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ABSTRACT

This report contains abstracts of Master of Science Theses, Doctoral Dissertations, and selected faculty publications completed during the 1973 calender year at the School of Engineering, Air Force Institute of Technology, at Wright-Patterson Air Force Base, Ohio.

PART I

INTRODUCTION

The mission of the School of Engineering is (1) to conduct accredited bachelor, master, and doctoral engineering and management programs that are particularly relevant to the needs of the Air Force; (2) to conduct jointly with Air Force Systems Command (AFSC) the Continuing Education Program for Scientists and Engineers at Wright-Patterson Air Force Base; and (3) to conduct a research and exploratory development program supplementing and supporting Air Force projects.

The primary mission of the School is education, but research is an inseparable and integral part of that activity. Since the School of Engineering offers predominantly graduate programs, strong emphasis is placed on research by both faculty and students. Most of this research is sponsored and supported by Air Force Laboratories.

The net product of research is a publication or presentation of research results. This report contains abstracts of theses, dissertations, and other research publications produced by the students and faculty of the AFIT School of Engineering during the 1973 calender year.

Most of the student abstracts list the AD number which may be used to order that particular thesis or dissertation from the Defense Documentation Center (DDC) or from the National Technical Information Services. Those without AD numbers may be obtained on interlibrary loan from the Air Force Institute of Technology Library, AFIT/LD, Wright-Patterson Air Force Base, Ohio 45433.

The abstracts of faculty publications give the Journal in which the publication appears. In many cases a copy of the article may be obtained by writing directly to the author and requesting a reprint.

Part V is an index of sponsoring organizations and Part VI is a subject index.

Additional information regarding research at the School of Engineering may be obtained by writing to the Associate Dean for Research, AFIT/EN, Wright-Patterson Air Force Base, Ohio 45433.

PART II

ABSTRACTS OF MASTER OF SCIENCE THESES

1. DEVELOPMENT OF A RESPONSIVE TARGET FOR TRACKING TASKS IN THE DYNAMIC ENVIRONMENT SIMULATOR

Robert P. Barrett, Capt, USAF | 152p | GA/MC/73-2
Advisor: Prof R. A. Calico | Lab Sponsor: AMRL | AD 769925

Research was conducted to determine whether any of the available air-to-air combat simulations could be readily adapted to the need for a responsive target in the Dynamic Environmental Simulator. Computer subroutines were written to make logical role and tactics decisions based on relative aircraft states, to make variations in decision parameters corresponding to differences in pilots, to provide desired control inputs to implement the role and tactics decisions, and to provide for finite control rates. A test program was written incorporating the differential equations of motion of the simulated target. The equations of state of the opposing vehicle were included in the test program. Four sets of initial conditions and target flights paths were run, each involving three different pilot skill levels. The results were evaluated to determine the validity of the programmed target.

2. AN INVESTIGATION OF PATTERN RECOGNITION OF AIRCRAFT ATTITUDE INDICATOR DISPLAYS

Robert P. Bateman, Major, USAF | 51p | GA/EE/73-3
Advisor: Dr. M. Kabrisky | Lab Sponsor: AFFDL | AD 768345

Spatial disorientation accident statistics are reviewed, along with unsuccessful attempts to prevent these aircraft accidents. The lack of a theoretical basis for flight instrument design is noted. A systems approach to the problem is proposed, which requires a knowledge of the human visual system. It is suggested that attitude indicator displays, the interface between man and machine, should be designed to be compatible with an internal model of spatial position. Orientation in space by the use of flight instruments is identified as a pattern recognition problem. A Fourier transform model of the human visual system is used to evaluate and classify attitude indicator displays. An algorithm is proposed for separating patterns with respect to single characteristics. Results of this experiment show that the fixed and moving horizon displays are mapped into opposite halves of the linear decision space. This discovery is the basis for a prediction that the human operator may commit errors of reversal when using the moving horizon display. The predicted reversals have been reported as results of an in-flight experiment. The filtered Fourier transform model results, being in agreement with psycho-physical phenomena, are found to provide a basis for instrument design.

3. AN EXPERIMENTAL STUDY OF ATTENUATION OF SHOCK WAVES IN AIRCRAFT FUEL TANKS

John R. Breuninger,Jr.,Capt,USAF | 62p | GA/MC/73-3
Advisor: Prof P. J. Torvik | Lab Sponsor: AFFDL | AD 769930

When a full, or partially full, aircraft fuel tank is penetrated by a high velocity projectile, a phenomenon known as hydraulic ram effect, created by the passage of the projectile through the fluid often causes massive damage to the tank. This study was conducted to continue experimental investigation of the attenuation of the hydraulic ram effect through addition of a gas to a fuel-foam mixture. The tests were

conducted using two types of projectile (1/2 in. steel spheres and 0.50 caliber ogival projectiles) which were fired into a test tank. The tank was filled first with water and then a water/Pneumacel mixture. Four pressure transducers were located in the back wall of the tank and two pressure transducers were located inside the tank to measure the pressure pulses. The initial pressure pulse caused by the projectile moving through the water alone was measured during the first series of tests. A significant reduction in this pressure was noted during the second series in which the water/Pneumacel mixture was used. It was also found that a projectile moving through the fluid creates a cavity in its wake. When the cavity collapses, a pressure wave is generated. The cavity created by the passage of the spheres through the fluid was small and the pressure wave generated by its collapse was insignificant when compared to the initial pressure wave. However, the pressure wave created by the collapse of the cavity behind the ogival projectile was approximately the same magnitude as the initial pressure wave. It appears that this second pressure wave may be a major contributor to massive fuel tank damage. During the second series of tests (water/Pneumacel mixture), this pressure wave was significantly reduced.

4. TOWARD THE DEFINITION OF ESCAPE AND CAPTURE REGIONS FOR A TWO AIRCRAFT PURSUIT-EVASION GAME

P. H. Cawdery, Flt/Lt, RAF — 66p — GA/MC/73-4
Advisor: Major G. M. Anderson — Lab Sponsor: AFATL — AD 770081

The motivation for this thesis originates in research currently being conducted at the USAF Armament Laboratory, Eglin AFB, Florida. These studies concern the performance of an F-4E aircraft in air-to-air combat; the weapon system considered is an infrared, heat-seeking missile. The studies fall into two categories: (a) Definition of those regions in the vicinity of a target aircraft which the attacker must penetrate in order to attain a probability of killing his opponent greater than zero. (b) Definition of optimal strategies for the attacker to intercept and penetrate the high probability of kill (P_K) regions. In all cases, the target aircraft is considered as passive and unaware of attack. This paper makes the logical extension to the above research, and attempts to develop a method by which the capability of the attacker may be defined against an intelligent and evasive target. The primary objective is to obtain regions for both aircraft which define or enclose those points in the game state space from which the attacker can always penetrate to a given probability of kill. These regions are called "capture" regions; the converse, for the target, are "escape" regions. The air-to-air combat encounter is considered as a free time, zero sum, perfect information differential game. The participants' dynamics are modelled upon an F4 type aircraft, the game state space is defined, and the P_K regions modelled mathematically. An original extension to classical differential game theory is then made by which it is shown that partitions of the game space into escape and capture regions can be made for the simple planar game models. These regions are separated by a boundary which will be called a "P_K barrier." Obviously, the extent of the region from which the attacker can "capture" a given P_K value is a measure of his capability against the evasive, fully-informed target. The theoretical development is applied to two planar game models. Numerical methods are used to generate optimal trajectories by backward integration from admissable

terminal conditions for the game. These trajectories are analyzed, and partitions, or P_K barriers, are shown to exist. Examples of the escape and capture regions are shown, within the limits of the graphical techniques currently available. Two major conclusions are made. From the analytic viewpoint, the methods developed show that partitions of the game space are possible for this class of game. Refinement of these methods would realize the potential of this form of analysis in defining the capability of an attacking aircraft in a variety of air combat situations. In the practical sense, it is shown that the particular weapon system modelled here has severe limitations when employing against an intelligent enemy. Although the analysis was restricted to two-dimensional maneuver for both aircraft, it is felt that generalization of the methods to three dimensions would reinforce the two-dimensional conclusions.

5. DYNAMIC CHARACTERISTICS OF BLOCKED PNEUMATIC ANNULAR TRANSMISSION LINES

Gerald R. Farney, Capt, USAF — 57p — GA/ME/73-2
Advisor: Prof M. E. Franke — Lab Sponsor: AFFDL

The small signal amplitude and phase shift frequency response curves were found experimentally for 3 ft long, blocked, annular cross section, pneumatic transmission lines of 0.07, 0.23, 0.49, 0.67, and 0.82 radius ratios (annular tube radius r_o was 0.187 in). The frequency range investigated was 20 to 1250 Hz. The experimental results for each tested radius ratio were compared with the results predicted by the small signal pneumatic transmission line theory using Moore's exact annular distributive impedance and shunt admittance equations. The experimental gains were within ±1 db and the phase shift angles within ±15° of those predicted by the exact annular theory over the investigated frequency range. These results were practically within the measurement capability of the equipment used. The theoretical exact annular solutions were further compared with two methods for approximating annular transmission line characteristics. The first method used annular aspect ratio and the rectangular impedance and admittance equations of Schaedel. The second method used hydraulic diameter and the round line impedance and admittance equation of Nichols. For the radius ratios and frequency range investigated, both methods were within 2.5 db of gain and 35° of phase shift of those predicted by Moore's exact annular equations.

6. A STUDY AND COMPARISON OF THE STIELTJES AND LEBESGUE-STIELTJES INTEGRATION THEORIES

Robert M. Gravelle, Capt, USAF — 106p — GA/MA/73-1
Advisor: Capt C. E. Oliver — Lab Sponsor: AFIT — AD 764766

In the second chapter of this thesis a generalization of the Riemann integral commonly referred to as the Stieltjes integral is studied. The three definitions of this integral found in the literature are compared and found to be dissimilar. The most general of them, the "Generalized Stieltjes" integral, is chosen for further study. Essential properties of this integral and criteria for establishing Stieltjes integrability (that is, whether the integral of a function over an interval assumes a finite value) are examined. In the third chapter the Lebesgue-Stieltjes integral, a generalization of the Lebesgue integral, is studied. Essential

properties of this integral are determined and criteria for establishing Lebesgue-Stieltjes integrability are established. The material from these two chapters is used in the last chapter to compare Stieltjes and Lebesgue-Stieltjes integrable. In this case it is shown that the value of the two integrals are equal. Next, the class of functions that are Stieltjes integrable but not Lebesgue-Stieltjes integrable is found. Last, the class of functions that are Lebesgue-Stieltjes integrable but not Stieltjes integrable is determined. Important theorems including many proofs and illustrative examples are used freely throughout the thesis.

7. A HIGH RESOLUTION MEASUREMENT OF THE ANISOTROPIC MODULATION TRANSFER FUNCTION OF THE HUMAN VISUAL SYSTEM

Roland D. Guidry, Major, USAF — 147p — GA/EE/73-1
Advisor: Dr. M. Kabrisky — Lab Sponsor: AMRL — AD 768344

Apparatus and procedures were designed to measure differences in threshold perception of gratings for 12 grating orientations and 9 spatial frequencies (2.3 to 20.4 cycles per degree). Gratings were generated on an oscilloscope and rotated electronically at 15 degree increments using an image rotation device designed for this experiment. Fifteen subjects were tested using a multiple staircase paradigm: 12 staircases (one for each orientation) were run concurrently and randomly intermixed, with spatial frequency held constant. Results are presented as plots of contrast sensitivity versus grating orientation for each spatial frequency tested. Considerable variation occurred among the subjects, both in orientational preferences and experimental consistency. Three subjects were classified as meridional amblyopes, three as "classics" (equal acuity for horizontal and vertical gratings but lower acuity for oblique gratings), and the remainder as having slight or inconsistent orientational preferences (from one spatial frequency to another). It was concluded that, for this paradigm and the low (1.9 foot lamberts) grating luminances used, not all subjects display the classic response pattern. Some subjects display severe depression in acuity for certain orientations at high spatial frequencies that could be related to large pupil and axis of astigmatism.

8. SURFACE CURRENTS ON A CONDUCTING SPHERE DUE TO A NON-ISOTROPIC EMITTED PULSE OF ELECTRONS

James J. Havey,Jr.,Major,USAF — 93p — GA/PH/73-1
Advisor: Prof D. G. Shankland — Lab Sponsor: AFWL — AD 757190

Equations for the surface currents on a perfectly conducting sphere are developed in terms of the motion of a pulse of electrons emitted from the exterior surface of the sphere. The motions of the emitted electrons are determined self-consistently by using Green's function techniques to solve for the electric and magnetic fields in the space surrounding the sphere. The problem assumes that the electrons are emitted non-relativistically with azimuthal symmetry, and that the fields are essentially quasi-static in character. The resulting integral equations are solved using a mixture of analytical and numerical techniques. A specific example is worked out assuming uniform emission over one hemisphere by a delta function pulse of electrons with an energy distribution in the kev range. The results are presented graphically for a variety of emission currents, and it was found that this technique will provide useful results for emission pulse densities below 10 coulombs per square meter.

9. VIBRATION OF A SEGMENTED PIEZOELECTRIC CYLINDER

Paul I. King, 1st Lt, USAF — 58p — GA/MC/73-1
Advisor: Prof P. J. Nemergut — Lab Sponsor: AFIT

The purpose of this study was to determine theoretically the resonant frequencies displacements, and stress distributions in a group of hollow, thick-walled, cylindrical piezoelectric crystals stacked together and subjected to electromotive driving forces in the longitudinal direction. General theory was developed including the equations of motion, strain, displacement and of state. A power series solution was programmed for the CDC 6600 computer system, and the fundamental modes of vibration were analyzed for various groupings of three separate PZT-4 cylinders. The maximum displacements were of the order of microinches near resonant frequencies when driven by 400 volts. All points on a cross section moved uniformly in the axial direction with only slight vibrations in wall thickness, and all stresses except axial direction stresses were negligible. A one-dimensional analysis solution for resonant frequencies yielded results within 25% of the power series solution.

10. DETECTION OF THE SLEEP SPINDLE IN THE HUMAN ELECTROENCEPHALOGRAM

Dominick R. Martinelli,Capt,USAF — 49p — GA/EE/73-2
Advisor: Dr. M. Kabrisky — Lab Sponsor: AMRL — AD 768343

A literature search into signal analysis of the human electroencephalogram (EEG) for sleep classification reveals an abundance of literature in data compression and analysis by gross averaging of the ongoing background EEG activity. In contrast, there is a definite lack of literature on detection of high-resolution events, i.e., sleep spindles or K-complexes. Several authors have stated the need for high-resolution event detection in automatic sleep stage classification because the accuracy achieved when averaging techniques are used without a high-resolution mode is less than desirable (85%). The purpose of this study is to develop and evaluate a computer program for detection of spindles in the human EEG. The computer program combines frequency analysis and cross-correlation to detect a sleep spindle, which is defined as a rhythmic burst of EEG activity of 12-14 Hz with a minimum of 0.5 sec duration. The results are presented in detection accuracies as an event to be counted and as projected accuracies for sleep classification when the spindle detection program is applied to separation of spindle stages and non-spindle stages. Over 678 minutes of nocturnal EEG data were analyzed with a resulting overall spindle detection accuracy of 66% (11% miss error and 23% false detection error). When the spindle detection program is used to separate the sleep data into spindle stages (Stage -2) and non-spindle stages (Stages -0, -1, and REM) an impressive 92% overall accuracy is attained. No difficulty was encountered in detecting spindles which are clearly visible in the clinical records. Errors arise in the detection of spindles which have minimum duration (0.5 second) or low amplitude spindles. Similar errors are encountered by the rater in visual classification of sleep spindles.

11. GAS HEATING AND VOLUME RECOMBINATION EFFECTS ON POSITIVE COLUMN EQUILIBRIA

John W. Moore, Capt, USAF | 75p | GA/PH/73-2
Advisor: Dr. D. A. Lee | Lab Sponsor: ARL | AD 761492

A three moment model of the positive column is applied to an axisymmetric rare gas discharge at a pressure of 35 Torr and a tube radius of 1 cm. A three species fluid is considered. The ions and electrons are considered as perfect fluids and the background gas is modeled as a viscous, thermally conductive, compressible fluid. The zero'th order equilibrium equations are solved numerically for a model with gas heating and for a model with both gas heating and volume recombination. The results indicate an electron kinetic temperature gradient due to gas heating alone with temperatures of .769 ev at the axis and .497 ev at the wall for a current of 60 ma and a much smaller temperature gradient for lower currents. The number density profiles are not affected significantly by gas heating. The addition of volume recombination amplifies gas heating effects as evidenced by electron temperatures of .895 ev at the axis and .497 ev at the wall for a current of 60 ma. Also, volume recombination decreases particle densities toward the wall; for example, at 60 ma and at half the tube radius, the electron number density is reduced to 12% of its value at the axis compared to 53% with gas heating alone.

