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RESEARCH IN FLIGHT DYNAMICS

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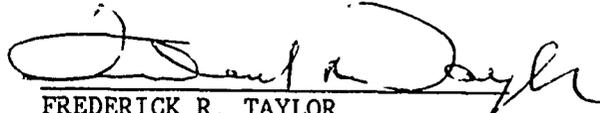
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FOREWORD

This report describes the multi-discipline technical efforts accomplished by Universal Energy Systems, Inc., for the Wright Research and Development Center, Flight Dynamics Laboratory, Wright-Patterson AFB OH, under Contract F33615-86-D-3800 (SB5861-0377) Project FY1456-86-00012.

The work reported on herein was performed during the period 1 May 1986 to 1 May 1989 under the direction of Universal Energy Systems, Inc. The Final Report was released 1 September 1989.

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SECTION I

INTRODUCTION

The Wright Research and Development Center, Flight Dynamics Laboratory is the principle source to the United States Air Force for technical management and implementation of research and development of flight dynamics technologies for advanced weapon systems. The Research In Flight Dynamics Program, reported on herein, utilized specialized capabilities for the effective solution of persistent multi-discipline problems in flight dynamics technical areas. Technical disciplines included vehicle dynamics, flight control, crew station design, crew escape, environmental control, mechanical subsystems, and flight vehicle technology integration.

Universal Energy Systems, Inc. (UES) was responsible for overall program performance and administration to achieve desired objectives of specialized research tasks. UES utilized staff engineers, scientists and support personnel along with expert senior scientists and organizations to accomplish assigned program tasks. The expertise of specialized personnel and organizations was obtained through short term subcontracting arrangements.

The efforts performed on the Research In Flight Dynamics Program have assisted greatly the research capabilities and specific research needs of the Flight Dynamics Laboratory. The unique and highly specialized research studies were accomplished with minimum delay and to the complete satisfaction of the scientists and engineers of the Flight Dynamics Laboratory.

SECTION II

FLIGHT DYNAMICS LABORATORY TASK SUMMARIES

This section reports on assigned tasks which were supported during the Research In Flight Dynamics Program. Presented are brief descriptions of each task objective and a short summary of the efforts managed and directed by Universal Energy Systems, Inc. (UES) to accomplish the desired task goals or to solve specialized problems.

TASK TITLE: DYNAMIC STALL OF TRANSONIC AIRFOILS

TASK NUMBER: 001

TASK OBJECTIVE: This effort was to investigate aerodynamic phenomenon on airfoils which are rapidly pitched upward beyond their static stall angle, resulting in dramatic increases in maximum lift and pitching moment. The primary objective was to establish a basic understanding of rotating airfoils and its potential applicability to supermaneuverability in improved aircraft performance.

PROJECT SUMMARY

Universal Energy Systems, Inc. (UES) supported this task with Dr Miguel Visbal. Dr Visbal conducted specialized research into numerical simulation of dynamic flows about transonic airfoils using advanced numerical simulation techniques. The results of this effort were reported in AIAA Preprint 86-1053 "Evaluation of an Implicit Navier-Stokes Solver for Some Unsteady Separated Flows."

TASK TITLE: PRE- AND POST-PROCESSING OF NUMERICAL FLOW FIELD DATA

TASK NUMBER: 002

TASK OBJECTIVE: This effort was to develop a software system which will prepare the information to solve the flow field over an aerospace configuration and also present the final solution form for use by the design engineer.

PROJECT SUMMARY

UES supported this task with Mr Gerald Trummer. Mr Trummer performed processing and modifying of software to support the advanced modeling and simulation studies of the Flight Dynamics Laboratory. The efforts performed on this task were documented in updates to the Flight Dynamics Laboratory's graphics system users manuals.

TASK TITLE: IMPINGEMENT COOLING

TASK NUMBER: 003

TASK OBJECTIVE: This effort was to investigate the aerodynamic cooling effect on the leading edge of a blunt body by an internal jet impingement on a concave surface with rapid rotating motion. Establish a basic

understanding of aerodynamic phenomenon of jet impingement problem and its potential application in improved hypersonic vehicle and propulsion system performance.

PROJECT SUMMARY

UES supported this task with Mr Sam Linton. Mr Linton conducted numerical simulations of the impingement problem by means of the Navier-Stokes equations in the non-Newtonian frame of reference. He validated the numerical results by comparing with experimental data. Mr Linton developed the necessary basic understanding of the concept of impingement cooling to enhance aircraft and aerospace vehicle performance. The results of his efforts were reported in AIAA Preprint 87-0609 entitled "Numerical Simulation of Jet Impingement Cooling in a Rotating Frame of Reference."

TASK TITLE: THREE-DIMENSIONAL FINITE-ELEMENT TRANSONIC EULER CODE

TASK NUMBER: 005

TASK OBJECTIVE: This task was to investigate the capability and demonstrate the advantage of a Finite-Element Transonic Euler solver in analyzing flows around complex wing-body and aircraft geometries.

PROJECT SUMMARY

UES supported this task by providing the services of Professor Akin Ecer of Purdue University. Professor Ecer directed efforts to install and stabilize a developed three-dimensional finite-element transonic code on the ASD Cray computer and perform numerical simulations of various flows about complex aerodynamic bodies. Professor Ecer was assisted in this effort by Mr John Spyropoulos of Purdue University and with assistance from UES. The task Final Report entitled "Implementation of the Block-Structured Euler Flow Solver (EFS) on the Cray X-MP Computer System," May 1987, describes the efforts undertaken to implement the EFS solver and the results of the program.

TASK TITLE: INTERACTION OF JET IN HYPERSONIC CROSS STREAM

TASK NUMBER: 006

TASK OBJECTIVE: This task was to numerically investigate aerodynamic interaction on an axisymmetric configuration with a jet issued normally from the surface at a hypersonic Mach number. Verify the computed interactive shock wave system and the expanding jet stream trajectory by comparing with experimental measurements and extend the productive method to include effects of configuration rotation.

