. Phase I of the system automatically generates matrices for joining, symmetric/antisymmetric disconnect, vibration, and stability analyses. Modules for converting continuous-to-discrete loads, analytic-to-discrete geometry, and a master case data file editor are provided to reduce input data requirements. Phase II of the system provides for the manipulation of matrices. The matrix operations include most of the basic matrix operations (e.g., add, multiply, etc.), several special matrix operations (e.g., adjoin), and several control operations (e.g., save matrices, conditional IF test, etc.). Phase III of the system provides for self-explanatory report form printing of matrices and a nominal graphical display capability, including a geometric display. (REF. AFFDL-TR-66-207, Vol. V).

Program Title: Automated Minimum Weight Structural Design

Computer Used: IBM 7044/7094 II DCS

Language: FORTRAN IV

FDL Contact: J. R. Johnson, FDTR, 55689

Contractor: Bell Aerosystems Co.

Date of Program Availability: January 1967

Mathematical Technique Used: Matrix Algebra, Calculus, Linear Programming

Program Usage Description: The objective of the computer programs is the automatic determination of the least weight of a given structural configuration under the action of a multiplicity of external loading and thermal conditions, and subjected to limitations on the stresses and deflections of the structure. The possibility of considering overall instability as a criterion is also provided for one class of structures. The range of structures which may be optimized using these programs is only limited by the extent to which a given structure may be satisfactorily idealized, using the structural elements available: axial force member, triangular plate in-plane stress, axial force-twist-flexural member, axial force-twist-flexural member with instability, rectangular shear panel, rectangular plate in bending in two dimensions, axial force-twist-flexural member in two dimensions.

AFFDL-TR-66-180 documents the computer programs. Two programs are discussed in detail, an intermediate capacity linear merit function program, and a large scale nonlinear program. The intermediate capacity program can be used for the optimization of major structural components of up to approximately 170 degrees of freedom with fixed configuration. The large scale program is capable of handling structures with up to 450 degrees of freedom and includes geometric variables. Detailed description on the preparation of input data are included. Examples are given of the applications of the programs to a wide variety of structures including major airframe components, indicating the weight savings possible through application of the optimization techniques. REF: AFFDL-TR-66-180)

Program Title: An Iterative Method for the Analysis of Large Structural Systems

Computer Used: IBM 7044/7094 II DCS

Language: FORTRAN IV

FDL Contact: V. B. Venkayya, FDTR, 53418

Contractor: In-House

Date of Program Availability: 1968

Mathematical Technique Used: Matrix Methods

Program Usage Description: An iterative method to analyze large structural systems subjected to static and thermal loadings is developed. This method is essentially the displacement method of analysis in which the finite elements are grouped into convenient size substructures. The analysis proceeds with one substructure at a time, and a process of iteration establishes the continuity of the system. The speed of convergence depends on the nature of the stiffness matrices of the substructures. The main advantages of the iteration method are that the entire computational scheme can be carried out without exceeding the core of the machine, and the method uses less computer time than the direct analysis. At the present, only beam elements and axial force elements are available in the computer program. (REF: AFFDL-TR-67-194)

Program Title: Lockheed Thermal Analyzer

Computer Used: IBM 7044/7094 II DCS

Language: FORTRAN IV

FDL Contact: R. M. Engle, Jr., FDTR, 55651

Contractor: Lockheed-California Co.

Date of Program Availability: 13 March 1967

Mathematical Technique Used: Finite Difference

Program Usage Description: The thermal analyzer program solves transient and steady state heat flow problems by providing a digital solution of an analogous R-C electrical network and by providing several functions which handle certain general and special heat flow conditions. This report describes how to transcribe the sketch of the electrical network to data cards. It also describes the available functions and subroutines and how they are used in the program.

The program consists of three basic sections. Section one compiles the input data. Section two performs the calculations and prints the desired results. Section three provides for on-line plots of temperature versus time for a maximum of twenty-five nodes. The input data limitations are very flexible. A maximum of 15,000 cells is available for data. Other restrictions include: 4000 nodes, 4000 resisters, 4000 capacitors, 2000 tables.

Program Title: Mass Properties Estimation Program (MPEP)

Computer Used: IBM 7094

Longuage: FORTRAN IV

FDL Contact: F. Boensch, FDTS, 52938

Contractor: Martin Marietta Corp.

Date of Program Availability: October 1969

Mothematical Technique Used: Straight forward calculation of empirically derived equations.

Program Usage Description: This program executes empirically derived estimating equations to present a detailed weight estimation for logitudinally propelled aerospace vehicles. The program requires from 100 to 300 inputs consisting of logic flow controls, geometric parameters, and throughput weight data. The output is in a modified MIL-STD-254 format. In addition to the weight estimation, some rudimentary balance and volumetric adequacy calculations are performed.

REFERENCES

A. B. Nutt, AFFDL-TR-68-66 (AD 835368) "A Compilation of Computer Programs in Flight Vehicle Technology - 1964-1967", Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, April 1968

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13. ABSTRACT

A compilation of computer programs useful in the design of flight vehicles. Technical domains covered include the following:

Structures
Aerodynamics
Vehicle Dynamics
Flight Control
Environmental Control
Crew Escape and Retardation
Landing Gear Subsystems

All programs were devised in-house in the Air Force Flight Dynamics Laboratory or were prepared for them under R&D contracts.

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