12. DROP AND STATIC TESTS ON A TENTH-SCALE MODEL OF AN AIR CUSHION LANDING SYSTEM (ACLS)

Anthony Rodrigues, Capt, USAF | 144p | GA/ME/73-3
Advisor: Dr. A. J. Shine | Lab Sponsor: AFFDL

An experimental investigation of the performance of an Air Cushion Landing System (ACLS) on a one-tenth scale model of a CC-115 Canadian aircraft is discussed. Several different types of tests were conducted on an extended version of the ACLS trunk at simulated full-scale trunk pressures of 315 psfg, out of ground effect, and 342 psfg, in ground effect. Cushion pressure was 160 psfg, in ground effect during hover. The experiments involved: vertical drop tests to measure the effects of sink rate and initial attitude between full-scale sink rates of 3.0 and 12.5 fps, and attitudes of pitch and roll from 0.0 to 12.0 and 0.0 to 7.5 degrees, respectively; static equilibrium tests to measure vertical stiffness, roll stiffness, pitch stiffness, and floor pressure exerted by the ACLS with loads up to 4.1 times the aircraft landing weight; and braking tests to obtain the effects of changing brake pillow thickness between simulated full-scale heights of 0.0 inches and 26.0 inches. The results of the vertical drop tests revealed that the air cushion will absorb most of the landing impact load except at initial attitudes of 12.0 degrees pitch, where the aircraft fuselage could touch the ground. Vertical stiffness test results showed the extended version of the ACLS trunk to be 39% stiffer than a previous shorter version between vertical load ranges of 0.5 and 1.9 times the aircraft landing weight. Floor pressure tests verified that the ACLS aircraft could land on low strength runways and never exert pressures higher than 3.8 psi above the atmospheric, full scale. Braking tests concluded that the maximum deceleration of the aircraft was about 0.34 g, and that increasing pillow thickness above 10.8 inches, full scale, would not increase that deceleration rate.

13. INVESTIGATION OF ELASTOMERIC VIBRATION ISOLATORS

Michael F. Tedesco, Capt, USAF — 63p — GA/MC/73-6
Advisor: Prof P. J. Nemergut — Lab Sponsor: ASD — AD 770279

This study was conducted to develop a simple mathematical model of the T22-AB-2 elastomeric vibration isolator. The isolators were tested both statically and dynamically to determine their response characteristics. It was found that the static stiffness as determined from force-deflection curves is significantly less than the stiffness determined from vibration testing. The dynamic modulus and loss factor were determined to be nonlinear functions of isolator displacement. Two mathematical models were developed. A linear model is adequate in predicting resonant frequencies and resonant peaks for double amplitude deflections of .1 inch or less. A nonlinear model following Duffing's method shows a small amount of the nonlinearity of the isolators. It was determined that it is not possible to develop a simple mathematical model of elastomeric vibration isolators based on their static characteristics.

14. MINIMIZATION OF PERTURBATIVE EFFECTS ON A HIGH ECCENTRICITY, HIGHLY INCLINED 24-HOUR SATELLITE ORBIT

Allen L. Thede, Capt, USAF — 96p — GA/MC/73-7
Advisor: Prof R. A. Calico — Lab Sponsor: FTD — AD 769964

A study was performed to analyze and minimize the effects of the perturbative forces on a 24-hour satellite orbit having an eccentricity of 0.6 and an inclination of 60° by selection of an optimum launch date. The computer model used includes the perturbations due to the oblate earth as described by the zonal, tesseral and sectorial harmonic series through 6th order, the solar and lunar third-body forces, and the solar radiation pressure on a vehicle whose area-to-mass ratio is 10 ft^2/slug. The orbit was computed for one year following launch with orbital parameter variations presented as functions of the launch date during 1970. The results of the study indicate that the total required impulses is significantly dependent on the launch date and oscillatory behavior of the orbital parameters due to the lunar-cycle. The largest component of the total impulse, due to the plane change to correct the nodal line and inclination, amounted to approximately 66 percent of the total yearly magnitude. The minimum total yearly impulse of 405 m/sec was required when daily orbital corrections were made following a 30 May 1970 launch. When the orbit was corrected at 14-day intervals, in phase with the lunar-cycle, two local minimums were found to be 355 m/sec for a 15 June 1970 launch or 360 m/sec for a 26 March 1970 launch.

15. A SPACE ESCAPE VEHICLE FEASIBILITY STUDY

George G. Wauer, Capt, USAF — 65p — GA/MC/73-8
Advisor: Prof H. C. Larsen — Lab Sponsor: AFIT

A preliminary design study was conducted to determine the feasibility of performing an escape from an endangered space station by using a ballistic re-entry vehicle. It was assumed that the escape vehicle would be carried on board the space station and that the space station's orbit could vary from 100NM to 400NM. A nominal re-entry trajectory was calculated and the effects of variations in thrust and thrust alignment

were analyzed. Heating analysis indicated that the re-entry problem could be overcome with currently available engineering materials.

16. THE DEVELOPMENT OF A FIRE CONTROL SYSTEM FOR OFF-BORESIGHT LAUNCH OF AIR-TO-AIR MISSILES

Gerald M. Bergeman, Capt, USAF — 112p — GA/GAM/EE/73A-1
Robert D. Green, Maj, USAF — Lab Sponsor: AFFDL
Advisor: Maj Moriarty

Aerial combat places extreme demands on aircraft, weapon, and pilot performance. The probability of success with present air-to-air missiles varies with a number of parameters, and the pilot's problem of correlating the changing variables and recognizing true firing opportunities in a maneuvering environment is complex. This report presents an attack concept using rear hemisphere pursuit strategies leading to off-boresight missile launch. A fire control system using parameters measurable from the attacking aircraft is developed with algorithms which predict the maximum allowable lag angle for missile success and provide an indication of maximum range. The maximum lag angle is estimated using a first order Taylor series expansion about one of 32 selected nominal points within the envelope. The range limit is predicted using time-of-flight estimates. The feasibility of this fire control concept is tested using a three dimensional, real-time, hybrid computer simulation of the attack situation. A cathode ray tube is used to present the attacker's view of the intercept and to simulate a heads-up display of the fire control solution. It is concluded that the maximum off-boresight angle and the maximum range boundary can be satisfactorily predicted using the described technique and that reasonably small on-board digital storage and computational capabilities are required for implementation.

17. A METHOD OF PREDICTING PILOT RATING FOR THE PITCH HANDLING QUALITIES OF AIRCRAFT FLOWN ON THE GLIDE SLOPE

Daniel J. Biezad, Capt, USAF — 77p — GA/MA/73A-1
Advisor: Maj J. Dillow — Lab Sponsor: AFFDL

A mathematical prediction scheme was developed to predict the pilot rating for the longitudinal handling qualities of aircraft flown on the glide slope in a turbulent environment. Actual pilot ratings and rms performance data were obtained from a fixed-base simulation of various aircraft configurations represented by the longitudinal short-period equations of motion. A linear equation was developed which expressed pilot ratings from the fixed-base simulation as a linear function of rms pitch angle, rms pitch rate, and rms glide-path deviation. The pilot-vehicle system was mathematically modeled by a closed-loop feedback system. Certain parameters of the pilot model used in the system were selected to minimize the linear rating expression developed from the fixed-base simulation. When subject to a stochastic disturbance, the covariance solution of the system determined closed-loop rms performances. Since pilot rating was was expressed as a linear blend of these rms performances, predicted ratings were analytically obtained for each configuration. All pilot ratings obtained from the mathematical prediction scheme were within

±1.05 rating units of the actual rating from the fixed-base simulation. The closed-loop rms pitch angle and rms pitch rate also agreed fairly well, but predicted rms tracking deviation did not correlate with the actual rms tracking deviation. The mathematical prediction scheme was applied to an independent flight data source for aircraft being flown in turbulent approach conditions. In 94% of the configurations tested, the predicted evaluation was within ±1.5 rating units of the actual pilot rating. The maximum difference was 2.07 rating units.

18. DETERMINATION OF THE EFFECTS OF MASS AND STIFFNESS OF THE VIBRATION RESPONSE OF RIBBED PANELS SUBJECTED TO RANDOM ACOUSTIC NOISE

Clarence M. Bose, Capt, USAF — 96p — GA/MC/73A-1
Advisor: Prof P. J. Nemergut — Lab Sponsor: AFFDL

The purpose of this report is to experimentally determine the effects of localized mass and stiffness parameters on the vibration response of stiffened panel structures excited by acoustic noise. Eleven panels were constructed, similar in weight and configuration with typical aircraft panel structures. A baseline panel was used to determine reference mass and stiffness properties: five panels were varied in mass with stiffness kept constant, and five panels with constant mass were varied in stiffness. The panels were excited in an acoustic reverberation test facility using a broad-band siren and horn assembly. Excitation and response measurements were taken using microphone and accelerometer transducers attached to the panels. The data were then reduced and correlated to construct vibration prediction curves as a function of excitation/response levels, frequency, and mass and stiffness parameters. In addition, an empirical mathematical model was derived to predict response levels knowing the excitations and the mass and stiffness parameters of a panel structure. A frequency dependent variable based on measured data was determined to relate these parameters to the panel responses. It was concluded that the vibration prediction curves and the empirical prediction model were sufficient to adequately predict responses to acoustic excitation provided certain limitations and assumptions were recognized. Further testing of many different types of panel structures was recommended to determine if these prediction techniques could be applied to all classes of panels.

19. AN INVESTIGATION OF MINIMUM TIME, LAUNCH-TO-RENDEZVOUS TRAJECTORIES

Steven H. Edelman, Capt, USAF — 61p — GA/MC/73A-2
Advisor: Maj G. M. Anderson — Lab Sponsor: AFIT

Minimum time trajectories between the surface of the Earth and a 270 statute mile circular orbit, generated with the assumption of impulsive thrusting, are used to determine minimum time-to-rendezvous with a target in the specified orbit. The amount of impulse is fixed by specifying the ratio of the launch vehicle's final to initial masses. The study is divided into two principal phases. In the orbit injection portion of the study, a set of minimum time orbit injection trajectories, subject to certain launch constraints, is generated by the solution of a fourth order polynomial for various range angles. The effect on the number of admissible trajectories of changing the mass ratio is also investigated.

During the rendezvous phase of the study, the generated set of trajectories is used to determine a window for direct launch to rendezvous. The trajectory resulting in minimum rendezvous time is then chosen as a function of the initial target position relative to the launch window. The dynamics of the launch window as the mass ratio changes are also investigated. Results indicate that for the baseline mass ra ratio of .05, the launch window is only 4.7% of the target's period; when the target is within the window, rendezvous will take from 96 to 413 seconds depending on initial target position. The study of various mass ratios indicates that a sizable tradeoff is available to the mission planner in terms of mass placed in orbit, time to rendezvous and rendezvous opportunities.

20. DIFFERENTIAL GAME BARRIERS FOR TWO SPACECRAFT ENGAGED IN A PURSUIT-EVASION GAME IN ORBIT

Victor W. Grazier, Capt, USAF — 81p — GA/MC/73A-3
Advisor: Maj G. M. Anderson — Lab Sponsor: AFFDL

This study searches for the differential game barrier for two spacecraft engaged in a pursuit-evasion game in orbit. By linearizing the equations of motion, a set of linear state equations is developed which, along with the non-linear state equations, is used to generate trajectories backward from the terminal surface. These trajectories for the linear and non-linear equations are then compared for equivalence and also used to provide necessary information on the barrier itself. Once the barrier has been determined, a method is developed theoretically to evaluate the location of a given starting point as to whether it lies in the escape zone or in the capture zone. The computer programs used in this study are included in the appendix for future research in this area.

21. A NEAR OPTIMUM LOW-THRUST TRAJECTORY FOR PHOBOS TO EARTH TRANSFER

Spencer A. Hawkins, Jr., 2nd Lt, — 86p — GA/MC/73A-4
Advisor: Maj J. Funk — Lab Sponsor: AFIT

This was a preliminary study for a transfer of the Martian Moon Phobos to a near Earth orbit. It contains the major considerations for the analysis of the trajectories, but would have to be refined to determine an accurate low-thrust trajectory. From preliminary investigation, using the near optimum technique of thrusting along the velocity vector, a low thrust acceleration of 4.00×10^{-8} km/sec^2 was chosen for the entire Phobos transfer. A feasibility study showed that the total transfer of Phobos from its initial orbit around Mars to the Moon's plane around Earth could be considered initially in two dimensions. To establish the final orbital radius of Phobos about the Earth, a preliminary, impulsive-thrust transfer analysis was made to minimize total velocity impulse. An Earth orbit of 99,000 km was found to be the most economical radius to attain, but the station-keeping expense was too much. Therefore, a stable Earth Moon libration point (L_4) was ultimately chosen as the final orbit location. The planetocentric trajectories were found by using the near optimum method of tangentially-directed thrusting. The "patched-spiral" method was used to transfer from one gravitational field to another. The heliocentric transfer was patched at Mars' and Earth's spheres of influence, using a second-order differential equation of the thrust angle to find the near optimal path. The time for the total near-optimal transfer was 5.81305 years for the given thrust-acceleration.

22. SPECIFIED FINITE SERIES CONTROL FOR THREE-DIMENSIONAL, MULTI-PHASE, OPTIMAL REENTRY

Ralph W. Holm, Maj, USAF — 101p — GA/EE/73A-2
Advisor: Maj James Funk — Lab Sponsor: AFFDL

An optimal, three-dimensional, multi-phase reentry problem is based on NASA's Mission 1 with a vehicle like the NR-ATP delta-wing vehicle's equations of motion include Earth rotation but are developed for relative velocity and express the vehicle's position relative to a reference trajectory plane which is fixed to the Earth. The reentry trajectory is divided into two phases. An entry phase from reentry at 400,000 ft to first pullup is optimized with respect to pullup heat rate by maintaining 0 degree roll angle. An equilibrium-glide phase from pullup to termination at 143,000 ft is optimized by varying roll angle to minimize terminal errors, total heat absorbed, and functions of heat rate and flight path angle rate. The roll control function is formulated as a specified finite series of terms, with each term being a function of system states and having a constant coefficient. Several optimal open-loop controls are obtained by specifying control forms and using Davidon's Variance Algorithm minimization routine to optimize the coefficients. Results indicated that a feasible roll control for orbiter reentry is a specified finite series form of control in which sinusoidal functions of range-to-go determine roll direction and interact with additional functions of the system states to vary the roll magnitude and optimize the trajectory.

23. SECOND- AND THIRD-ORDER ITERATIVE BOUNDARY PARAMETER SCHEMES FOR OPTIMAL CONTROL

Joe H. Jarvis, Capt, USAF — 103p — GA/EE/73A-3
Advisor: Maj James Funk — Lab Sponsor: AFFDL

This study investigated three higher order methods of iterating on the boundary parameters of an optimal re-entry problem cast as a two-point boundary value problem, and compares the results with a first-order Newton-Raphson method which has often been used in the past. A planar, lifting re-entry problem with convective-heating rate as the cost or performance function was used as a test of the computation methods. Initial and final boundary conditions are related through a matrix differential equation, and a Newton-Raphson first-order integration method to perform the generalized numerical integration of this matrix equation is presented. Second- and third-order numerical integration methods are developed using a parametric change of independent variable. Nominal optimal boundary conditions for the test problem were perturbed to obtain five test cases. Performance of the three higher order methods on the test cases were compared to the Newton-Raphson scheme. The higher order methods did achieve larger step sizes in the integration process, but a significant improvement in computation time over the Newton-Raphson method was not obtained. However, the results indicate the higher order predictor-corrector schemes may offer significant improvements in convergence time if further study and modifications are made.