PROJECT SUMMARY

UES supported this task with Mr Daniel McMaster. Mr McMaster performed numerical simulations using the Navier-Stokes equations and modifications of existing DLF software packages. Numerical simulations were compared with experimental data to validate the numerical result and evaluate the accuracy. Mr McMaster extended the predictive numerical procedure to

include effects of rotation by modifying the existing computer code to accommodate the coriolis and centrifugal accelerations. He also developed the necessary understanding to interpret the observed aerodynamic phenomenon for final documentation. The results of this effort were reported in AIAA Preprint 87-0055 entitled "Interaction of Jet in Hypersonic Cross Stream."

**TASK TITLE: F-16 FLAPERON INTEGRATED SERVOACTUATOR MODIFICATION
REQUIREMENTS FOR ACTIVE FLUTTER SUPPRESSION**

TASK NUMBER: 007

TASK OBJECTIVE: This task was to determine the most appropriate, feasible, and cost-effective modifications to the F-16 flaperon integrated servoactuator (ISA) necessary to achieve sufficient frequency for the flight demonstration of an active/adaptive system to suppress flutter caused by the carriage of external stores.

PROJECT SUMMARY

UES supported this task by providing the services of Dynamic Controls of Dayton OH. Dynamic Controls, under the direction of Dr Gavin D. Jenney and Mr William G. Talley, reviewed published reports from various sources describing results of dynamic testing on the F-16 flaperon ISA and other reports covering analytical investigations of the feasibility of improving the frequency response of the subject servoactuator. Dynamic Controls presented their results of the investigation in a task Final Report entitled "F-16 Flaperon Integrated Servoactuator Modification Requirements for Active Flutter Suppression" dated 31 October 1986.

**TASK TITLE: DETERMINATION OF DEFLECTION-TIME HISTORY FOR POINTS ON THE
INSIDE SURFACE OF AN AIRCRAFT TRANSPARENCY DURING BIRD IMPACT
TESTING**

TASK NUMBER: 010

TASK OBJECTIVE: The objective of this task was to enhance a data processing technique currently being used to obtain deflection-time history for points on the inside surface of aircraft transparencies during bird impact testing. Simulated bird impact includes the dynamic loading and deflection of a transparent panel and its supporting frame. The data processing technique includes extraction of position data from two high speed motion picture cameras which have a common field of view containing points on the transparency surface.

PROJECT SUMMARY

UES supported this effort with Mr Steve Lindeman. Mr Lindeman modified, optimized and documented existing software as well as generated new code for different machines. The project consisted of two major tasks. The first task was to rewrite and optimize the Triangulation Process computer code. This code was originally written for the HP-85 microcomputer used in conjunction with the HP 9872A plotter. The second task was to convert the HP-85 microcomputer code so that it could be used on an IBM compatible Zenith 248 microcomputer. All mathematical derivations implemented in the

new computer code were the same as those supplied by AFWAL/FIER in the original HP-85 Triangular Process computer code. The results of this task were presented in a Final Task Report entitled "Triangulation Process."

TASK TITLE: IRDA CONCEPT DEVELOPMENT

TASK NUMBER: 011

TASK OBJECTIVE: The objective of this task was to continue preparing the ITAD DBMS program software for transition into a new CAD System prototype. This preparation was to be in the form of code modifications that impress the disciplines and practices of structured programming onto the current FORTRAN V software. An on-going, secondary objective for this task was to eliminate code segments that do not perform or support any functions within the current prototype system and that will not be useful in any future system development. Finally, this task was to provide information needed in determining the approach to be used in imposing modularity on the entire CAD System.

PROJECT SUMMARY

UES supported this task by providing the services of Mr Daniel Saks of Saks & Associates, Springfield OH to conduct this effort. Mr Saks directed the modification of all modules in the DBMS and made minor changes to the ITAD Executive. The modifications yielded significant improvements in the readability of the source code. Several useless features were removed and a large number of bugs fixed. The results of this task were reported by Mr Saks in a Final Task Report entitled "Revised Program Specifications for the ITAD Data Base Management System" dated 11 December 1986.

TASK TITLE: ITDA USER INTERFACE EVALUATION AND

TASK NUMBER: 012

TASK OBJECTIVE: There were two objectives which were pursued under this task. First, a prototype Executive program, developed under previous tasks, was to be used to generate a detailed Systems Executive Specification. Next, the resulting document was to be used in developing/abstracting a general Requirements Specification to be applied in future Executive design efforts. In particular, these documents will serve as baselines in formulating detailed requirements for the functional capabilities and operational interfaces of an evolving Expert-Like Engineering CAD System called ITAD.

PROJECT SUMMARY

UES supported this task by providing the services of Mr William Savage of Xenia OH. Mr Savage accomplished efforts to generate a detailed System Executive Specification and a General Requirements Specification to be applied in future Executive design efforts. The results of Mr Savage's efforts were reported in the Final Technical Report entitled "ITAD USER Interface Evaluation and Design" dated 26 November 1986.

**TASK TITLE: ROUGH/SOFT/SHORT FIELD LANDING GEAR OPERATIONAL BENEFIT
TRADEOFF ANALYSIS**

TASK NUMBER: 013

TASK OBJECTIVE: The objective of this task was to determine the improvement in operational capability obtained by applying RSSF landing gear jump, rough field, and high sink rate strut technologies to the F-16 aircraft.

PROJECT SUMMARY

UES supported this task by providing the services of Verac, Inc., of San Diego CA. Verac accomplished efforts to develop an analytical methodology and apply it to evaluate four alternative landing gear designs:

- * The currently fielded F-16 system (Baseline)
- * A combined pyrotechnics jump strut/rough field system
- * A rough field system only
- * A compressed gas jump strut system

The results of this investigation were reported in a Final Technical Report entitled "Preliminary Assessment of Alternative Landing Gear Designs" dated March 1987.

TASK TITLE: HIGH PERFORMANCE TIRE TECHNOLOGY DEVELOPMENT PROGRAM

TASK NUMBER: 014

TASK OBJECTIVE: Define the required tire technology to support advanced aerospace vehicle development. Outline in detail a development program of the required technology.

PROJECT SUMMARY

UES supported this task utilizing the services of Dr Samuel Clark of Precision Measurement Company of Ann Arbor MI. Dr Clark made assessments of current high performance tire technology and test methods, or lack thereof, that would accommodate the high speed/high load requirements of an advanced aerospace vehicle. From these assessments, Dr Clark then formulated a detailed high performance tire technology development program. The results of this investigation were presented in a Final Technical Report entitled "Technology Needs for High Velocity Vehicle Aircraft Tires" dated February 1987.

TASK TITLE: SOURCE CODE, OBJECT CODE INSTALLATION AND VERIFICATION

TASK NUMBER: 016

TASK OBJECTIVE: The objective of this task was to modify existing code to correct deficiencies in WAND 3.1 software, compile and link to create object code and libraries. In addition, efforts were undertaken to develop new source code, compile, and link to create object code to support work being developed under AFWAL/FIMG Missile Aerodynamic Design Method (MADM) contract.

PROJECT SUMMARY

UES supported this task using the services of Mr Joe J. Alemanni, Jr., of Visual Integration of San Diego CA. Mr Alemanni installed and verified specialized software to support FDL work. This work involved the correcting of several errors in the existing code. The results of this effort were reported in a letter to Mr Dick Smith dated 18 August 1986.

TASK TITLE: FEASIBILITY OF SOFT-GROUND AIRCRAFT ARRESTING SYSTEMS

TASK NUMBER: 017

TASK OBJECTIVE: Determine the feasibility of using soft-ground materials for the emergency arresting of current civil aircraft which overrun a conventional runway. Provide a plan to develop design and construction criteria for such an arrestment system.

PROJECT SUMMARY

UES supported this task with Mr Bob Cook. Mr Cook worked in conjunction with the University of Dayton Research Institute (UDRI) to determine the feasibility of using soft-ground materials for the emergency arresting of current civil aircraft. Efforts were undertaken to develop functional design criteria for the arrestment system, determine the tire/material interface model, select the most promising materials for the arrestor system, apply the selected material to a broad range of aircraft weights, determine the installation method for the final arrestment materials selected, and develop an experimental program to validate the prediction methods used in the analysis. The results of this effort were reported in the Final Technical Report entitled "Soft-Ground Aircraft Arresting Systems" dated August 1987 and published by the U.S. Department of Transportation, Federal Aviation Administration.

TASK TITLE: LETHALITY I FAILURE CRITERIA

TASK NUMBER: 018

TASK OBJECTIVE: Develop analytical requirements and procedures for solid rocket boosters exposed to laser irradiation including applicable failure criteria.

PROJECT SUMMARY

UES supported this task utilizing the services of Mr R. D. Eisler of Mission Research Corporation in Santa Barbara CA. Mr Eisler directed the efforts to conduct an in-depth literature search of articles relative to failure analysis and target response of solid propellant ballistic missiles typical of foreign designs subject to Continuous Wave (CW) laser impingement. From these efforts work was undertaken to develop analytical requirements and procedures for solid rocket boosters exposed to laser irradiation. The results of this investigation were reported in a Final Technical Report entitled "Literature Search and Technology Assessment Task" dated 31 December 1986.

TASK TITLE: DECENTRALIZED CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES
TASK NUMBER: 019
TASK OBJECTIVE: Develop a decentralized robust controller for high-order systems with uncertain parameters.

PROJECT SUMMARY

UES supported this task by providing the services of Dr Mehdi Ahmadian, Assistant Professor in the Mechanical Engineering Department, Clemson University. Dr Ahmadian performed efforts to develop an effective control technique which can be applied to modular dynamic systems, particularly those intended to be used for space missions. He investigated closed-loop stability and robust control strategy as well as a decentralization technique. Dr Ahmadian formulated the problem and presented a method for solving the coupled Riccati equation for each subsystem in a closed form. The results of this investigation were reported in the Final Technical Report entitled "Decentralized Control of Large Space Structures" dated November 1987.

TASK TITLE: COUPLED THERMOVISCOPLASTICITY
TASK NUMBER: 022
TASK OBJECTIVE: Formulate a coupled thermoviscoplasticity theory that incorporates thermal relaxation. Determine under what conditions the thermal relaxation can be neglected.

PROJECT SUMMARY

UES supported this task by providing the services of Professor Richard Hetnarski, Department of Mechanical Engineering, Rochester Institute of Technology in Rochester NY. Professor Hetnarski worked to derive a general coupled thermoviscoplasticity theory that incorporates thermal relaxation. He specialized the theory toward the case of small deformations and large temperature variations. The results of the effort were reported in the Final Technical Report entitled "Coupled Thermoviscoplasticity."

TASK TITLE: ROTATING BODY WITH A BLOWING JET IN HYPERSONIC STREAM
TASK NUMBER: 023
TASK OBJECTIVE: Numerically simulate aerodynamic interaction of rotating configurations with a blowing jet in a hypersonic stream. Extend the classic Navier-Stokes equations to include effects of the rotating frame of reference. Verify the calculated interactive shock waves system and the expanding jet trajectory with related experiments. Generate the index of refraction by the first principle.