24. PREDICTING LINE-OF-SIGHT CONJUNCTION BETWEEN A SPECIFIC SATELLITE AND OTHERS

Lee A. Mietz, Capt, USAF — 79p — GA/MC/73A-6
Advisor: Sqn Ldr G. Perry — Lab Sponsor: NORAD

The feasibility of designing a computer model to determine conjunction times between a primary object and any other satellite is investigated. An analytical integration scheme, which includes first order perturbations due to atmospheric drag and earth oblateness, is developed to predict satellite position in an inertial frame. Using an ellipsoidal, rotating earth model, conjunction between the primary object and any other satellite is determined by analyzing the respective topocentric vectors. Computer time is reduced by introducing discard schemes which retain only satellites that are a possible conjunction risk. Comparison between the computer model and existing methods of determination indicates the model is not only efficient, but computation time is significantly reduced.

25. SOME TECHNIQUES FOR OPTIMAL LINEAR REGULATOR DESIGN TO SATISFY CONVENTIONAL FIGURES OF MERIT

Edward V. Mirmak, Capt, USAF — 99p — GA/EE/73A-4
Advisor: Prof C. H. Houpis — Lab Sponsor: AFFDL

The time-invariant optimal linear regulator is analyzed for single-input-single-output systems. A correlation is made between the elements of a weighting vector and the conventional figures of merit, such as magnitude of peak overshoot and time to peak overshoot. Nomograms are developed for third and fourth order all-pole plants. Leake's method of Bode plot analysis is extended to a general weighting vector, resulting in expressions for minimum gain for which nomograms are valid. An algorithm is presented for obtaining root-square-locus plots for general quadratic weighting matrices. A sub-optimal design is achieved for an aircraft pitch-control system, using state-variable feedback with constant coefficients.

26. PREDICTING LATERAL HOVER FLYING QUALITIES WITH PAPER PILOT

David L. Nolting, Capt, USAF — 130p — GA/MA/73A-2
Advisor: Maj J. Dillow — Lab Sponsor: AFFDL

Data was obtained from a fixed base simulation of VTOL aircraft in the lateral hover mode and used to develop a technique for predicting lateral hover flying qualities. The task for the simulation was to maintain position in the presence of lateral gusts. Root-mean-square aircraft state and pilot input data were obtained and correlated with Cooper-Harper Pilot Ratings. A mathematical model for predicting the pilot rating of VTOL aircraft in lateral hover is developed. This model includes: (1) the lateral hover aircraft equations of motion; (2) a stochastic gust model; (3) a linear pilot model; and (4) a pilot rating expression that is a function of rms position error, rms lateral velocity, rms roll rate, and pilot lead terms. Pilot gains and lead time constants are chosen to minimize the pilot rating. This model is exercised on a digital computer. Predicted and actual pilot ratings and performance are compared for the fixed base simulation data. The difference between predicted and actual pilot ratings have a mean of

0.11 rating units and a standard deviation of 0.24 rating units on a 10 point scale. Predicted and actual pilot ratings are compared for 131 additional aircraft configurations with differences less than ±1.0 rating unit for 82.4% of the cases.

27. AN ANALYSIS OF THE DANIELL AND MCSHANE THEORIES OF INTEGRATION

William J. Riley, Capt, USAF — 122p — GA/MA/73A-3
Advisor: Capt E. Oliver — Lab Sponsor: AFIT

The second chapter of this thesis concerns the development of a theory of integration based upon the Daniell integral. The Daniell integral is defined on an initial class of functions and then extended to include a larger class of functions. Important properties of the Daniell integral and the class of functions upon which the Daniell integral acts are proven. The equivalence of a suitably restricted Daniell integral and the Lebesgue integral is demonstrated. Finally, a generalization of the Daniell integral, the Daniell-Stieltjes integral, is developed and the relation between the Daniell-Stieltjes and the Lebesgue-Stieltjes integrals is shown. In Chapter III the theory of the McShane integral is developed. The equivalence of the McShane and Lebesgue integrals is proven. A generalization of the McShane integral is defined, and it is stated that the generalization of the McShane integral is equivalent to the Lebesgue-Stieltjes integral.

28. AN EXPERIMENTAL INVESTIGATION OF A HIGH LIFT DEVICE ON THE OWL WING

George W. Anderson, Capt, USAF — 86p — GAM/AE/73-6
Advisor: Lt Col F. Tolle — Lab Sponsor: ASD — AD 769492

A study was made of the aerodynamic function of the comblike fixtures found on the leading edge of owl wings. Microphotographs of an owl's wing showed the comb to resemble a row of spanwise twisted airfoils oriented to form a cascade. Smoke flow visualization tests on an owl wing showed that the comb acts as a cascade which turns the flow close to the wing leading edge in a spanwise direction. Flow visualization experiments were run using flat plate and cambered airfoils with combs in a low speed three-dimensional wind tunnel. Results showed that the leading edge comb produced a stationary spanwise vortex that delays flow separation at high angles of attack. The high lift device was related to the vortex lift phenomena observed on delta wing aircraft. The comb's small relative size, simple structure, and lack of moving parts may make it attractive for aircraft use.

29. MAXIMUM LIKELIHOOD ESTIMATION OF AIRCRAFT STABILITY AND CONTROL COEFFICIENTS FOR LOW TO NEAR STALL/SPIN ANGLE OF ATTACK FLIGHT REGIMES

Jerry B. Callahan, Capt, USAF — 101p — GAM/MC/73-5
Advisor: Prof R. Calico — Lab Sponsor: AFFDL

The maximum likelihood parameter estimation theory is explained and applied to the six degree of freedom, first order time differential equations of motion for a rigid body aircraft. A NASA, Langley, computer program to compute 32 first order aerodynamic force and moment stability and control derivatives, was modified to run "batch

job" on the Wright-Patterson AFB, CDC 6600, digital computer. The computer program was further modified to use a set of 59 first, second, and third order stability and control derivatives, chosen for their effect at high angles of attack. The computer program and its application is explained. A successful attempt was made to estimate the standard first order coefficients, but computer accuracy and programming errors precluded results from and attempt to extract higher order terms.

30. THE EFFECT OF GRAVITY UPON THE "MELT-THROUGH TIME" OF A SOLID SUBJECTED TO A HIGH INTENSITY LASER

Gilbert L. Camburn, Capt, USAF — 79p — GAM/MC/73-6
Advisor: Prof P. J. Torvik — Lab Sponsor: AFWL — AD 759168

An analysis was made of the effect of gravity upon the "melt-through time" of a solid subjected to a high intensity laser. The analysis was accomplished by dividing a slab into a number of finite elements and performing an energy and force balance for each finite element, resulting in a computer-programmed mathematical model. Two metals, aluminum and titanium, each having a thickness of either 0.08 or 0.127 cm, were considered using absorbed peak intensities that ranged from 2,000 to 256,000 watts/cm^2. The effect of gravity upon the "melt-through time" was found to be dependent upon the physical properties of the solid, the magnitude of the absorbed peak intensity, the thickness of the solid, and to a lesser degree, upon the type of distribution of the incident radiation. Gravity had the greatest effect upon the "melt-through time" at low absorbed peak intensities and gradually reduced in effect as the magnitude of the absorbed peak intensity was increased until, finally, at very high absorbed peak intensities, the effect of gravity upon the "melt-through time" was negligible. The effect of gravity upon the "melt-through time" was found to increase as the thickness of the slab was increased. The "melt-through times" were plotted according to a dimensionless absorbed peak intensity and a dimensionless "melt-through time". The dimensionless plot appears to be a suitable means to correlate the thickness, the absorbed peak intensity and physical properties of the material.

31. STUDY OF INLET DIFFUSER BUZZ

Myron D. Cowell, Capt, USAF — 19p — GAM/AE/73-7
Advisor: Maj R. M. Jensen — Lab Sponsor: AFAPL

With flight at higher supersonic Mach numbers comes the emphasis of achieving low drag intake designs. The factors which provide a low drag design are severely restricting the range of stable operating conditions of the design. An experimental study was made on a diffuser instability, commonly called buzz. Test runs were made on different inlet models in the AFIT blowdown tunnel at Mach-2. The two-dimensional models used were throttled by a translating plug system which simulated the combustor of an actual engine by positioning the external shock system in the region of unstable subcritical operation. This study showed that buzz could be produced in the AFIT blowdown tunnel using different model configurations. It was found, once continuous buzz had been established, that throttling deeper into the subcritical operating region had no effect in stopping buzz or altering the frequency of buzz cycles. The study also showed that buzz initiation possessed no inherent hysteresis characteristics.

32. A THERMAL CONTROL SYSTEM FOR THE KS-87B CAMERA

Hugh W. Davis, Maj, USAF — 76p — GAM/ME/73-1
Advisor: Prof J. E. Hitchcock — Lab Sponsor: AFAL

Thermal gradients within the lens cone of the KS-87B aerial camera cause focal length changes which degrade photographic quality. A thermal control system has been developed in an attempt to maintain isothermal conditions at 105°F within the lens cone. It consists of a thermal blanket, a heater film sandwiched between two layers of insulation, and thermostatic controls. The inner layer of blanket insulation serves as impedance to reduce the amplitude of temperature fluctuations at the inner surface, or lens cone. Testing was accomplished in natural indoor and outdoor environments, using thermistors to measure temperatures at 14 locations within the system. Tests revealed that temperature differences between different parts of the lens did not exceed 4°F in an environment of 33°F ambient temperature. Improved insulation should further reduce this difference. This thermal control system is simple, reliable, and relatively inexpensive.

33. THE INSTRUMENTATION AND CALIBRATION OF THE AFIT HYPERSONIC SHOCK TUNNEL

David A. Dick, Capt, USAF — 70p — GAM/AE/73-8
Advisor: Lt Col F. Tolle — Lab Sponsor: AFIT

Transducers were sought having rise times of a few micro-seconds, capable of measuring pressure pulses as small as 0.01 psi, and small enough to fit inside a tunnel model, with a maximum length and diameter of 1/4 inch. In order to provide dynamic calibration of the gages, an 8 inch diameter, 48 foot long calibration shock tube was assembled. Shock speeds were measured from 0.65 psi to 9.79 psi. Twelve gages were calibrated with sensitivities ranging from 3.69 to 12.65 mv/psi. The major limitation of the gages appears to be inaccuracy due to vibration and calibration error rather than gage sensitivity. The initial hypersonic tunnel results are discussed, with emphasis on shock speed measurement, flow visualization, and impact pressure measurement.

34. WIND TUNNEL TEST OF A DOUBLE-SLOTTED RUDDER

Bruce L. Fister, Capt, USAF — GAM/AE/73-9
Advisor: Lt Col F. Tolle — Lab Sponsor: AFFDL — AD 769493

A double-slotted rudder (DSR) proposed for an advanced medium STOL transport (AMST) was tested against the same rudder with the slots closed. Multi-element airfoil theory and its application to a DSR was reviewed. Various design criteria for slotted airfoils were discussed. The tests were performed in a 7 x 10 foot wind tunnel at a dynamic pressure of 17.0 psf and a nominal Reynold's number of 2×10^6. The rudder was tested in 10 degree increments of deflection up to a maximum of 40 degrees, and at sidewash angles varying from -10 to +10 degrees. The DSR showed a 60% increase in side force over the plain double-hinged rudder which was the next best performance rudder configuration. The side force versus sidewash angle curve was linear. A rudder deflection schedule was devised which produces nearly linear side forces and minimum drag. The L/D polar of the DSR was significantly better than those of other configurations. No adverse aerodynamic properties were observed that would preclude the use of a DSR on an AMST.

35. A PHOTOGRAPHIC STUDY OF A SHOCK INITIATED DETONATION IN A STOICHIOMETRIC HYDROGEN-OXYGEN MIXTURE

Charles M. Hutcheson, Capt, USAF — 55p — GAM/ME/73-3
Advisor: Maj R. M. Jensen — Lab Sponsor: ARL

The development of air-breathing hypersonic flight vehicles is dependent upon the design of a supersonic ramjet combustor. One possible mode of providing supersonic combustion is through the use of a standing detonation wave. This study was undertaken to contribute to a better understanding of detonation phenomena by conducting a photographic study of detonation waves in a stoichiometric hydrogen-oxygen mixture. A viewing section was installed in a helium driven shock tube and a schlieren optical system was used to photograph the detonation wave. A spark light with a spark duration of less than 0.5 micro-seconds was used to stop the motion of the detonation wave as it was recorded on Polaroid film. A wratten #3 light filter had to be added to the schlieren system to filter out the chemical luminescence of the detonation. Detonation wave photographs were obtained at initial gas pressures ranging from 0.5 psia to 4.5 psia. At these pressures, it was observed from the waves photographed that detonation waves in a stoichiometric H_2-O_2 mixture are planar, do not spin, and have an indistinguishable ignition delay length. It was also observed that the chemical luminescence of the detonation increases as the initial pressure increases.

36. BIOMECHANICS OF BONES AND LIGAMENTS IN PRIMATES: THE EFFECT OF IMMOBILIZATION ON ULTIMATE PROPERTIES

Walter B. Hyde, 2/Lt, USAF — 94p — GAM/MC/73-1
Advisor: Prof P. J. Torvik — Lab Sponsor: AMRL

Experiments were conducted to determine the effects of immobilization on bones and ligaments in Macaca Mulata. Rhesus monkeys of similar size were divided into two groups--a group to serve as controls and a group to be immobilized for eight weeks in full body casts. Three types of tests were conducted for each group: tension of anterior cruciate bone-ligament-bone preparations, torsion of tibae, femora, and humeri, and four-point bending of second, third, and fourth matatarsals. All specimens were loaded to failure. Experimental apparatus and procedures are described. After eight weeks of immobilization: Bone-ligament-bone preparations are shown to experience a 26% reduction in structural strength, a shift in failure mode, and an increase in structural flexibility. Tibae, femora, and humeri undergo reductions in strength. Tibial and femoral fractures shift toward the knee; the percentage of bone involved in humeri fractures decreases. Structural flexibility is increased for femora and humeri and remains the same for tibae. Metatarsals are not affected with regard to structural properties.

37. INVESTIGATION OF VARIOUS FACTORS AFFECTING CORROSION RATE DETERMINATION BY GALVANOSTATIC RESISTANCE POLARIZATION

Robert L. Kuhnle, LCDR, USCG — 374p — GAM/MC/73-8
Advisor: Capt W. B. Crow — Lab Sponsor: ARL — AD 770084

Controlled laboratory tests using galvanostatic resistance polarization techniques have provided generally reliable, reproducible, and accurate indications of the instantaneous rate of metal surface dissolution. This

investigation sought to design and test an apparatus for use in operating environments to reliably and accurately indicate, by galvanostatic resistance polarization techniques, the metal surface corrosion rate. Cathodic and anodic resistance polarization data were obtained within ±10 millivolts of the steady-state corrosion potential in both a laboratory and the experimentally designed test cells at 24 hour intervals during the 120 test hours. Using two high purity iron specimens with different impurity content, tests were conducted in hydrogen saturated and aerated environments of 1N and 0.1N sulfuric acid and 3% sodium chloride/0.5N potassium sulfate. In the experimental test cell, resistance polarization data were obtained at various cathode-to-anode surface area ratios. Both graphical and computerized linear regression techniques were used to determine specific run and average polarization resistance values. Indicated corrosion rates were calculated using the Stern-Geary relationship and Faraday's law. Weight-loss tests were conducted simultaneously with resistance polarization tests to provide comparative "actual" corrosion rate information. In addition, actual corrosion penetration measurements were made and photomicrographs taken to show the extent of localized attack. In both laboratory and experimental test cells, both cathodic and anodic resistance polarization techniques appeared to accurately indicate the metal surface dissolution rate. Corrosion rates determined from weight-loss tests were consistently higher than those determined by resistance polarization techniques. Similarly, actual penetration was much greater than indicated by either resistance polarization or weight-loss tests. Localized attack - intergranular, pitting, and crevice attack - could not be eliminated from either corrosion rate indicating system. Actual corrosion damage was found most dependent upon grain orientation, electrolyte agitation, and the specific impurity content. A correlation was observed between the variation of steady-state corrosion potential and instantaneous indicated corrosion rate with time.

38. APPLICATION OF THE LATERAL EQUATIONS OF MOTION TO AN INERTIALLY-SLENDER AIRCRAFT IN UNSYMMETRIC, RECTILINEAR FLIGHT

Frank W. Larson, Maj, USAF — 77p — GAM/MC/73-7
Advisor: Prof R. A. Calico — Lab Sponsor: AFFDL

The purpose of this study was to investigate the application of the linearized small-perturbation lateral equations of motion to an unsymmetric, rectilinear flight condition. The A-7D was chosen as the physical model to use for correlation of the results. The stability parameters $C_{n_{\beta,dyn}}$ and Aileron-Alone Divergence Criteria (AADC) were compared with the stability predicted by the dix-degrees-of-freedom trim equation, and the roots of the aircraft characteristic equation. All indicators showed reasonable correlation, lending credance to the use of the uncoupled lateral equations for evaluation of the alpha-beta envelope. The results of this study also agree with the initial results of a parallel study done by the Cornell Aeronautical Laboratory.

39. AN ANALYSIS OF ENERGY MANEUVERABILITY AND ITS INFLUENCE ON AIRCRAFT DESIGN

Phillip V. Maywald, Capt, USAF — 53p — GAM/AE/73-10
Advisor: Lt Col F. Tolle — Lab Sponsor: ASD

Energy performance, energy maneuverability, maximum maneuver concepts, and their influence on the design of air superiority fighters are considered. The assumptions, limitations, and applications of energy performance are examined. The primary application of energy performance is the Rutowski path used for gaining energy prior to an air-to-air engagement. The need for maneuverability in fighter aircraft originates from the identification problem. Horizontal performance is shown to be more significant than vertical performance. Fighter aircraft designed for maximum energy maneuverability are shown to need optimum maneuverability in the high subsonic and transonic regions, at the expense of maximum speed and range. The need for development of energy gauges is established.

40. CONFIGURATION OPTIMIZATION USING A STACKED POD GEOMETRY DESCRIPTOR

Russell D. Morrison, Capt, USAF — 47p — GAM/AE/73-11
Advisor: Lt Col F. Tolle — Lab Sponsor: AFFDL

A computer program was developed that uses stacked pods to describe the fuselage geometry and a similar approach to define the airfoil shapes. This geometry descriptor was bombined with routines that estimate weight, propulsion, aerodynamics and performance so that a simple method could be used to search for the optimum configuration. The wing parameters of aspect ratio, thickness ratio, taper ratio and reference area were used as search variables with the fuselage dimensions and the mission profile remaining constant. The two search techniques used were an adaptive creeper technique and a modified sectioning technique. The methods used resulted in rapid convergence to an optimum solution that was within the constraints specified by the mission profile and the parameter limits.

41. PREDICTING ROLL TASK FLYING QUALITIES WITH "PAPER PILOT"

Flynoy R. Naylor, 2/Lt, USAF — 118p — GAM/MA/73-1
Advisor: Maj J. Dillow — Lab Sponsor: AFFDL

A mathematical model for predicting the pilot rating of a fighter aircraft in a roll task is described. The model includes: (1) the lateral-directional aircraft equations of motion; (2) a stochastic gust model; (3) a pilot model with two free parameters; and (4) a cost functional that is a function of aircraft performance and pilot workload. The pilot gain and lead time are selected to minimize the cost functional. The parameters are adjusted to provide a 20% stability margin and the adjusted parameters are used to compute a pilot rating of the aircraft/gust configuration. The "roll paper pilot" rating was computed for 25 aircraft/gust configurations. The computed ratings are compared to actual pilot ratings obtained in a moving base simulation. The difference between the "roll paper pilot" and the actual pilot ratings had a mean of -0.077 rating units and a standard deviation of 0.726 rating units on a 10 point scale.

42. STATISTICAL TECHNIQUES FOR THE ANALYSIS OF SHEAR FLOW FIELDS

Richard C. Oliver, Capt, USAF — 70p — GAM/ME/73-4
Advisor: Prof H. C. Wright — Lab Sponsor: AFAPL — AD 769498

Statistical analysis, which has found increasing use in the solution of complex problems in recent years, is presented in a form suitable for subsonic turbulent flow investigation. A computer program, designed for the CDC 6600 and written in FORTRAN IV, is the core of the analytical process. The statistical techniques employed are the probability density function, the autocorrelation function, the power spectral density, and the crosscorrelation function. The results of these techniques are discussed in general terms and related to turbulent flow parameters. The analytical process, including the digitizing of analog data, was verified using known functions. The analysis of constant temperature anemometer data from screen and cylinder turbulence generators matched results previously reported. The program was developed to support the investigation of flow/laser interactions, but due to time constraints no experimental data of this nature were available for analysis. The program is not limited to fluid analysis.

43. AN APPLICATION OF HOT FILM ANEMOMETRY TO A TURBULENT MIXING PROBLEM

John F. Osborn, Capt, USAF — 52p — GAM/AE/73-12
Advisor: Prof H. C. Wright — Lab Sponsor: ASD

An experimental study was conducted to investigate a particular type of turbulent flow field. The type of flow field of interest was that set up by two-dimensional, co-flowing streams of air mixing in a confined chamber. The work was intended to provide preliminary data for comparison with a theoretical model being developed for such a flow field. An apparatus was constructed to provide the desired type of flow field. The hot film anemometry equipment available at the Air Force Institute of Technology was used to obtain preliminary data from the apparatus. Application of hot film anemometry to the problem also involved determining the most satisfactory way to calibrate hot film probes. Preliminary data was obtained for the vertical and horizontal planes of the test section. The data indicates that the apparatus constructed provided the type of flow field desired, and is suitable for further experimental work. The data shows the relationship between the mean velocity profiles and the turbulent intensities as the flow field moves downstream in the test section. For each profile obtained, the turbulence in the longitudinal direction was predominant.

44. EXPERIMENTAL STUDY OF FATIGUE CRACK PROPAGATION AND RETARDATION USING POLYMETHYLMETHACRYLATE

Francis J. Pitoniak, Capt, USAF — 72p — GAM/MC/73-2
Advisor: Maj L. T. Montulli — Lab Sponsor: AFML

Fatigue cracks were grown in compact tension specimens of polymethylmethacrylate, a transparent polymer which was used as a model for metals. Various peak overloads applied to the constant ΔK baselines used produced changes in the baseline load crack growth rates. One thousand overloads

of ΔK = 900 psi $\sqrt{in}$ on a baseline ΔK = 600 psi $\sqrt{in}$ produced a reduced or "retarded" growth rate followed by a net baseline growth rate increase. Five overloads to ΔK = 900 psi $\sqrt{in}$ on a baseline load level of ΔK = 450 psi $\sqrt{in}$ produced apparent crack arrest. A study of the monochromatic light interference fringe patterns emanating from the fatigue cracks at zero load indicated that the crack surfaces were closed along the saw cut edge and on the free surface of the specimens. The crack surfaces were displaced in the interior of the specimen at zero load. Measurement of the crack opening displacements from the fringe patterns indicated that the crack surfaces opened on the free surface at approximately half the baseline load level for a stress ratio of approximately zero. This is in agreement with the Elber crack closure concept.

45. INVESTIGATION OF STAGE II CRACK PROPAGATION IN 7075 ALUMINUM

Jeffrey M. Posner, Capt, USAF — 118p — GAM/MC/73-3
Advisor: Maj L. T. Montulli — Lab Sponsor: AFML

Crack growth rates were measured for 7075 aluminum in the T6, T73, TMT and TMT II conditions in both the longitudinal and short-transverse directions. The tests were conducted in laboratory air with a constant amplitude, uniform rate of 40 cycles per second and a ratio of minimum stress to maximum stress of less than 0.1. The tests showed the same crack growth rate for each treatment in both the longitudinal and short-transverse directions. The crack growth rate was found to be independent of both microstructure and grain direction.

46. TWO-DIMENSIONAL AIR CUSHION LANDING SYSTEM PERIPHERAL JET CONFIGURATION STUDY

John R. Rogers, Capt, USAF — 98p — GAM/AE/73-13
Advisor: Dr. A. J. Shine — Lab Sponsor: AFFDL — AD 769494

A simplified two-dimensional peripheral jet theory for the equilibrium performance of an air cushion vehicle is investigated. The proposed theory intends to yield a rapid prediction of the actual flow rate and actual power requirements for an Air Cushion Landing System in the hover condition. Nine specific nozzle configurations were tested to determine which resulted in the best power-height performance and whether the theory is able to predict the experimental performance. Three single peripheral jet configurations were tested at a trunk pressure of 80 psfg. Six distributed jet configurations were tested at a trunk pressure of 40 psfg. Effects of inward flow injection angles of 30 degrees and 60 degrees were investigated. It was found that the simplified theory can adequately predict a value of the flow coefficient C_Q for an ACLS nozzle configuration. Values of the power-height parameter C_{hd} predicted by the theory always indicated better performance than was achieved experimentally. The beneficial effect of inward flow injection was demonstrated for each group of similar nozzle configurations. The single slot with 60 degree flow injection resulted in the best performance below cushion to trunk pressure ratios of 0.5. Above this pressure ratio the distributed jet configurations with 60 degree inward injection resulted in superior performance.

47. AN INVESTIGATION OF THE BENDING OF SYMMETRIC PLATES UNDER SYMMETRIC TRANSVERSE LOADING

Thomas A. Runner, Capt, USAF — 117p — GAM/MC/73-4
Advisor: Lt Col S. W. Johnson — Lab Sponsor: AFFDL — AD 769928

An investigation is conducted on transversely loaded clamped plates using the displacement method computer program "Matrix Analysis via Generative and Interpretive Computations" (MAGIC). Three plate configurations are examined. These are a rectangular plate without cutouts, a rectangular plate with cutouts, and a circular plate with a central circular hole. Each plate configuration is modeled using a number of different structural idealizations. Three bending elements from the MAGIC element library are used for the investigation. The elements used are the quadrilateral thin shell, the triangular thin shell, and the quadrilateral plate element. Results from the solutions obtained using MAGIC are compared with exact solutions when these exact solutions exist. In addition, the solutions obtained using MAGIC for the rectangular plates are compared with solutions obtained using a numerical point matching method and a laser holographic technique. The investigation indicates that the MAGIC computer program can be used and good results can be obtained for the class of problems investigated in this study.

48. EFFECTS OF GEOMETRY CHANGES ON FLOW CHARACTERISTICS OF SWIRL-TYPE DUMP COMBUSTOR MODELS

Henry W. Steinkamp, Jr., Maj, USAF — 92p — GAM/ME/73-5
Advisor: Maj R. M. Jensen — Lab Sponsor: AFAPL

Plexiglass models of Swirl-type Dump Combustors (STDC) were built and tested with water flows for Reynolds numbers of 78,000 to 270,000 to determine the effect of geometry changes on flow properties. A STDC is a ramjet combustion without flameholders in which air enters through a series of ports in the chamber wall rather than along the longitudinal axis. Five port arrangements and three nozzle area ratios were combined to form 15 configurations. Maximum to minimum nozzle discharge coefficients and loss factors varied in ratios of 2:1 and 4:1, respectively, as fluid entry into the chamber varied from radial to near tangential. Maximum to minimum discharge coefficients and loss factors varied in ratios of 1.3:1 and 2.3:1, respectively, as fluid entry into the chamber varied from perpendicular to the longitudinal axis to an angle of 45 degrees in the direction of chamber flow. As nozzle area ratio increased, discharge coefficients decreased but loss factors remained unchanged.

49. STATISTICAL DETERMINATION OF THE LIFT AND DRAG OF FIGHTER AIRCRAFT

Thomas A. Tomasetti, Maj, USAF — 83p — GAM/AE/73-1
Advisor: Maj S. Kitowski — Lab Sponsor: AFFDL — AD 769491

Multiple linear regression analysis was used to develop two statistical equations representing the coefficients of lift and drag due to lift as functions of 14 non-dimensional geometric parameters and Reynolds number. A set of regression coefficients were computed for each of

the parameters to permit prediction of the coefficients of lift and drag due to lift for Mach numbers in the range of 0.4 to 2.5 and angles of attack in the range of 0 to 18 degrees. A computer program is available to perform the required computations and plot the resulting drag polars. The wind tunnel data used in the regression analysis consisted of 104 configurations and a computer program is available for recomputing the regression coefficients as new data becomes available. Error less than 10 percent can be expected except in the transonic speed range. Results were compared to wind tunnel test data for the F-5E and F-8U aircraft.

50. ANALYSIS OF CONTROL SURFACE AUGMENTATION IN HIGH-PERFORMANCE AIRCRAFT BY THRUST VECTORING

Deas H. Warley III, 2/Lt, USAF — 96p — GAM/AE/73-14
Advisor: Lt Col F. Tolle — Lab Sponsor: AFFDL — AD 769495

The feasibility of engine thrust vectoring for lateral control of aircraft in the high angle-of-attack regime was investigated for an airplane with F-111 characteristics. The technique was found to be effective in increasing the angle-of-attack at which departure occurs. The method used an effective dynamic directional stability parameter to account for the thrust effect alteration of the static lateral stability parameters C_{n_β} and $C_{\ell_{\beta,dyn}}$ could not be used to predict departure in the model studied, it was useful in evaluating the effectiveness of the thrust vectoring concepts.

51. AIR CUSHION LANDING SYSTEM, DROP DYNAMICS THEORY (MECHANICAL)

Frederick C. Bauer, Capt, USAF — 88p — GAM/AE/73A-1
Advisor: Capt J. Karam — Lab Sponsor: AFFDL

A mechanical analog Vertical Energy Absorption Model (VEAM) is developed to predict the dynamics of an Air Cushion Landing System (ACLS) in the vertical dimension. Three degrees of freedom and thus three primary modes of oscillation are investigated: heave, pitch, and roll. Data from AFFDL tests of a full-scale Australian Jindivik drone are used to develop and verify the model. The VEAM study demonstrates that the use of a mechanical analog prediction scheme for an ACLS has sufficient merit to warrant further investigation. It shows that a mechanical analog model can predict system response within the model domain of three degrees of freedom without knowledge of the numerous and varying trunk and cushion parameters if the mode spring and damper coefficients are provided. The model response correlates with Jindivik test data much better in pitch and roll than in heave. Both the pitch and roll mode spring and damper coefficients are shown to be linear in accordance with model assumptions. Model response in heave is heavily dependent upon the mode damping ratio (ξ) and the undamped natural frequency (W_n), but the results are reasonable; that is, response frequency correlates to test data and response displacement is in the proper direction but sometimes of incorrect magnitude. The heave mode spring coefficient is shown to hold to the linear approximation. The inability to match magnitudes exactly suggests that the heave damper coefficient is non-linear.

52. FLOW VISUALIZATION IN AXIAL-FLOW COMPRESSOR AND TURBINE CASCADES UTILIZING THE WATER TABLE

Philip W. Bruce, Capt, USAF — 68p — GAM/AE/73A-3
Advisor: Prof W. C. Elrod — Lab Sponsor: AFAPL

This thesis analyzes the use of a recirculating water table in propulsion system design. The relation of flow phenomena in gases to those for liquid flow is established through the hydraulic analogy. In this study, water flow through a cascade of compressor or turbine blades is used to simulate gas flow in turbomachinery. Limitations include the two-dimensional modeling of a three-dimensional environment. The hydraulic analogy assumes that the specific heat ratio of the gas is 2.0, rather than approximately 1.4. This discrepancy produces an error in quantitative simulation of gas flows; however, below a simulated Mach number of 3.0, the error in pressure measurements is less than 20%. Flow simulations of Mach numbers between 0.8 and 1.0 were not produced during this study. This range of Mach numbers requires a tow tank, rather than the recirculating water table available at the Air Force Institute of Technology. This study demonstrates that the water table can provide valuable assistance to an engineer in the initial phase of turbine or compressor design. The main advantages are ease of operation, low cost, and flow visualization. Utilization of the water table is especially advantageous in the visualization of boundary layers and flow separation regions.

53. BOUNDARY LAYER CONTROL ON A NON-RIGID AIRFOIL

Robert D. Cason, Capt, USAF — 53p — GAM/AE/73A-4
Advisor: Prof H. E. Wright — Lab Sponsor: AFAPL

A two-dimensional investigation was conducted to determine the effectiveness that a slot or a vortex generator in the form of a trip wire had in controlling the separation of the boundary layer on a rigid body and the reattachment of the flow to a non-rigid airfoil that was attached to the body. The study was conducted in two phases: a flow investigation using a water table and a two-dimensional test using the AFIT Five Foot Wind Tunnel. The study showed that both control devices worked, but the slot was the most consistent in its performance. The slot improved the coefficient of lift by approximately 5 to 10 percent. In addition, the curve became flat at this value and stall did not occur until 6° to 8° later.