PROJECT SUMMARY

UES supported this task with Mr Daniel McMaster. Mr McMaster conducted efforts to investigate the numerical resolution requirement for the three-dimensional separated flow field around the non-rotating body. The major portion of the investigation was devoted to the simulation of the flow field

around the body configuration with the added complexity of rotating motion about the principal axis of the body. Numerical solutions over a wide range of angular velocities were obtained in the rotating frame of reference. Comparisons were made between experimental and numerical data. The results of this study were reported in the Final Technical Report entitled "Supersonic, Transverse Jet from a Rotating Ogive Cylinder in a Hypersonic Flow" dated September 1987.

TASK TITLE: GRAPHIC PACKAGE FOR COMPUTATIONAL AERODYNAMICS

TASK NUMBER: 024

TASK OBJECTIVE: Develop a dynamic display software package for numerical simulation of a wide range of unsteady fluid dynamics phenomena associated with Forecast II, PT-203 Project.

PROJECT SUMMARY

UES supported this task with Mr Gerald Trummer. Mr Trummer generated and improved the software package for computer graphic systems available to personnel of the Aerodynamics and Airframe Branch including the CRAY XMP-12, CYBER 850, PRIME 750, VAX 780 as well as the color graphic workstations AED 512 with ILSI and IRIS 3030. He also maintained the graphic software developed in the Computational Aerodynamics Group for daily operation and for the purpose of technology transfer. Efforts included the modifying of line, vector, contour and pseudo color spectrum codes as necessary to be compatible with the NOS, VMS, and Primal operating systems. The results of this effort were compiled as updates to user's manuals for software packages and operating systems.

TASK TITLE: PERFORMANCE METHODS ENHANCEMENT STUDY

TASK NUMBER: 026

TASK OBJECTIVE: Modernize and incorporate new techniques into the components of the FIMG performance program library to add capability, increase efficiency, and simplify use.

PROJECT SUMMARY

UES supported this task with Mr Fay Young. Mr Young made major changes to the NSEGI III program which included a reorganization of the code, more general vehicle specification, additional plotting capability including energy maneuverability plots and overlay and delta plotting, revisions and additions to mission segments and the addition of a new take-off routine. The results of this effort supersedes AFFDL-TM-FXG-79-38, NSEG-Segmented Mission Analysis Program, AFFDL User's Manual, April 1979. This report is an updated version that includes additions and enhancements made to NSEGI III Computer Program.

TASK TITLE: LIQUID HYDROGEN FUEL STIMULANT DEVELOPMENT

TASK NUMBER: 027

TASK OBJECTIVE: Develop techniques to allow the use of cryogenic stimulants, such as liquid nitrogen and liquid helium to duplicate the actual heat flux distribution experienced by a structural component which is exposed to liquid hydrogen.

PROJECT SUMMARY

UES supported this task with Mr Robert Buzdon, Mr James Harold, and Mr Tom Stevenson of UES, and Dr Louis I. Boehman, Department of Mechanical Engineering, University of Dayton. This task was to develop techniques to allow the use of cryogenic stimulants to duplicate the actual heat flux distribution experienced by a structural component which is exposed to liquid hydrogen. The investigation consisted of six tasks that were examined. They were the following:

- * Establish the range of heat fluxes that will be encountered by the external walls of the liquid hydrogen fuel tanks.
- * Determine the boiling heat transfer characteristics of liquid hydrogen, liquid helium, and liquid nitrogen, the free convection and forced convection heat transfer characteristics of both subcooled and gaseous states of these gases.
- * Determine sources of the best heat transfer data for the three cryogens.
- * Perform the necessary analysis to determine if the thermal effects of liquid hydrogen can be duplicated by the two inert cryogens.
- * Perform thermal stress computations for representative tankage structures.
- * Investigate the prospects for determining the three-dimensional temperature field in the walls of possible fuel tanks.

The results of this investigation were reported in the Final Technical Report entitled "Liquid Hydrogen Fuel Stimulant Development" dated November 1987.

TASK TITLE: X-29 AERODYNAMIC AND PERFORMANCE ANALYSIS

TASK NUMBER: 028

TASK OBJECTIVE: Update and expand upon previous performance evaluations of the X-29 and compare with other fighter aircraft. Assist with the correlation of flight test and wind tunnel aerodynamic data.

PROJECT SUMMARY

UES supported this task with Mr Charles Bursey. Mr Bursey developed aircraft flight performance data for the X-29 aircraft and made comparisons

with the F-16A, the F-15C and the F-20 aircraft. Steady-state performance was developed using the AFWAL/FIMG NSEG flight performance program. Dynamic turns were constructed from data produced from the AFWAL/FIMG Six-Degree-of-Freedom Program (SDF). The MULTAC air combat program developed by AFWAL/FIMG was used to provide data for the combat analysis. The results of this effort were reported in the Final Technical Report entitled "Fighter Aircraft Performance Comparisons" dated September 1987.

TASK TITLE: ACTIVE VIBRATION CONTROL OF LARGE SPACE STRUCTURES

TASK NUMBER: 030

TASK OBJECTIVE: The objective of this task was to analytically investigate active vibration control of large space structures with low frequency, closely spaced modes. Determine the effectiveness of available control approaches in reducing the dynamic response in the AFWAL/FIB Advanced Beam Experiment.

PROJECT SUMMARY

UES supported this effort using the services of Professor U. Ozguner of Ohio State University. Professor Ozguner developed an analytical and an experimental model of the proof-mass actuator with the cooperation with AFWAL researchers. He also designed a compensator for the actuator for its effective utilization and developed a model of the Advanced Beam using a combination of analytical means and finite element models. In the course of this investigation, one controller was implemented on the Advanced Beam and two other designs were selected for future validation tests. The results of the task were reported in a Final Technical Report entitled "Active Vibration Control of Large Space Structures" dated January 1988.

TASK TITLE: ITAD USER INTERFACE SURVEY

TASK NUMBER: 031

TASK OBJECTIVE: The primary objective of this task was to survey various Air Force Systems Program Offices and other engineering/support activities in order to document specific user needs and requirements for incorporation into the Phase II ITAD/CAD Expert-Like System development.

PROJECT SUMMARY

UES supported this task with the services of Mr. William Savage of Xenia OH. Mr Savage assembled a group of demonstration modules/programs which represented the features and capabilities of the ITAD/CAD system. These demonstrations were sufficiently detailed as to include such human engineering features as on-line help, input error management and basic screen management. Mr Savage prepared a critique form to record input from interviews and demonstrations. The results of the task were reported in a Final Technical Report entitled "ITAD USER Interface Survey" dated 31 March 1988.

TASK TITLE: HOT STRUCTURES CONSULTIVE EXPERTISE

TASK NUMBER: 034

TASK OBJECTIVE: Two objectives were to be achieved in this effort. The first objective was to develop and demonstrate a method for lowering the temperature of transatmospheric vehicle leading edges that are heated beyond structural limits because of excessive aerodynamic heating. The second objective was to prepare a User's Manual to instruct relatively inexperienced thermodynamic engineers to become proficient in using the Advanced Environmental Control System AECS steady-state digital computer program.

PROJECT SUMMARY

UES supported this effort using the services of Mr Carl Feldmanis of New Carlisle OH. Mr Feldmanis conducted a seminar in which preparation and computation of input data for the Advanced Environmental Control System Computer Program were outlined. He also determined the physical properties of the leading edge heat exchangers. Mr Feldmanis also prepared a draft of the user's manual for the Advanced Environmental Control System Computer Program.

Because of Air Force scheduling problems, this task had to be extended twice to provide time for the Air Force to provide Mr Feldmanis with test data for analysis. Test data were never received. Therefore, the task was not totally completed.

TASK TITLE: BIFURCATION OF SEPARATED FLOWS UPSTREAM OF A BLUNT FIN

TASK NUMBER: 041

TASK OBJECTIVE: Develop a flux-splitting, relaxation numerical procedure for the three-dimensional, compressible, Reynolds-averaged Navier-Stokes equations to investigate the control effectiveness of a blunt fin with variable sweep-back angles. Verify the calculated inviscid-viscous interaction, including the separated flow by comparing with available experimental data. Demonstrate that the basic aerodynamic phenomenon is closely related to the bifurcation of separated flows.

PROJECT SUMMARY

UES supported this effort with Mr Daniel McMaster. Mr McMaster performed a series of numerical simulations for supersonic flow past a blunt fin mounted on a flat plate with progressively increasing leading edge sweepback. The numerical results were validated with a known numerical solution and experimental data at Mach 2.95 and unit Reynolds number of 64 million per meter. The results of this effort were reported in a Final Technical Report entitled "A Numerical Study of Three-Dimensional Separated Flows Around a Sweepback Blunt Fin" dated July 1988.

TASK TITLE: COMPUTATIONAL AERODYNAMICS GRAPHICS PACKAGE

TASK NUMBER: 042

TASK OBJECTIVE: The objective of this task was to develop an interactive dynamic display software package for computational aerodynamics in direct support to the Forecast II initiatives.

PROJECT SUMMARY

UES supported this effort with Mr Gerald Trummer. Mr Trummer worked to develop and improve the interactive computer graphic package based on DISSPLA for FIM's integrated computing system including the CRAY XMP-12, CYBER 845, PRIME 750 as well as the color graphic workstations. He also was responsible for generating and maintaining the caption/label display, composite compositions, and editorial options for the existing graphic software of the Aerodynamic and Airframe Branch. The results of this effort were included in updates to the user's manual entitled "Titler User's Manual."

TASK TITLE: FLIGHT DYNAMICS LABORATORY INDUSTRY DAYS

TASK NUMBER: 044

TASK OBJECTIVE: To disseminate information on present and future technology investments of the Flight Dynamics Laboratory to contractors, industry, and government personnel. This will provide a forum for interaction between the Laboratory and organizations working in related research and development activities.

PROJECT SUMMARY

UES supported this task with Mr Gary D. Streby and Ms Ann Corbitt with assistance from the UES graphics and support groups. The Industry Days Conference was held on 18-19 October 1988 and presented the many different advanced technology areas in which FDL presently conducts R&D efforts. There were approximately 470 attendees. UES was responsible for scheduling of the conference center, making arrangements for accommodations for attendees, arrangements for breaks and meals, the design and preparation of invitations and brochure for printing, and processing registrations and registration fees. The results of this effort were reported in the Final Technical Report entitled "FDL Briefing to Industry" dated November 1988.

TASK TITLE: HYDRAULIC ANALOG HIGH SPEED ESCAPE SYSTEM MULTI-BODY SEPARATION STUDY

TASK NUMBER: 045

TASK OBJECTIVE: The objective of this effort was to obtain a qualitative definition of the flowfield existing during high speed escape capsule ejection.

PROJECT SUMMARY

UES supported this task utilizing the services and facilities of Martin Marietta of Orlando FL. UES provided engineering and technical support to

design the hypersonic test models for hydraulic analog testing program. Martin Marietta conducted the actual tests using their hydraulic analog water table facility. An analysis of crew escape capsule separation from hypersonic aircraft was performed by water table tests. Water depth measurements were converted to equivalent compressible gas pressure coefficients to supplement flow visualization. Aerodynamic coefficients were generated for several generic capsule shapes and compared to existing two- and three-dimensional wind tunnel test data. Limitations on the hydraulic analogy were derived from the results for future application of the water table to hypersonic separation problems. The results of this effort were reported in the Final Technical Report entitled "Final Report of Hydraulic Analog High Speed Escape System Multi-Body Separation Study" dated June 1989.