54. A COMPARISON OF THE SECTION LIFT-DRAG CHARACTERISTICS OF A BIWING WITH A MONOWING

James A. Clamon, Capt, USAF — 42p — GAM/AE/73A-5
Advisor: Prof M. E. Franke — Lab Sponsor: ASD

Although many early airplanes were built using more than one wing, there is little information available on multielement wing theory or on tests conducted on multielement wings. This study contains a comparison of the section lift-drag characteristics of several biwing configurations from which an optimum configuration was selected. That data are compared with the section characteristics of a single airfoil. The tests were performed in the AFIT 5 ft wind tunnel. The model was suspended with a three-wire balance from which lift and drag measurements were taken. In addition a drag rake was used from which momentum changes were obtained. The drag

data for both methods are compared. The data collected shows that, for a C_d higher than 1.3, the C_d for the biwing configuration selected as optimum is lower than the single airfoil C_d. The data also shows that the C_d for the biwing is lower than the C_d for the single airfoil at angles of attack greater than 8°.

55. INVESTIGATION OF DIFFUSERS FOR GAS DYNAMIC LASER NOZZLES

David G. Clawson, 2/Lt, USAF — 27p — GAM/ME/73A-3
Advisor: Prof W. C. Elrod — Lab Sponsor: AFWL

Schlieren photographs were used to analyze the flow characteristics of diffusers for a Mach 6.0 double nozzle assembly. This assembly of two nozzles, comprised of one (1) full center and two (2) half side channels, was more conducive to greater boundary layer growth than a nozzle assembly with more nozzle throats. Schlieren photographs of the air flow were in line with the laser beam's orientation to the nozzles of a Gas Dynamic Laser. Dry air at 85 F total temperature, and 120 psia total pressure was expanded with a nozzle area ratio of 66.0. Different diffuser configurations were tried to determine the diffuser throat area required to start the cavity. It was determined that the cavity would start when the ratio of diffuser throat area to channel cross-sectional area was near 0.6, which is in agreement with other studies, considering the presence of wakes in the flow. Boundary layer growth is accelerated at these high Mach numbers, limiting the distance between the nozzles and diffuser; excellent optical charity flow was obtained emerging from the nozzles and close to the channel center using a multi-element diffuser, but, deteriorates rapidly further downstream.

56. AN EXPERIMENTAL INVESTIGATION, A COMPARISON OF THE BOX WING TO PLANAR WINGS

Anthony Covais, Capt, USAF — 99p — GAM/AE/73A-6
Advisor: Prof H. C. Larsen — Lab Sponsor: ASD

Von Karman's theory that a closed rectangular system (a box wing) would produce less induced drag than a monowing of the same span was tested. A box wing and two monowings were designed, manufactured, and their performance in the AFIT low speed wind tunnel was compared. A box wing is a biplane with two horizontal wings of equal span, with the corresponding tips of the upper and lower wings united by vertical wings which serve to alter the lift distribution over the span of both wings. Tuft tests showed that the box wing consolidates the four vortices of a biplane into two vortices reducing the induced drag. Wing flaps were included in the design of the monowings and the box wing. In addition, the box wing incorporates flaps on the vertical wings for the purpose of attaining the optimum lift distribution described by Von Karman. It was found that the flaps of the vertical wings were effective in approximating that lift distribution. The data were reduced to coefficient form and corrected to account for differing aspect ratio of the monowings and the box wing. A graph C_D vs C_L revealed that the zero lift drag was slightly less for the monowing but that for increasing C_L, C_D of the box wing was in the order of 30% less than the monowing. It is concluded that the box wing may increase the range and endurance for future aircraft.

57. ATTENUATION OF WEAK SHOCK WAVES IN A NON-UNIFORM REGION

Raymond L. Eheart, Capt, USAF 75p GAM/AE/73A-7
Advisor: Dr. A. J. Shine Lab Sponsor: AFWL

The results of an experimental study of the attenuation of a shock wave traveling through a non-uniform region were compared to the results of a numerical solution developed from the continuity, momentum, energy, and Rankine-Hugoniot equations using G. B. Whitham's rule. The region of non-uniformity consisted of a converging section which was porous. The angles of convergence tested were 0, 4, and 6-degrees having a maximum porosity of approximately 44%. The 0- and 4-degree channel had a height of 3/4 in. and the 6-degree channel had an equivalent height of 1-1/2 in. with the porous section of both convergent channels being 4 in. long and the 0-degree channel 3-1/2 in. long. The results obtained showed that for the straight test section the one-dimensional theoretical analysis predicted within 7 to 8 percent of the experimental vlaues of Mach number change. For the 4-degree test section the experimental showed a larger change in Mach number than was predicted by 40%. This difference was reduced to 26% by including the loss of x-momentum leaving with the mass outflow in the momentum equation. The 6-degree test section experimental data showed that the Mach number to increase rather than decrease and differed from the theoretically predicted change by 300%. The inclination of the porous wall by a small amount showed a greater amount of attenuation than the straight porous wall. The 4-degree test section reduced the Mach number by 0.54 compared 0.42.

58. EXPERIMENTAL INVESTIGATION OF THE DYNAMIC CHARACTERISTICS OF NON-ISOLATED EQUIPMENT MOUNTS

Lucien S. Franscini III, Maj,USAF 83p GAM/MC/73A-2
Advisor: Prof P. Nemergut Lab Sponsor: AFFDL

The study was conducted to determine the dynamic characteristics of non-isolated avionics equipment mounts and the effect of the characteristics on the equipment and mount supports. The response to both sinusoidal and random acceleration inputs was investigated. Lumped mass models were postulated to describe the mount response to sinusoidal inputs. These models reduced the mount characteristics to a single parameter, the stiffness. Experimental investigation showed a wide range of stiffnesses for existing mounts in service so these models were considered unsatisfactory. A linear system model was postulated to describe the mount response to random input. Experimental investigation showed that non-isolated mounts have magnification factors near unity on an average basis but that individual points may have significantly higher g levels. The current practice of qualification of non-isolated mounts is found unsatisfactory and it is recommended that non-isolated mounts be specified by a maximum average magnification factor and a maximum local increase in equipment response.

59. VELOCITY MEASUREMENTS AND TURBULENCE RELATED PARAMETERS IN TWO-DIMENSIONAL AIRSTREAMS

Alfred L. Freathy, Capt, USAF 70p GAM/AE/73A-8
Advisor: Prof H. Wright Lab Sponsor: ASD

This thesis reports the methods and results of an experimental study involving the turbulent mixing of a primary jet of air with a surrounding secondary flow entrained in a confining test section. The test section was designed to approximate a two-dimensional flow field which was being investigated independently by analytic methods. The parameters selected to describe the flow were the mean velocity, the velocity fluctuations, cross-product velocity terms related to the Reynolds' shear stresses, and the microscale of turbulence. The velocities were measured as components in the coordinate directions. An approximation for a time microscale was measured, and used to calculate a spatial microscale. An anemometer system using dual sensor, hot film probes was selected to measure the parameters of interest. Two correlators were used to process the anemometer output. Special calibration techniques for the dual sensor probes were also investigated. Data was taken at test velocities of 100 feet per second (fps) and 150 fps in the primary jet. These correspond to Reynolds' numbers based upon the jet width, of approximately 2.9×10^4 and 4.4×10^4, respectively.

60. AN EXPERIMENTAL STUDY OF THE EFFECT OF A LOW SPEED EXTERNAL FLOW ON A COANDA EFFECT FLAP

Henry G. Hamby III, Capt, USAF 62p GAM/AE/73A-9
Advisor: Dr. A. J. Shine Lab Sponsor: AFFDL

An experimental study of the effect of a low speed air flow external to the blowing flow over a coanda effect flap was conducted. The test model had a 122 ft/sec external flow over an airfoil surface which terminated with a coanda effect flap. The flap had an internal flow velocity of 452 ft/sec at the coanda nozzle exit. The model was equipped to make possible vertical force measurements and schlieren photography of the flap area. The force measurements showed that the net vertical force produced by the combined internal and external flows was equal to the net vertical force of the individual flows. For example, the net vertical force at 20 degrees flap angle using the combined flow was 5.2 lb_f while the sum of the net vertical forces produced by the external flow only and internal flow only was 5.15 lb_f. The schlieren photography showed that the flap angle at which the flow separates for the combined flows was approximately 35 degrees. The flap angle for separation of the internal flow only was approximately 50 degrees. Also this difference in flap at separation corresponds to the portion of the flow turning angle occuppied by the internal flow stream.

61. AERODYNAMIC COMPARISON OF TWO DOUBLE-SLOTTED RUDDERS

Tyler B. Huneycutt III, Capt, USAF 146p GAM/AE/73A-10
Advisor: Lt Col F. Tolle Lab Sponsor: AFFDL

Double-slotted rudders (DSR), proposed for an Advanced Medium STOL Transport (AMST) by the L. O. M. Corporation and Convair Division of General Dynamics Corporation, were tested in a 7 X 10 ft wind tunnel

at a dynamic pressure of 17.0 psf and a Reynolds number of 2 X 10^6. The rudders were tested in 5 deg increments of deflection from 0 to 40 deg, and at sidewash angles varying from -10 to +10 deg. In the range of deflection angles from 0 to stall, the Convair DSR design (DSR1) produced slightly higher side-forces; however, the L. O. M. DSR design (DSR2) stalled at a higher deflection angle than DSR1. Maximum side-force produced by DSR1 and DSR2 were almost exactly equal. The side-force versus sidewash angle curves were linear. A rudder deflection schedule for DSR2 was devised which produces minimum drag and linear side-forces. The L/D polar of DSR2 was slightly better than that of DSR1. No adverse aerodynamic properties were observed which would preclude the use of either DSR on an AMST, although the simpler actuating mechanism of the Convair DSR makes it more attractive.

62. AN EXPERIMENTAL INVESTIGATION OF TRANSONIC FLOW AROUND A NOSE SECTION WITH AN OFF AXIS LONGITUDINAL CAVITY

Steven E. Icardi, Capt, USAF — 181p — GAM/AE/73A-11
Advisor: Prof H. Wright — Lab Sponsor: AFFDL

This study is a preliminary investigation of the transonic flow about an ogive-cylinder body with an off axis longitudinal cavity. The manner in which the cavity dimension affect the aerodynamic forces on the body and the pressure variations in the cavity are determined experimentally. Wind tunnel models were tested at transonic Mach number from 0.8 to 1.0. An internally mounted force balance and high-response pressure transducers were used to measure the forces on the model and pressure variations in the cavity. The depth of the cavity (X) was varied from zero to a maximum of 1.3 to 2.4 cavity diameters (D) for a range of D from 22 to 44 percent of the model diameter (MD). In the analysis of the force data, the drag coefficient was observed to be near a minimum when the ratio X/D was approximately 0.5. The pressure measurements revealed that if X/D was kept between 0.5 and 1.0, the pressure variations remained near their minimum. These two characteristics were present for all cavity diameters Mach numbers, and angles of attack considered. In addition, the lift curve was found to decrease slightly when the cavity diameter was increased from .22 to .44 MD and remained relatively constant as X was varied.

63. ON THE APPLICATION OF THE COOLED HEAT FLUX PROBE IN A SONIC EJECTOR

Robert E. Jahnke, Capt, USAF — 41p — GAM/ME/73A-4
Advisor: Prof W. C. Elrod — Lab Sponsor: ASD

The cooled heat flux probe permits measurement in high temperature environments with a higher frequency response than conventional measurement methods. Two probes together in a flowing environment of known composition can provide flow temperature and velocity. A study was conducted using the Thermo Systems, Inc. Model HF-22 probe in a highly turbulent sonic ejector to determine the feasibility of using such a probe in this environment. Mixing performance was also investigated using thrust and thermocouple measurements. The cooled probe continually failed mechanically in the sonic ejector in this study.

It is recommended that the probe be physically strengthened to enhance its survivability. Negligible thrust augmentation was realized with the sonic ejector and mixing in the constant area section was poor. Thermocouple measurements confirmed the poor mixing.

64. AN ANALYSIS OF STEADY ASYMMETRIC VORTEX SHEDDING FROM A MISSILE AT HIGH ANGLES OF ATTACK

John S. Kubin, Major, USAF — 72p — GAM/AE/73A-13
Advisor: Maj C. Stolberg — Lab Sponsor: AFFDL

Recent developments of highly maneuverable missiles capable of operating at high angles of attack have shown that large unexpected side forces and yawing moments occur due to asymmetric vortes separation from a slender missile body. The objective of this report was to develop a mathematical model which accounted for the viscous effects of the boundary layer fluid that sheds as discrete vortices, and to predict the forces and moments on a missile. An aerodynamic model in the crossflow plane based on von Karman's vortex street theory was developed. The number of vortex filaments which were shed and the positions of the filaments were determined from experimental data as a function of the crossflow Mach number. The Strouhal number was used to relate time in the crossflow plane with time to travel along the missile. Force and moment equations were developed using a 2-D complex potential flow field in the crossflow plane which consisted of a doublet in a free stream (crossflow velocity) and a vortex, plus its image. These equations were used to compare transverse forces and moments with experimental data to test the mathematical theory. The trend of the normal (lift) forces was predicted; however, the trend of the side force predictions was adequate only for low Mach numbers and low missile fineness ratios.

65. STUDY OF REVERSE-FLOW CHARACTERISTICS OF A TIP FAN AND AN EJECTOR

Ernest Kunstadt, 2/Lt, USAF — 57p — GAM/ME/73A-1
Advisor: Dr. A. J. Shine — Lab Sponsor: AFFDL

An investigation was carried out in order to determine the reverse-flow characteristics of an ejector and a tip-turbine fan. The components tested were a model TD-530 ejector and model TD-457 tip-turbine fan manufactured by Tech Development Corp., of Dayton, Oh. A plenum chamber and air flow system were designed and constructed to permit variation of flow rates and back pressures, as well as fan and ejector driving pressures. Measurements of pressures and temperatures were taken in order to determine air mass flow rates of drive and inlet air as a function of back pressure. Fan speed for the tip-turbine fan was also monitored as a function of back pressure, and various ejector exit conditions were studied to determine their affect on basic ejector performance. The secondary air mass flow rates for both devices were found to be practically linear functions of back pressure, up to and including the reverse-flow regime. The results of these studies are presented in graphical form and discussed.

66. APPLICATION OF THE LATERAL AND LONGITUDINAL (COUPLED) EQUATIONS OF MOTION TO AN INERTIALLY-SLENDER AIRCRAFT IN UNSYMMETRIC RECTILINEAR FLIGHT

Charles W. McConnell, Maj, USAF 72p GAM/MC/73A-3
Advisor: Prof R. Calico Lab Sponsor: AFFDL

The dynamics of an aircraft in flight may be represented by a set of six coupled non-linear equations of motion that are usually linearized about a symmetrical equilibrium position and divided into uncoupled lateral and longitudinal equations. The present high speed fighter aircraft requires a configuration that is prone to lateral instabilities which are not analyzed by the uncoupled equations. Solution of the coupled equations of motion is of considerable value because the cross-coupling effects may be determined and analyzed. For this study the F-4D aircraft was chosen as the physical model because of known stability difficulties. The parameters $C_{n_{\beta,dyn}}$ Aileron Alone Divergence Criteria, and $C_{\ell_{\beta,dyn}}$ were also obtained and compared with the results obtained from the equations of motion. For conditions requiring additional information mode characteristics (Argand diagrams) were drawn utilizing data obtained from the eigenvalues. Evaluation of the equations of motion indicated that considerable cross-coupling occurs at high angles of attack with sideslip and that correlation with the stability parameters may vary more than desired within the area. For this reason the aircraft's alpha-beta envelope should be defined from data obtained by the equations of motion with the stability parameters adding corroborating information.