TASK TITLE: FDL HERITAGE DOCUMENTATION

TASK NUMBER: 046

TASK OBJECTIVE: This task was to document and present the history of the Flight Dynamics Laboratory and its direct predecessors, back to the formation of McCook Field. The objective was to assimilate the history, technological trends, and lessons learned from the Laboratory's past.

PROJECT SUMMARY

This task was to prepare for publication a historical review of the accomplishments of the Flight Dynamics Laboratory. UES supported this effort with Mr Jim St. Peter and Mr Tom Martin. They reviewed literature and conducted individual interviews with FDL personnel to develop a complete history of Flight Dynamics Laboratory. Mr St. Peter and Mr Martin compiled and wrote the document which was then prepared by UES as a camera-ready manuscript. The final document is entitled "The Flight Dynamics Laboratory: Evolution of an Engineering Miracle" and will be published by the Flight Dynamics Laboratory.

TASK TITLE: NUMERICAL SIMULATION PROCEDURE FOR VERTICAL MOTION AROUND FOREBODIES IN PLUNGING MOTION

TASK NUMBER: 047

TASK OBJECTIVE: Develop a second-order temporal and spatial accurate numerical procedure in solving the unsteady, compressible Navier-Stokes equations for forebodies executing a plunging motion.

PROJECT SUMMARY

UES supported this effort with Dr Raymond Gordnier. Dr Gordnier worked to develop a second-order temporal and spatial accurate numerical procedure to solve the unsteady, compressible Navier-Stokes equations for forebodies executing a plunging motion. Efforts were accomplished to generate a body conformal grid system for blunt/sharp-nose forebodies with grid-space clustering near surface suitable for resolving the shear stress terms and to develop the basic understanding from research results to interpret and evaluate possible sources of the unsymmetric vortex formation induced by the

plunging motion. The results of this effort were presented in the Final Technical Report entitled "3-D Composite Velocity Solutions for Subsonic/Transonic Flow over Forebodies and Afterbodies" dated July 1989.

TASK TITLE: COMPUTATIONAL AERODYNAMICS GRAPHIC PACKAGE

TASK NUMBER: 048

TASK OBJECTIVE: Develop and upgrade an interactive dynamic display software package for computational aerodynamics in direct support to the non-linear aerodynamics initiative.

PROJECT SUMMARY

UES supported this effort with Mr Gerald Trummer. Mr Trummer developed and improved the interactive computer graphics package to support various FDL hardware systems. He generated and maintained the caption/label display, dynamic display and editorial options for existing graphics software of the Aerodynamic and Airframe Branch. Mr Trummer also prepared and updated user's manuals for all procedures modified or added. The results of this effort were presented in a Final Technical Report entitled, "Making Movies" dated August 1989.

TASK TITLE: NUMERICAL SIMULATION PROCEDURE FOR DELTA WING IN ROCKING MOTION

TASK NUMBER: 049

TASK OBJECTIVE: Develop a second-order temporal and spatial accurate numerical procedure to solve the unsteady, compressible Navier-Stokes equations for delta wings in rocking motion. Verify the computed unsteady vortical dominated flowfield with related experimental data.

PROJECT SUMMARY

UES supported this task with Dr Datta Gaitonde. Dr Gaitonde verified the computed unsteady vortical dominated flowfield with related experimental data and determined the effects of alternative leading-edge separation phenomenon to aerodynamic performance of delta wings. Dr Gaitonde developed a vectorized version of MacCormack's 1984 explicit/implicit line Gauss-Seidel method for three-dimensional flow computation. The results of this effort were reported in the Final Technical Report entitled "A Vectorized Gauss-Seidel Line Relaxation Scheme for Solving 3D Navier-Stokes Equations" dated July 1989.

TASK TITLE: METHODS AND CRITERIA TO EVALUATE THE SAFETY OF AIRCRAFT OPERATIONS ON DAMAGED AND REPAIRED RUNWAYS

TASK NUMBER: 050

TASK OBJECTIVE: Develop and demonstrate a computational method to evaluate the safety of aircraft operations on damaged and repaired runways.

PROJECT SUMMARY

UES supported this effort by utilizing the services of Mr Bob Cook of the University of Dayton Research Institute. Mr Cook conducted an investigation, using linear models, to determine aircraft landing gear loads resulting from operations on an AGARD runway repair. Work consisted of using a single-degree-of-freedom oscillator to find the easiest means of representing the AGARD repair mat. This study showed that the solutions from two infinite ramps, one with positive slope and one with a negative slope was all that was required. The total solution was just the sum of the solutions for each of the ramps when properly time phased. The results of this effort was reported in the Final Technical Report entitled "Methods and Criteria to Evaluate the Safety of Aircraft Operations On Damaged and Repaired Runways" dated May 1989.

TASK TITLE: MISSION ADAPTIVE WING (MAW) VALIDATION AND TRANSITION
TASK NUMBER: 051
TASK OBJECTIVE: Complete the AFTI/F-111 Mission Adaptive Wing program.

PROJECT SUMMARY

UES supported this effort by providing the services Mr Joe Hall of Boeing Advanced Systems of Seattle WA. Mr Hall provided technical support in the areas of development and testing of a smooth skin variable camber wing system. Support was provided to maintain on-site contractor support, provide flight test support for the MAW system, continue MAW wing system configuration documentation as defined by contract F33615-78-C-3027, and provide technology transition support. The results of this effort were presented as vugraphs and technical papers at the Air Force/NASA AFTI Symposium held at Edwards Air Force Base on 4-6 April 1989.

TASK TITLE: EXPERT-LIKE CAD ENGINEERING DATA REPRESENTATIONS AND EXCHANGE FORMAT STANDARDS STUDY
TASK NUMBER: 052
TASK OBJECTIVE: The primary objective of this task was to canvass, analyze and report on efforts to standardize the representations of mechanical, as well as electronic, engineering data for the purpose of automated information exchange.