67. AIR CUSHION LANDING SYSTEM PERFORMANCE ON A TENTH-SCALE MODEL JINDIVIK RPV

Philip M. Parker, Jr., Capt, USAF 71p GAM/AE/73A-15
Advisor: Dr. A. J. Shine Lab Sponsor: AFFDL

Tests were conducted on an air cushion landing system (ACLS) installed on a tenth-scale model Jindivik RPV. The model has the correct Froude-scaled values of weight, center of gravity cg and moment of inertia about all three axes. The results of these tests were compared to the results of similar tests conducted on the ACLS of a full-scale model Jindivik. Static tests on the tenth-scale ACLS determined the heave stiffness to be 11 lb per in., the pitch stiffness to be .155 lb ft per deg (for a nose down moment) and the roll stiffness to be .0048 lb ft per deg. These values were within 60% of the full-scale values. Drop tests showed the maximum load at the cg of the model to vary between 2.2 g's at the scaled nominal landing rate of descent, to 5.4 g's at the maximum landing rate of descent. Comparison between systems at the nominal landing rate of descent show the load dynamics to be similar. The pressure dynamics of the tenth-scale system showed no correlation with the full-scale ACLS data. At launch speeds of 8 mph and 12 mph, high speed films of the catapult tests showed that the tenth-scale Jindivik had less pitch oscillations after touchdown with the air cushion vented than in the normal landing configurations. Touchdowns at higher speeds were not analyzed due to the narrow field of view of the high speed camera.

68. AN ANALYSIS OF THE LONGITUDINAL DYNAMICS OF A STOL TRANSPORT IN LANDING APPROACH

Glen M. Personius, Maj, USAF 69p GAM/MC/73A-1
Advisor: Prof R. Calico Lab Sponsor: AFFDL

The longitudinal dynamic response of a representative STOL transport in landing approach was analyzed and the results compared with existing military handling qualities specifications. Eigenvalues and eigenvectors for the basic airplane were calculated using EISPACK subroutines for the CDC 6600 computer. Time histories of response were obtained by using series expansion techniques to solve the state equations. The parameter, M_u, change in pitching moment with change in forward speed, was found to have a powerful effect on both static and dynamic stability. Low short period frequency and negative phugoid damping in the landing approach speed range, combined with strong coupling between flight path and airspeed, make the basic airplane longitudinal dynamics unacceptable. Some suggestions are made relative to the preliminary design of a stability augmentation system for this airplane.

69. A PRELIMINARY DESIGN STUDY OF A REMOTELY-PILOTED HIGH SPEED GLIDER

Albert C. Piccirillo, Maj, USAF 93p GAM/AE/73A-16
Advisor: Prof H. C. Larsen Lab Sponsor: ASD

A preliminary design for a small air-launched, high-speed, TV equipped glider capable of providing inexpensive training for pilots of high performance RPV-type aircraft was completed. This design is also adaptable without modification as a stand-off remotely piloted attack glider carrying a 150 pound special purpose warhead. The configuration, which features canards as well as folding wingtips to enable carriage on standard military aircraft armament pylons, was designed with sufficient built-in growth potential to enable future development as a powered, air launched mini-RPV for use in penetrating extremely high threat areas to accomplish either strike or reconnaissance missions. The design has a folded wingspan of 3.33 ft, a length of 10.37 ft, and a gross weight of 368 pounds. The wing extends to a span of six ft following launch to improve flying characteristics and performance. The glider was designed to have satisfactory flight characteristics and to be stable throughout the flight envelope from Mach 0.2 to 0.8.

70. THE DESIGN OF A STATOR IN A HIGH PRESSURE RATIO COMPRESSOR STAGE

Major D. Scott, Maj, USAF 137p GAM/ME/73A-5
Advisor: Prof W. C. Elrod Lab Sponsor: ARL

The aerodynamic design of a stator for a supersonic axial compressor stage is described in detail. The stator is a replacement for that component of an existing stage for which complete experimental data is available. The purpose of the design is to improve the overall performance of that stage. The most significant aerodynamic characteristics of the new stator design are inlet Mach numbers varying from 1.0 to 1.2 and diffusion factors varying from 0.5 to 0.7. Unusual geometric characteristics include splitter vanes located at mid-passage in the stator exit region, and leading edges that are swept back from both walls toward mid-radius on the main stator blades. A preliminary design

employs a technique which results in equilibrium radial distributions of total pressure loss coefficient and relative flow angle consistent with relative Mach numbers and diffusion factors on each streamsurface according to a specified loss mode. The design is optimized by adjusting the variation in angular momentum along each streamsurface through the stator until a predetermined static pressure distribution is obtained. This optimization process is limited to a resulting blade design that is practical to manufacture. Finally, the detail design is determined by using a recently developed method which defines an arbitrary camber line and blade element on each streamsurface. This method also uses the aerodynamically defined airfoils to determine the Cartesian coordinates for manufacturing details of the stator.

71. AN EXPERIMENTALLY BASED PREDICTION OF THE STATIC PERFORMANCE IN THE VERTICAL DIRECTION OF AN AIR CUSHION LANDING SYSTEM

John L. Stuart, Capt, USAF — 44p — GAM/AE/73A-17
Advisor: Dr. A. J. Shine — Lab Sponsor: AFFDL

The purpose of this study was to develop an analytical procedure which can be used to predict the static performance of an Air Cushion Landing System (ACLS) in the vertical direction. A mathematical model of an ACLS was developed which interrelates the system variables used to describe the force balance, the flow balance, and the geometric constraints which exist in the static mode. Since the mathematical model yielded only nine equations in thirteen unknowns, four additional equations were generated from experimental data taken from scale models of an ACLS-equipped CC-115 aircraft. Experimental values of trunk pressure, cushion pressure, and ground clearance at different gross weights for both floor-in and floor-out conditions are required as inputs to the prediction procedure. The predicted values of ground clearance versus aircraft gross weight differed from the experimental data by less than 3% for the quarter-scale model and less than 4% for the tenth-scale model. In addition to ground clearance and aircraft gross weight, the procedure also predicts trunk pressure, cushion pressure, flow rate, and cushion exhaust height.

72. HYPERSONIC FLOW OVER A FLAT PLATE

William M. Tuck, Jr., Capt, USAF — 80p — GAM/AE/73A-18
Advisor: Maj R. Bestgen — Lab Sponsor: ARL

The purpose of this study was to determine the performance of the AFIT hypersonic shock tunnel and to demonstrate the use of heat transfer gages and miniature pressure transducers in the facility by analyzing the flow over a flat plate model. The performance of the tunnel was determined by calibrating the driven tube and test section. Calibration of the driven tube consisted of measuring driven shock speed, pressure ratio across the driven shock, and pressure after shock reflection. The data obtained were then plotted as a set of performance curves. The test section performance was determined from an impact rake survey of the nozzle exit. The Mach number of the flow was found to be 11.10 and the diameter of the nozzle inviscid core nominally 18 in. A flat plate model

was constructed and instrumented with thin-film heat transfer gages and pressure transducers. The model was tested at 0, -5, -10, and -15 deg angle of attack, and the data obtained generally agreed favorably with theory and with the results from similar studies.

73. ANALYSIS OF THE INFLUENCE OF AIRCRAFT DESIGN PARAMETERS ON AIR-TO-AIR COMBAT CAPABILITY

Dean F. Vikan, Maj, USAF — 146p — GAM/AE/73A-19
Advisor: Prof H. Larsen — Lab Sponsor: AMRL

A computer study was made to analyze the influence on close-in-air-to-air combat success rates of wing loading, thrust loading and limit load factor utilizing twelve different combinations of these aircraft design parameters. A single set of engine performance data was used for all aircraft. Wing loadings of 50 psf, 60 psf and 80 psf were combined with limit load factors of 6.5 g, 7.5 g, 8.5 g, and 9.5 g with appropriate thrust loading increases to account for the weight growth due to structureal changes. These parameter variations were analyzed in 66 one-on-one air combat engagements. Results of the study showed a decided advantage for the aircraft with the lowest wing loading. At a low wing loading, the advantage then increased with limit load factor growth but peaked at 8.5 g's. Data analysis indicated a limit load factor of approximately 9 to be optimum for the given engine performance at the 50 psf wing loading. Large increases in thrust-to-weight ratios for a high wing loaded aircraft were necessary to offset the advantage of a low wing loading. In addition, an increase in thrust-to-weight ratio did not significantly improve the success rate when lift or limit load factor was the primary maneuvering constraint.

74. ADDITION OF AN ARBITRARY BODY ANALYSIS CAPABILITY TO THE BOEING TEA 236 FINITE ELEMENT COMPUTER PROGRAM

James L. Westphal — 77p — GAM/AE/73A-20
Advisor: Capt J. Karam — Lab Sponsor: AFFDL

The Boeing TEA 236 computer program, used to calculate wing pressure distributions of wing-body configurations, is examined. Small perturbation potential theory, as used by the program, is reviewed. The method used by the TEA 236 in the analysis of a fuselage of circular cross-section, in calculating wing pressures, is examined. The capability to analyze an arbitrary body cross-section is added by employing a least-squares fitted cosine series to more accurately describe the actual body cross-section. Comparison is made between C-5A wind tunnel data, computed data obtained from the TEA 236 using its unmodified circular body routine, and computed data obtained from the TEA 236 using the analytical body description technique developed in this study. Data calculated uwing the TEA 236 with the arbitrary body routine shows improved agreement with experimental wing pressure data, in comparison with data calculated using the TEA 236 with the standard circular cross-section routine, at essentially no increase in computer time. CALCOMP plots comparing the cross-sections used in the program runs, to obtain wing pressure distributions, are provided. A user's guide to the analysis option of the TEA 236 is provided.

75. PROTOTYPE FOR A LOW COST LASER GUIDANCE UNIT FOR A BDU-33 PRACTICE BOMB

William C. Ayers, Capt, USAF | 60p | GAW/MC/73-2
Advisor: Dr. P. J. Torvik | Lab Sponsor: AFATL | AD 763711

Training is required if laser-guided weapons are to be used effectively, but the cost when utilizing the full scale weapon is prohibitive. This report describes a prototype for a low cost ($140) laser guidance unit designed to be used in conjunction with a BDU-33 practice bomb. This unit, completely self contained, can be dropped from the SUU-20 practice ordnance dispenser. It utilizes the same type laser illuminator and has a guidance logic similar to the standard laser guided bomb and therefore provides realistic training. The unit could be used for low cost and effective laser-guided weapons training.

76. FATIGUE CRACK GROWTH AND RETARDATION USING POLYCARBONATE

Daniel H. Banasiak, Capt, USAF | 58p | GAW/MC/73-3
Advisor: Maj L. T. Montulli | Lab Sponsor: AFML | AD 769926

This experimental study investigated the "retardation" effects observed when tensile overloads were applied during fatigue tests of polycarbonate, a transparent polymer. Fatigue cracks were grown in 4-point bend polycarbonate specimens at constant stress intensity ranges in order to obtain constant fatigue crack growth rates. Peak overloads were then applied to the specimens in order to investigate their effects on subsequent crack growth. Simple optical methods were used to observe and photograph the crack tip front at the center of the specimen. Tensile overloads were shown to retard fatigue crack growth in polycarbonate in a manner similar to that observed in metals. Crack tip blunting and crack closure appeared to be associated with the retardation mechanism; however, their exact relationship was not investigated. It was concluded that polycarbonate offers potential as a model material for further retardation studies.

77. PRODUCT DISTRIBUTION AND INDUCTION TIMES IN THE SHOCK-INITIATED IGNITION OF CYANOGEN-OXYGEN-ARGON MIXTURES

Davy M. Bass, Capt, USAF | 78p | GAW/ME/73-1
Advisor: Prof E. A. Dorko | Lab Sponsor: ARL | AD 769502

Mixtures of cyanogen and oxygen diluted in argon were ignited behind reflected shocks in a single-pulse shock tube. The ignition delay times were determined from pressure observations. The experiments covered the temperature range 1400 K to 2000 K. This range permitted ignition delay times from 15 up to 430 microseconds. Eight mixture groups and their initial conditions were chosen in such a manner that the influence of each particular parameter on the induction period would be unequivocally evaluated. The resulting equation for induction time was:

$$\tau = 5.22 \times 10^{-16} \exp(34700/RT) [C_2N_2]^{-1.01} [O_2]^{-0.20} [Ar]^{0.21} \text{ sec}$$

where the brackets denote concentrations in mode/cc. Product distribution before and after ignition was determined by a CEC 21-103C mass spectrometer. Results indicate that the combustion of cyanogen is thermodynamically controlled. Tests of a ninth mixture containing 1% hydrogen revealed that hydrogen lowers activation energy and shortens induction time. This indicates that with the addition of H_2 a chain branching mechanism becomes rate controlling.

78. THE REDUCTION OF KINETIC DATA FROM THE ISOTHERMAL DECOMPOSITION OF SOLID STATE SYSTEMS BY MEANS OF A WEIBULL PLOT

William F. Bryant Jr., Capt, USAF | 78p | GAW/AM/73-1
Advisor: Prof E. A. Dorko | Lab Sponsor: ARL | AD 769499

A study was made of the kinetics of solid state decomposition below the melting point to determine the suitability of modeling the reaction with the Weibull cumulative distribution function. Reaction histories for the isothermal decomposition of malonic acid and cupferron tosylate were obtained from literature sources, and differential scanning calorimetry was used to produce thermograms of the isothermal decomposition of benzoyl peroxide. Percent of reaction was plotted as a function of time on Weibull graph paper, and the resulting linearity implied a mixed Weibull distribution model. A graphical algorithm was developed to separate the combined solid and liquid phase data, which were re-plotted on the Weibull paper as independent data sets. The solid phase plot produced Weibull parameters identical with the equation of the Avrami-Erofeev solid state model. The liquid phase plot indicated first order kinetics. Rate constants and activation energies computed from the liquid phase Weibull parameters were in close agreement with published values, suggesting that the mixed Weibull model permits a simple graphical analysis of the kinetics of a solid state reaction accompanied by melting.

79. BIOMECHANICS OF BONES AND LIGAMENTS IN PRIMATES: THE EFFECTS OF STRAIN RATE, EXERCISE, AND RECONDITIONING ON ULTIMATE PROPERTIES

James L. DeLucas, 2/Lt, USAF | 136p | GAW/MC/73-5
Advisor: Dr. P. J. Torvik | Lab Sponsor: AMRL | AD 759647

Experiments were conducted to determine the effects of strain rate, exercise, and reconditioning on bones and ligaments in Rhesus monkeys. In the strain rate tests, the anterior cruciate knee ligament was tested to failure in tension. The maximum load of this ligament increased 24% when the strain rate was changed from 0.2 inch/min to 20.0 inch/min. The strain to failure and energy absorbed at failure also increased when the ligament was tested at the fast strain rate. In the exercise tests, Rhesus monkeys were inducted to exercise their right leg while the rest of their body was kept immobilized in a plaster cast. At the end of eight weeks of exercise the monkeys were sacrificed. The anterior cruciate ligaments were tested to failure in tension, while the tibae, femora, and humeri were tested to failure in torsion. Eight weeks of exercise was not sufficient to compensate for the weakening effects of partial immobilization of the body. In the reconditioning tests, Rhesus monkeys were first totally immobilized in plaster body casts for a period of eight weeks. At the end of this period, the monkeys were removed from the plaster casts and transferred to large cages for recuperation. The monkeys remained in the large cages for 16 or 24 weeks. At the end of these periods the monkeys were sacrificed. The anterior cruciate ligaments were tested to failure in tension and the tibae, femora, and humeri were tested to torsion. After 24 weeks of reconditioning, the knee ligament did not completely recover from the weakening effects of immobilization, while the femur and humerus had recovered their normal strength.

80. MAXIMUM LAUNCH RANGE FOR AN AIR-TO-AIR MISSILE EMPLOYING PROPORTIONAL NAVIGATION FOR GUIDANCE

Timothy J. Graves, Capt, USAF | 63p | GAW/MC/73-6
Advisor: Maj G. M. Anderson | Lab Sponsor: AFATL | AD 770082

Optimal control theory is used to find the necessary conditions for maximizing the launch range of an air-to-air missile employing proportional navigation for guidance. Use of the first-order gradient technique provides an optimal solution for one- and two-dimensional intercept trajectories where thrust magnitude is the only control. A near-optimal, empirical method is developed and used for comparison. Results indicate that the launch range of the class of missiles considered is nearly insensitive to the thrusting schedule employed, suggesting that the low gain in launch range over present constant thrust methods may not warrant the increased complexity of an optimal design. Further, the results of the easier empirical method agree closely enough with the optimal method to suggest use of the empirical method in lieu of the gradient technique.