PROJECT SUMMARY

UES supported this effort with the services of Mr Dan Saks of Saks & Associates of Springfield OH. Mr Dan Saks contacted personnel from various organizations involved in defining and/or implementing engineering data representations. Interviews were conducted to ascertain the current status of their respective efforts in standardizing engineering data representations. The results of this effort were reported in a Final Technical Report entitled "E-L/CAD Engineering Data Representation and Exchange Formats" dated 30 May 1989.

TASK TITLE: SLIDING MODE CONTROL DESIGN FOR FIGHTER AIRCRAFT
TASK NUMBER: 053
TASK OBJECTIVE: To determine the feasibility of developing a nonlinear controller design and analysis technique based on the variable or sliding mode method.

PROJECT SUMMARY

UES supported this task utilizing the services of Professor J. Carl Hedrick of the University of California at Berkeley CA. Professor Hedrick conducted an investigation to evaluate the suitability of sliding mode control methods for nonlinear fighter aircraft control system design. The results of this effort were reported in a Final Technical Report entitled "Sliding Mode Control Design for High Performance Aircraft" dated 10 May 1989.

TASK TITLE: USER INTERFACE SOFTWARE DEVELOPMENT FOR THE COMPUTER GRAPHIC VIDEO ANIMATION SYSTEM (CGVAS)

TASK NUMBER: 054

TASK OBJECTIVE: The first objective of this effort was to develop software for the CGVAS to allow interactive and batch generation of animations on videotape. The second objective was to translate the output of Air Force flight data recorders into input trajectories for animation. The third objective of this task was to develop software for the CGVAS to provide the capability of generating animations on either a terminal screen or on videotape.

PROJECT SUMMARY

UES supported this effort by providing the services of American Computational Services of Dayton OH and in-house computer programming support. UES provided software specialists to write software to convert trajectory and control surface position information from Air Force flight data recorders into trajectory information acceptable as input to animation computer programs. American Computational developed software to provide still and animation depictions of solid bodies. After software was developed, it was installed into the Air Force's graphics workstation. The results of this effort were submitted as a user's operations manual entitled "Facile Limning Integrated Computer Software (FLICS)" dated June 1989.

SECTION III

PLANNING DATA

Presented in this section is the Task Log for the Research In Flight Dynamics Program. Listed in Table 3.1 are the government contacts for each task as well as the investigators.

Table 3.1 Research In Flight Dynamics - Task Log

TASK	TITLE	SCIENTIST (LOCATION)	PHONE OFFICE/HOME	INITIATOR ORGANIZATION	PHONE OFFICE
0001	DYNAMIC STALL AND TRANSONIC	DR MIGUEL VISBAL (BLDG 450 ROOM C022)	(513) 255-7127 UES 426-6900	DR J. SHANG FIMM	(513) 255-7127
0002	PRE AND POST PROCESSING	GERALD TRUMMER (BLDG 450 ROOM C022)	(513) 255-7127 UES 426-6900	DR J. SHANG FIMM	(513) 255-7127
0003	JET IMPINGEMENT	SAM LINTON (BLDG 450 ROOM C022)	(513) 255-7127 UES 426-6900	DR J. SHANG FIMM	(513) 255-7127
0005	3-D FINITE-ELEMENT TRANSONIC EULER CODE	PROF AKIN EGER PURDUE UNIV	(317) 923-1321	LT FREIDMAN D. SEDLOCK/FIMM	(513) 255-4052 (513) 255-3761
0006	JET AND SHOCK INTERACTION	DANIEL MCMASTER (BLDG 450 ROOM C022)	(513) 255-7127 UES 426-6900	DR J. SHANG FIMM	(513) 255-7127
0007	F-16 FLAPERON INTEGRATED SERVOACTUATOR MODIFICATION REQUIREMENTS	DYNAMIC CONTROLS, INC	(513) 254-2529	TERRY HARRIS FIBRC	(513) 255-7384
0010	DEFLECTION TIME HISTORY OF AN AIRCRAFT TRANSPARENCY DURING BIRD IMPACT	STEVE LINDEMAN	(513) 255-2516	BOB PINNELL FIER	(513) 255-2516
0011	IRDA CONCEPT DEVELOPMENT	SAKS & ASSOCIATES SPRINGFIELD OH	(513) 324-8669	DON REESE FIEE	(513) 255-5082
0012	ITDA USER INTERFACE EVALUATION AND	WILLIAM SAVAGE XENIA, OHIO	(513) 372-7055	DON REESE FIEE	(513) 255-5082
0013	ROUGH/SOFT/SHORT FIELD LANDING GEAR OPERATIONAL BENEFIT TRADEOFF ANALYSIS	VERAC, INC. SAN DIEGO CA	(619) 457-5550	DAVID MORRIS FIEM	(513) 255-2663
0014	HIGH PERFORMANCE TIRE TECHNOLOGY DEVELOPMENT PROGRAM	DR SAMUAL CLARK PRECISION MEASUREMENT CO	(313) 995-0041	JON CHAMPION FIEM	(513) 255-2663
0016	PROVIDE SOURCE CODE, OBJECT CODE, INSTALLATION AND VERIFICATION	JOE ALEMANNI VISUAL INTEGRATION	(619) 225-9251	DICK SMITH FIMG	(513) 255-5750
0017	FEASIBILITY OF SOFT-GROUND AIRCRAFT ARRESTING SYSTEMS	UES/UDRI	(513) 426-6900 (513) 229-3030	R. ASCHENBRENNER FIBE	(513) 255-6434
0018	LETHALITY I FAILURE CRITERIA	MISSION RESEARCH CORP SANTA BARBARA CA	(805) 963-8761	CHRIS CLAY FIBEB	(513) 255-6434
0019	DECENTRALIZED CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES	MEHDI AHMADIAN CLEMSON UNIV	(803) 656-5620	DR VENKAYYA FIBRA	(513) 255-6992

Table 3.1 Research In Flight Dynamics - Task Log (Cont'd)

TASK	TITLE	SCIENTIST (LOCATION)	PHONE OFFICE/HOME	INITIATOR ORGANIZATION	PHONE OFFICE
0022	COUPLED THERMOVISCOPLASTICITY	PROF RICHARD HETNARSKI RIT	(716) 475-2157	DR G.SENDECKYJ FIBE	(513) 255-6104
0023	ROTATING BODY WITH A BLOWING JET IN HYPERSONIC STREAM	DANIEL MCMASTER UES	(513) 255-7127	DR J. SHANG FIMM	(513) 255-7127
0024	GRAPHIC PACKAGE FOR COMPUTATIONAL AERODYNAMICS	GERALD TRUMMER UES	(513) 255-7127	DR J. SHANG FIMM	(513) 255-7127
0026	PERFORMANCE METHODS ENHANCEMENT STUDY	FAY YOUNG UES	(513) 255-6578 (513) 229-2919	MIKE STRINGER FIMG	(513) 255-2021
0027	LIQUID HYDROGEN FUEL SIMULANT DEVELOPMENT	R. BUZDON/UES DR BOEHMAN/UDRI	(513) 229-3847 (513) 229-2993	MICHAEL CAMDEN FIBEB	(513) 255-6434
0028	X-29 AERODYNAMIC AND PERFORMANCE ANALYSES	CHARLES BURSEY UES	(513) 255-4077 (513) 897-9263	LT DORN FIF	(513) 255-4077
0030	ACTIVE VIBRATION CONTROL OF LARGE SPACE STRUCTURES	DR U. OZGUNER OSU MR RUNDLE	(614) 422-5940 (614) 292-1673	ROBERT GORDON FIBAA	(513) 255-5236
0031	ITAD USER INTERFACE SURVEY	MR WILLIAM SAVAGE XENIA OH	(513) 372-7055	DON REESE FIEE	(513) 255-3021
0034	HOT STRUCTURES CONSULTIVE EXPERTISE	MR CARL FELDMANIS XENIA OH	(513) 849-1568	TODD BISHOP FIEE	(513) 255-6078
0041	BIFURCATION OF SEPARATED FLOWS UPSTREAM OF A BLUNT FIN	DANIEL MCMASTER UES	(513) 426-6900	DR JOE SHANG FIMM	(513) 255-7127
0042	COMPUTATIONAL AERODYNAMICS GRAPHICS PACKAGE	GERALD TRUMMER UES	(513) 426-6900	DR JOE SHANG FIMM	(513) 255-7127
0044	FLIGHT DYNAMICS LABORATORY INDUSTRY DAYS	ANN CORBITT UES	(513) 426-900	Ricky Peters FIOR	(513) 255-4294
0045	HYDRAULIC ANALOGY OF HIGH SPEED ESCAPE SYSTEMS	MR BOB WITTMAYER MARTIN MARIETTA	(407) 356-7065	LT DAVE FLYNT	(513) 255-4008

Table 3.1 Research In Flight Dynamics - Task Log (Cont'd)

TASK	TITLE	SCIENTIST (LOCATION)	PHONE OFFICE/HOME	INITIATOR ORGANIZATION	PHONE OFFICE
0046	FDL HERITAGE DOCUMENTATION	JIM ST. PETER UES	(513) 426-6900	Dave Anderson FIOP	(513) 255-4294
0047	NUMERICAL SIMULATION OF FOREBODIES FOR PLUNGING MOTION	DR RAYMOND GORDNIER UES	(513) 255-7127	DR J. SHANG FIMM	(513) 255-7127
0048	GRAPHIC PACKAGE FOR COMPUTATIONAL AERODYNAMICS	GERALD TRUMMER UES	(513) 255-7127	DR J SHANG FIMM	(513) 255-7127
0049	NUMERICAL SIMULATION OF DELTA WING IN ROCKING MOTION	DR D. GAITONDE UES	(513) 255-7127	DR J. SHANG FIMM	(513) 255-7127
0050	AIRCRAFT OPERATIONS ON DAMAGED AND REPAIRED RUNWAYS	MR BOB COOK UDRI	(513) 845-1258	DR JAMES OLSEN	(513) 255-7329
0051	SMOOTH SKIN VARIABLE CHAMBER WING TECHNOLOGY	MR JOE HALL BOEING ADVANCED SYS.	(206) 655-1280	MR R. DeCAMP WRDC/FIMF	(513) 255-4008
0052	EXPERT-LIKE CAD ENGINEERING DATA REPRESENTATION	MR DAN SAKS SAKS & ASSOCIATES	(513) 324-3601	MR DON REESE WRDC/FIVE	(513) 255-3021
0053	SLIDING MODE CONTROL DESIGN FOR FIGHTER AIRCRAFT	PROF J. CARL HEDRICK UNIV. OF CALIFORNIA BERKELEY	(415) 642-2482	MR F. BARFIELD WRDC/FDCX	(513) 255-8472
0054	USER INTERFACE SOFTWARE DEVELOPMENT FOR COMPUTER GRAPHIC VIDEO ANIMATION SYSTEM	MR MIKE MIEDLAR AMERICAN COMPUTATIONAL	(513) 237-7753	MR BILL PICKL FIER	(513) 255-4008

SECTION IV

CONCLUSIONS

Many diverse and specialized investigations were accomplished under this contract. Tasks were conducted in a timely manner with minimum delays and difficulties. Universal Energy Systems, Inc., believes a necessary service was provided to the Flight Dynamics Laboratory to carry out the advanced and high technology programs in support of the Air Force mission. This program has demonstrated the requirement for a quick-response laboratory support program to provide diverse and specialized expertise to assist major efforts within the Flight Dynamics Laboratory.