81. DAMAGE INTERACTION IN COMPOSITES

Terry D. Gray, Capt, USAF | 97p | GAW/MC/73-7
Advisor: Prof P. J. Torvik | Lab Sponsor: AFML | AD 769927

An investigation was conducted to study the effects of foreign object damage on the bending fatigue characteristics of a composite material, unidirectional boron/aluminum-6061. Fatigue curves were generated for a control group and each of four levels of foreign object damage. The composite was further characterized by static tensile, static bending, and nondestructive tests. All tests were carried out at room temperature. A similar damage and fatigue analysis was done for a titanium alloy, Ti-6Al-4V, to provide baseline data with which to compare the composite. For a given foreign object impact energy, boron/aluminum-6061 suffered more physical damage and a greater percentage reduction in fatigue strength than did Ti-6Al-4V. Boron/aluminum-6061 was found to be insensitive to impact-induced cracks for long fatigue lives (10^7 cycles); crack-induced stress concentrations did not affect the failure stress at 10^7 cycles.

82. PRELIMINARY CONFIGURATION DESIGN OF A MODULAR WEAPON WITH CANARD CONTROLS

Wendell R. Hull, Lt Col, USAF | 93p | GAW/MC/73-8
Advisor: Maj F. E. Eastep | Lab Sponsor: AFATL | AD 769929

A geometric configuration design for a guided modular weapon with an 800 lb warhead and canard controls was developed, based on preliminary computation of aerodynamic data. The applicable stability derivatives for 45 variations of canard and tail wing size were computed and the subsonic longitudinal stability and control characteristics were evaluated. The primary criteria considered in the evaluation were maneuver load factor capability and perturbed dynamic response, with constraints on static margin, control deflection, and trimmed angle of attack. The sensitivity to weight and center of gravity variations and the time response to control deflection inputs were also evaluated to arrive at a suitable configuration design. Maneuver load factor capability greater than 1.5 g's with a controls fixed static margin exceeding 1.5 calibers appears feasible for the preliminary design. The maneuver capability can be achieved with both maximum trimmed angle of attack and maximum control deflection less than 10°.

83. WEIGHT OPTIMIZATION OF SOLID BEAMS WITH DYNAMIC CONSTRAINTS

Floyd W. Isley, Capt, USAF — 70p — GAW/MC/73-9
Advisor: Maj F. E. Eastep — Lab Sponsor: AFFDL — AD 759169

The mass distribution of solid beams and panels is optimized to produce a weight savings while maintaining a dynamic constraint. The basic procedure used in solving the problems in the transition matrix method, a numerical technique of optimization adapted from optimal control theory. The weight of a solid beam of rectangular cross section is shown to be reduced from that of a beam of uniform thickness by ten percent. The weight savings was accomplished by varying the thickness while insuring that the beam with the optimal thickness had the same fundamental frequency as the beam of uniform thickness. Similar savings are shown for beams with the second natural frequency fixed and for beams of circular cross section. Additionally, a solid panel with a flutter constraint is optimized and it is shown that the weight savings could be over ten percent.

84. AERODYNAMIC INTERFERENCE BETWEEN AN AIRCRAFT AND WING STORE

Larry N. Looney, Capt, USAF — 95p — GAW/MC/73-10
Advisor: Maj F. E. Eastep — Lab Sponsor: ASD — AD 759170

Aerodynamic interference between an aircraft and wing store is studied by the use of analytical wing, fuselage, and store models. Inviscid flow is assumed and the Gothert transformation is used to correct for compressibility. An elliptic wing is represented by a bound vortex followed by a trailing vortex sheet. The fuselage and store are assumed to be slender bodies and modeled by a series of sources and doublets along their axis of revolution. Aerodynamic interference of the aircraft model is studied by observing the store in captive and free flight modes in the vicinity of the wing and fuselage models. The aerodynamic forces and moments experienced by the store as well as store trajectories are computed. Comparisons are made of store reactions (motion and trajectory) to only the wing model and to the wing and fuselage models combined.

85. OXIDATION OF ALUMINUM NITRIDE

Bruce A. Rasmussen, Capt, USAF — 68p — GAW/MC/73-11
Advisor: Capt W. B. Crow — Lab Sponsor: ARL — AD 770038

The oxidation characteristics of hot-pressed aluminum nitride were investigated. Three materials were studied in the temperature range 1100° to 14 1400°C in 15, 150, and 400 torr oxygen environments. The oxidation process was evaluated using thermogravimetric measurements, X-ray diffraction, optical and scanning electron microscopy and electron microprobe results. The response of each of the three materials to the high temperature oxygen environment varied. The first material exhibited poor thermal shock characteristics, spalling on insertion into a 1200°C test chamber. The second material varied in density from 93% to 97% of the theoretical for AlN. Thermogravimetric data obtained from this material was irreproducible; oxidation rates were found to be highly sensitive to minor variations in density. The third material had nearly zero porosity; gravimetric measurements obtained with this material were reproducible (deviation <±2%). Activation energy for oxidation of this material was calculated to be 86.2 ± 2.6 Kcal/mole. The oxidation rates were also found to be dependent on oxygen pressure

$$(K_p : P_{O_2}^{1/2}).$$

86. THE EFFECT OF THE MODE OF COLD DEFORMATION ON THE RECRYSTALLIZATION AND SUBSEQUENT GRAIN GROWTH OF Ti-5Al-2.5Sn

Richard E. Rumph, 1/Lt, USAF | 53p | GAW/MC/73-12
Advisor: Capt W. B. Crow | Lab Sponsor: AFML | AD 770083

The effect of the type of deformation on the recrystallization and subsequent grain growth of Ti-5Al-2.5Sn was investigated for tension, compression, and swaging. The amount of cold work (as measured by true strain) was kept constant for each type of deformation. Each mode of deformation was investigated for 15%, 25%, and 40% deformation. The specimens deformed 15% did not recrystallize. The specimens deformed by tension recrystallized at a lower temperature and had a smaller "as recrystallized" grain size than did the specimens deformed by compression for both 25% and 40% deformation. The swaged samples' recrystallization temperature and "as recrystallized" grain size was between the recrystallization temperature and "as recrystallized" grain size of the specimens deformed by tension and compression for both 25% and 40% deformation. After annealing the specimens at 1600°F (871°C) for 30 minutes, the deformed tensile specimens had the smallest grain size, compression had the largest grain size, and swaging had a grain size between the other two.

87. USE OF THE ANALOG COMPUTER IN THE STUDY OF THE EFFECTS OF AERODYNAMICS ON BALLISTIC TRAJECTORY

John A. Wiles, Capt, USAF | 53p | GAW/MC/73-1
Advisor: Prof R. Calico | Lab Sponsor: AFATL | AD 770281

A study was made to see if the analog computer could be programmed in such a manner that it became a useful tool for the weapons design engineer in his analysis of free-fall bomb trajectories. The equations of motion were derived for the two-dimensional trajectory of a bomb, including pitching motion about the nominal flight path. The aerodynamic forces and moments were generated on the computer by means of nonlinear components. Several trial runs were made and it was determined that the accuracy of the analog solution, when compared to an equivalent digital solution, was sufficient for a first order analysis of trajectory variations. The use of the program was demonstrated by varying static margin and initial angle of attack and observing the resultant changes in the ground range of the bomb. The program is more versatile than this, however, and can be used to observe all trajectory phenomena while varying any of the physical or aerodynamic parameters.

88. THE DETECTION AND IDENTIFICATION OF MAN-MADE OBJECTS FROM AERIAL RECONNAISSANCE PHOTOGRAPHS

John B. Ashbaugh, 1/Lt, USAF | 93p | GE/EE/73-1
Advisor: Prof M. Kabrisky | Lab Sponsor: AMRL | AD 760755

An algorithm is proposed which detects and identifies man-made objects from actual aerial reconnaissance photographs. The objects are detected by cross-correlating the contour map of the digitized photograph against a generalized model for all man-made objects. This model, consisting of only three prototypes, detects objects regardless of their size, shape, and orientation. The boundary of each man-made object is then traced and represented as a parametric set of complex points. This representation is then cross-correlated with prototypes representing different general shapes in order to gain information about the size and shape of the object. This

information is then combined with a logical decision process, based on some generalized rules, to classify the objects. The results of this investigation are based on a test set of six actual photographs. The procedure exhibited a detection accuracy of 71% and an identification accuracy of 87%.

89. SEISMIC PATTERN RECOGNITION

Ronald D. Bouvier, Capt, USAF | 119p | GE/EE/73-2
Advisor: Prof M. Kabrisky | Lab Sponsor: AMRL | AD 757877

This paper applies various pattern recognition techniques to the problem of discriminating underground nuclear explosion seismic signals from those of natural earthquakes. The data set consists of 186 short period seismograms recorded by the Large Aperture Seismic Array in Montana. Enough seismic and pattern recognition theory is developed to allow easy interpretation of the results. The techniques tested run the gamut from simple, linear classifiers to a complex, adaptive, nonlinear classifier. The best results were 99.4% correct identification of earthquakes and 94.2% correct identification of explosions.

90. THE DETECTION AND CLASSIFICATION OF OVERLAPPING BINARY WAVEFORMS

Larry L. Burk, Capt, USAF | 105p | GE/EE/73-3
Advisor: Capt J. Neff | Lab Sponsor: AFAL

A bank of aprallel correlators was used to detect and classify a signal known to be one of a set of signals where the selected signal was generated repetitively in time according to the overlapping sporadic-Poisson process. Local detection of individual waveforms was not considered; detection and classification decisions were made after the total period of reception. The detection capability and classification accuracy was compared to that of the optimum detector for these signals. Receiver operating characteristics are derived by computer simulation for a range of parameter variations--signal-to-noise ratio, length of observation, and signal generation probability.

91. APPLICATION OF FINITE ELEMENT ANALYSIS TO COPLANAR WAVEGUIDE

Arnold C. Celestini, Capt, USAF | 79p | GE/EE/73-4
Advisor: Prof R. A. Potter | Lab Sponsor: AFAL | AD 760756

An accurate method of calculating the transmission line characteristics of coplanar waveguide is required for design considerations. In his conformal mapping approach, C.P. Wen assumed the dielectric was infinitely thick and employed a quasi-static approximation. Wen's approach was modified by taking into account the finite thickness of the substrate and the resulting calculations were very accurate. With these calculations to use as a standard, the primary investigation was shifted to applying finite element analysis in the form of two computer programs to the coplanar waveguide problem. The two programs were modified to make them compatible with one another and permit their operation on the CDC 6600 computer. A solution to Laplace's equation resulted in the production of equipotential plots which were analyzed using a field mapping technique. Although the results achieved were not as accurate as the modified Wen's approach, this was attributed to the difficulty in trying to apply the field mapping technique to a complicated geometry. The

primary accomplishment was the implementation of two computer programs that represent powerful tools for use in the analysis of any electromagnetic field problem where the boundary conditions are known.

92. REUTILIZATION OF THE MINUTEMAN GUIDANCE COMPUTER AS A NUMERICAL/PROCESS CONTROLLER

Raymond V. Cicirelli, Lt, USCG — 119p — GE/EE/73-5
John M. Hill, 1/Lt, USAF — Lab Sponsor: AFIT — AD 760757
Advisor: Dr. G. B. Lamont

As a result of the D17B computers from the Minuteman I missiles being made available to qualifying organizations, several studies have been implemented to assess the usefulness and adaptability of the D17B in other applications. This report is directed toward their use in control applications. The report outlines a few of the basic concepts of numerical control and process control toward the end of adopting these computers to those purposes. The primary emphasis is on numerical control with merely a small account being given of process control. The primary functional features of the computer are presented in detail for the D17B and merely mentioned in passing for the D37C computer (Minuteman II) with the expressed hope that the results of the work can be applied to the D37C. An analog computer model of a machine positioning system was developed in order to test the control that could be exerted on a machine by the computer under program control. Various programs were developed to control the machine model in X and Y coordinates. The programs were able to control the machine model continuously over a specified trajectory. Representative paths describing arcs of circles and squares in arbitrarily selectable locations are presented as results. In addition the shaft-angle of a laboratory motor-trainer was controlled in discrete increments.

93. THE USE OF SCANNING AUGER SPECTROSCOPY FOR SURFACE ANALYSIS

Roger L. Counts, Maj, USAF — 53p — GE/EE/73-6
Advisor: Prof J. Lubelfeld — Lab Sponsor: AFAL — AD 760550

A scanning Auger microscope was constructed at the Air Force Avionics Laboratory (AFAL) to permit surface analysis of solid state devices. The instrument was operated in a scanning electron microscope mode for initial tests and calibration. Electron gun operation was verified by measuring a beam current of 0.8 microampere. Electron beam diameter was determined to be approximately 20 microns by observing the resolution of the display. A cylindrical mirror analyzer was installed on the electron gun assembly and synchronous detection techniques were used to record Auger spectra. An apparent inability to record Auger peaks was localized to the analyzer. Wiring diagrams and operating instructions were formulated for the use of future operators of the apparatus.

94. THEORETICAL MODEL OF A SPARTON MODEL 601M HORIZONTAL VELOCITY GAGE

Elsmer K. Elkins, Jr., Capt, USAF — 79p — GE/EE/73-7
Advisor: Lt Col J. Hanson — Lab Sponsor: AFWL — AD 762268

A theoretical model of a Sparton Model 601M horizontal velocity gage is developed. The mechanical and electrical systems of the velocity gage are treated as separate entities and separate models of each system are developed. Lagrange's equations are used to develop the mechanical equation of motion. Ampere's circuital law is used to develop the inductance equations for the electrical model. The electrical system equations are developed by applying Kirchhoff's voltage law to an equivalent circuit for the bridge network. Then by defining state variables, the overall system equations are written. A Fortran program was developed to solve the overall system equations using a fourth order Runge-Kutta algorithm. The computer program is used to verify the overall system state model against a known laboratory result. Then results are shown which indicate the linear and non-linear operating ranges of the gage. Finally, results are shown which compare the gage output to the theoretical velocity for a known dynamic input.

95. MODELING AND ANALYSIS OF THE F-4E FIRE CONTROL SYSTEM

James W. Evatt, Capt, USAF — 113p — GE/EE/73-8
Advisor: Lt Col J. Hanson — Lab Sponsor: AFAL

Analysis was performed on the Modified Lead Computing Optical Sight System (LCOSS) for the purpose of determining the projectile miss distance resulting from the assumptions and approximations contained in the LCOSS. The analysis of the LCOSS examined both the analog computer and two-degree-of-freedom gyroscope components of the LCOSS computing system. Mathematical representations of the computing components were used to determine weapon alignment for simulated firing situations. Firing situations were provided from an aerial encounter simulation which permitted pursuit tracking of a maneuvering target in a horizontal plane. The projectile's terminal miss distance was computed using Siacci range and drop functions. The Siacci functions were corrected for both yaw-drag and swerve effects. Simulations were conducted with the production sight stability number of 0.25 and the additional values of 0.0, 0.125, and 0.5.

96. SOFTWARE EMULATION OF THE PDP-12 COMPUTER

Jackson M. Hall, Capt, USAF — 137p — GE/EE/73-10
Advisor: Dr. G. B. Lamont — Lab Sponsor: AFIT — AD 760552

A computer program was developed to simulate the operation of the Digital Equipment Corp. (DEC) PDP-12 computer at the register transfer level. The program is written in FORTRAN IV Extended language, and it is designed to be used interactively from teletypes under control of the Control Data Corp. (CDC) 6600 computer INTERCOM system. The program emulates the PDP-12 front console, the PDP-8 mode set of instructions, the LINC mode set of instructions, and the DEC PAL III assembler program. The execution of input and output instructions for the teletype and two types of simulated storage devices are also emulated. The logic used to simulate the PDP-12 front console and the execution of PDP-8 mode instructions was previously developed by Capt. Edgar E. Burkett as a minicomputer

emulator program. Both PDP-8 and LINC mode programs may be executed by loading the instructions in octal form using emulator input commands at the teletype. PDP-8 mode programs may also be executed by entering the instructions in symbolic form and using the emulator assembler. This thesis discusses the overall organization of the emulator program, the routines which emulate the LINC mode set of instructions, the input-output routines which emulate special storage devices, and the assembler program. A supplement to the Minicomputer Emulator User's Manual is also provided which contains program examples and material reflecting the additions and changes made to the PDP-12 minicomputer emulator program.

97. AN ANALYSIS OF PHASE CHARACTERISTICS AS A FUNCTION OF AMBIENT TEMPERATURE OF IMPATT DIODE AMPLIFIERS

Phillip W. Hawkins, Lt, USCG — 125p — GE/EE/73-11
Advisor: Prof R. A. Potter — Lab Sponsor: AFAL

The Avalanche Diode Amplifier is directed towards the long-term requirements of efficiency, high power, and microwave applications required for use in transportable phased array networks. The phase dependence of the IMPATT diode amplifier upon ambient temperature is of interest. A theoretical model of the phase characteristics as a function of ambient temperature, based upon the interaction of an electromagnetic wave with a conducting medium, is developed, and the phase-temperature relationship found to be basically logarithmic. Using a network analyzer especially configured to increase usable oscillator power by 40 db, phase measurements are obtained on a GaAs IMPATT diode amplifier ober a temperature range of 11.7°C to 69.7°C for frequencies from 9.0 to 9.6 GHz. Phase change rates calculated for 100 MHz intervals over the bandwidth are found to favorably agree with the phase change predicted by the proposed model.

98. A RELOCATABLE ASSEMBLER AND ASSOCIATED LOADER FOR THE D17B MINUTEMAN GUIDANCE COMPUTER

Donald D. Henson, 1/Lt, USAF — 180p — GE/EE/73-12
Advisor: Dr. G. B. Lamont — Lab Sponsor: AFIT — AD 760758

The D17B Minuteman Guidance Computer is a serial data processor with a rotating disk memory. After conversion to laboratory use at AFIT, the problem of programming in machine language remained. The addition of an I/O system has allowed the development of a relatively sophisticated operating system and assembler. The D17B Operating System uses a punched paper tape library to load and execute programs under the direction of commands entered at a teletype keyboard. Programs are on the Library Tape in a relocatable object code format and external references are allowed. Programs from the Library Tape or user programs are loaded and external references are linked to entry points by a relocatable program loader. The Minuteman Assembler is designed to work with the relocatable program loader. The assembly language is designed using customary syntax and semantics where possible. External references are allowed. The assembler is to be implemented in a segmented format to allow more sophisticated features in the small memory of the D17B computer. The segmenting takes advantage of a Tape Controller which is to be part of the AFIT D17B system. The output of the assembler is in a relocatable object code format.

99. AUTOMATED DIGITAL SYSTEMS DESIGN - LOGIC REALIZATION PHASE

Lawrence E. Jennings, Capt, USAF 183p GE/EE/73-13
Advisor: Dr. G. B. Lamont Lab Sponsor: AFIT

The objectives for an automated digital design system are threefold: first, to develop a system in circuit design, second, to develop a system which uses the man-machine interface to best advantage, and third, to develop a system to augment and compliment digital design courses at AFIT. The objective of this thesis is to develop and implement automated logic realization procedures used in automated digital systems design. The program chosen to achieve the logic design objective of the paper was the General Electric Automation System (GELAS). A program to draw the logic diagrams of the designed circuit was also developed. GELAS, a hardware design system for combinational and sequential logic circuits, is examined program by program. A flow-chart of each major program is presented along with discussion of the program. The discussion includes the requirements of each program, the arrays used by each program, and the procedures used by the program to realize its function. Two different types of programs are discussed: first, the implementation sub-routines, and second, the array handling subroutines. The implementation sub-routines are the sub-routines which read in and print out data, perform the design algorithms, and print the results. The array handling sub-routines are the tools the implementation subroutines use to perform the necessary design functions. A procedure for producing logic diagrams of circuits defined by a simulator deck is included. The logic diagrams produced used the military standard symbols. Several limitations of this procedure are discussed.

100. AUTOMATIC RECOGNITION OF PHONEMES USING A VOCODER INPUT

Richard D. Kier, Capt, USAF 62p GE/EE/73-14
Advisor: Prof M. Kabrisky Lab Sponsor: AMRL

Digital speech spectrograms of various words, phrases, and utterances by one male speaker are obtained on a PDP-12 computer through a KY-585 Vocoder. The individual phonemes are extracted by the operator through software options. Walsh transforming and spatial sequency filtering of the data are performed when the data are accepted. After sufficient data are obtained, a basic phonemic "vocabulary" is formed, trained, and then tested. Recognition rates of 55% on first attempt to 80% on third attempt were obtained for a 22 phoneme vocabulary.

101. INTERACTIVE GRAPHICS INTERFACE FOR DIGITAL LOGIC SIMULATOR

Fred F. Kirk, 1/Lt, USAF 170p GE/EE/73-15
Advisor: Lt Col T. Purnhagen Lab Sponsor: AFIT AD 760530

A graphics-application program was developed to interface an existing digital-logic-simulator program with the Control Data 6000 series, 274 Interactive Graphics System. The logic simulator, developed by J. R. Niederhauser, simulates synchronous and asynchronous digital-logic networks. The graphics-application program interfaces the logic simulator with the graphics system, thereby enabling one to play an interactive

role in digital-logic simulation. The program allows the user, while operating at the graphics console, to "draw" his network on the CRT face of the console screen, input the network parameters and data through lightpen picks or keyboard entries, and observe the results of the simulation of the network as they are displayed on the CRT. After observing the results of a simulation, the user is allowed to easily make changes to his network, network parameters, or data for another simulation. Several suggestions related to possible useful extensions of the interfacing program are presented.

102. INVESTIGATION OF FEATURE SELECTION CRITERIA FOR PATTERN RECOGNITION MODELS INCLUDING THE FOURIER TRANSFORM

Edwin A. Olson, Capt, USAF	70p	GE/EE/73-16
Advisor: Prof M. Kabrisky	Lab Sponsor: AMRL	AD 760762

Feature selection is of fundamental importance in pattern recognition. The investigation evaluates and compares 10 feature selection criteria. The two-dimensional, discrete Fourier transform is specified so that the low-pass spatial filter criterion can be included in the comparison. Feature space extraction and feature space evaluation processes are modeled and implemented. Two sets of data consisting of handprinted characters are used in a series of experiments that extract feature spaces corresponding to the various criteria and evaluate the feature spaces by a class separability measure and an error estimate. The results are tabulated for comparison and conclusions are drawn on the empirical and theoretic bases established. It was concluded that a viable feature extraction process was established, that the truncated Fourier transform was effective (0.06 error estimate reduction a 12:1 dimension-reduction in the Fourier domain), and that as the number of pattern classes increase the feature spaces corresponding to the various statistical criteria become increasingly low-pass (in spatial frequencies).

103. AUTOMATIC MICROWAVE NETWORK ANALYSIS

Kerry R. Sandstrom, Capt, USAF	77p	GE/EE/73-18
Advisor: Prof R. A. Potter	Lab Sponsor: AFAL	AD 760759

A program and procedure are developed for the automatic measurement of microwave networks using a Hewlett-Packard network analyzer and programmable calculator. The program and procedure are used in the measurement of a simple microwave two port network. These measurements are evaluated by comparing with measurements on the same network using other techniques. The program used in the programmable calculator are listed in Appendix I. The step by step procedure used is listed in Appendix II.

104. MULTITONE MASKING OF SELECTED SPEECH MATERIAL

Donald D. Shillcutt, Capt, USAF	87p	GE/EE/73-19
Advisor: Prof M. Kabrisky	Lab Sponsor: AFML	AD 760531

A continuous electronic noise whose amplitude statistics and frequency spectrum approximate the amplitude statistics and frequency spectrum of continuous speech was generated by combining four frequency modulated sine waves and filtering the combination signal. The masking effect of

the multitone noise was compared to the masking effect of a white noise source for the vowel rhyme test material. Within the range of S/N ratios studied, the multitone noise creates probabilities of error comparable to the white noise source with approximately 2.5 dB higher S/N ratios. The results clearly indicate that the multitone noise is more effective in masking the vowel sounds than white noise.

105. PREDICTING HEADING TASK FLYING QUALITIES WITH PAPER PILOT

Calvin R. Taylor, Capt, USAF | 118p | GE/MA/73-1
Advisor: Maj J. Dillow | Lab Sponsor: AFFDL | AD 764695

A mathematical model for predicting the pilot rating of a fighter aircraft in a precision heading task is described. The model includes: (1) the lateral-directional aircraft equations of motion; (2) a stochastic gust model; (3) a pilot model with four free pilot parameters; and (4) a pilot rating expression that is a function of rms heading angle, rms yaw rate, and rms roll rate. The pilot gains and lead time constants are selected to minimize the pilot rating expression. The resulting minimum is used to compute a heading paper pilot rating. The heading paper pilot rating was computed for 32 flight conditions at different gust intensities for the F-5 and A-7 aircraft. Heading paper pilot ratings agree well with the actual ratings for the F-5, but are low for the A-7. In addition, there is good correlation between computed and actual rms heading angle, rms yaw rate, and rms slideslip.

106. DESIGN EXPANSION OF THE D17B COMPUTER INPUT/OUTPUT FACILITY FOR GENERAL-PURPOSE APPLICATIONS

Joseph R.T. Theriault, 1/Lt, USAF | 280p | GE/EE/73-20
Advisor: Dr. G. B. Lamont | Lab Sponsor: AFIT | AD 760761

In an effort to determine the extent to which the capabilities of the D17B computer can be applied to general-purpose information processing tasks, this report presents the results of a study which was made on the input/output structure of the processor. Based on the findings of this study, a technique is presented which enables the processor to transfer data to and from peripheral equipment on a program-controlled basis and at a rate which approaches the execution rate the the processor. The technique employs a bus-structured I/O system which also controls program loading and verification operations to achieve the 800 char/sec maximum loading rate of the computer. Another technique is presented which applies certain specialized functions of the D17B to directly link high-speed peripheral equipment with the memory for output transfers. By using this partial direct-memory access method, a transfer rate of 12.8K words/sec can be achieved. A third and final design expansion is presented which enables the peripheral equipment to interrupt CPU program execution. This program interrupt capability is based on the operational characteristics of the Master Reset and Halt functions of the computer. Following the development of the proposed schemes, the design of an I/O system is presented which encompasses the three general functions of I/O control, direct-memory access and program interrupt. The design is fully defined in register transfer language and other logic expressions which are finally used to realize and implement the design.

107. A STUDY OF BINARY LEARNING MACHINES

Robert H. Toews, Capt, USAF | 99p | GE/EE/73-21
Advisor: Prof M. Kabrisky | Lab Sponsor: AFAL

This thesis is a statistical study of binary learning machines in search of a general theory. Starting with a theoretically perfect model, various sources of operational error are identified in the reduction to a practicable machine. The associated error probabilities are expressed in terms of exact probabilities (as opposed to estimates) which are derivable from a set of Bernoulli trials called the "training data." These probabilities are derived by integration over the maximum likelihood regions of the two-dimensional joint probability density function developed by application of Bayes' postulate to the binomial distribution. A conceivable, albeit impractical, method is developed for designing an optimum learning machine given any set of training data. A more practical method of designing and building such a machine is suggested, but not fully developed. The author feels that the statistical results of this study suggest that classical information theory may be extended to a vector concept, with qualitative as well as quantitative properties. This would allow one to "tag and trace" specific information throughout a complex non-linear information processing system with relative ease.

108. APPLICATION OF STATE-VARIABLE AND CONDITIONAL FEEDBACK METHODS TOWARD REDUCING THE POINTING ERROR OF A TWO-AXIS BEAM DEFLECTOR

Warren B. Watkinson, Capt, USAF | 114p | GE/EE/73-22
Advisor: Prof C. H. Houpis | Lab Sponsor: AFWL | AD 760532

The base motion disturbance error and dynamic tracking error of a two-gimbal planar-mirror optical tracking system are reduced by application of modified conditional feedback compensation and by conventional state-variable feedback. A general procedure is developed for application of state-variable feedback to other tracking systems having base motion disturbance, such as gimbaled airborne-radar control systems. The procedure provides a direct mathematical relationship between the base motion disturbance transfer function, the control ratio, and the system type. A Type 4 system is achieved by application of the method to the optical tracking system. A simple graphical approximation procedure is developed for evaluating rms error from mean-square integrals involving high order power spectral densities.

109. RF SPUTTER ETCHING OF Al, SiO_2 AND PHOTORESIST

Kenneth D. Wilkinson, Maj, USAF | 129p | GE/EE/73-23
Advisor: Prof J. Lubelfeld | Lab Sponsor: AFAL | AD 757878

The procedures followed to determine the feasibility of using an rf-generated argon plasma to sputter etch windows through 8000 Å of SiO_2 are described in this thesis. The sputtered windows will be used to fabricate Schottky diodes and interconnections for multilayer devices. The rf sputter etch rate for Al, SiO_2 and Waycoat photoresist was investigated at various self-bias voltages and longitudinal magnetic fields. All experiments were carried out at 27.12 MHz and 10 mTorr argon pressure. When the photoresist was sputtered simultaneously with SiO_2 the photoresist etch rate increased. The increase was due

to the reactive influence of the sputtered oxygen; therefore, the etch rate for photoresist is tabulated both with and without SiO_2 present. All the sputter etch rates vary linearly with the magnetic field when the self-bias voltage is held constant. A self-bias voltage of 1050 volts and a longitudinal magnetic field of 28 gauss (4 amp) is the best overall power setting, providing etch rates of 290, 444, 565 Å/min, respectively, for Al, SiO_2 and photoresist. The "windows" were successfully sputter etched in the SiO_2 using masks of both photoresist and chemically etched SiO_2. The edge definition of the sputtered "windows" is very good with no undercutting. Also, the bottom of the etched hole is contamination free. The clean surface will permit an immediate deposition of Al through the SiO_2 "window" to fabricate a perfect Schottky diode or interlayer metallic connection.

110. DIRECTIONAL COUPLER DESIGN USING COPLANAR WAVEGUIDE

Earl W. Williams, Capt, USAF — 50p — GE/EE/73-24
Advisor: Prof R. A. Potter — Lab Sponsor: AFAL — AD 760533

Coplanar Waveguide (CPW) is a surface transmission line having properties that make it attractive for microwave integrated circuit applications. The CPW was investigated primarily to develop a design procedure for a directional coupler; however, it was necessary to first determine the effects of a finite substrate thickness on the effective dielectric constant. A Schwarz-Christoffel transformation was used to map the CPW boundaries into a rectangular region to simplify the analysis. Calculations of the effective dielectric constant indicated that significant changes in the CPW parameters occured as the substrate thickness decreased and the slot width increased. Three CPW configurations were fabricated and tested to verify the theoretical work. The results indicated that the effects were negligible for a substrate thickness three times the width of the slot, but may be significant for smaller values. The dispersion measurements showed that, for frequencies below about 8 GHz, the electrical length of the line was larger than expected. A similar conformal-mapping approach was used to determine the even and odd-mode impedances for a simple CPW coupler, as functions of the CPW geometric and material properties. These parameters were used in conjunction with the normal-mode procedure to formulate a directional coupler design procedure.

111. ERROR REDUCTION IN A TWO-GIMBAL, AIRBORNE, ANGLE TRACK SYSTEM

George L. Wright, 1/Lt, USAF — 66p — GE/EE/73-25
Advisor: Prof C. H. Houpis — Lab Sponsor: AFAL — AD 760551

Angle measurement in a two-gimbal, airborne, tracking system is complicated by the motion of the aircraft. The two-gimbal system is characterized by the azimuth and elevation channel control systems. Rolling motions introduce error-causing disturbance inputs into each channel. One method of reducing the error investigated in this report is a linear transformation method which treats both channels simultaneously by considering a cross-coupled multivariable system. Another method, the

invariance method, utilizes a feed forward branch whose input is the unwanted disturbance to reduce the error due to aircraft roll rate for each channel separately. Computational and physical realization difficulties inherent in the linear transformation method render it inapplicable from a practical viewpoint. On the other hand, the invariance method is much more tractable and results in a design which could possibly be incorporated into present operational angle track systems.

112. SUB-OPTIMAL CONTROL OF A GAS TURBINE ENGINE

Robert J. Bowles, Capt, USAF — 113p — GE/EE/73A-1
Advisor: Sqn Ldr McLean — Lab Sponsor: AFAPL

Gas turbine engine technology has been advanced to the point where it is increasingly difficult to apply conventional feedback control theory to the design of its necessary multiple-input and multiple-output control systems. Modern linear control theory was applied to the engine control problem in four stages. Stage 1 involved formulating a simple, reliable, and representative mathematical model of the engine and describing the model in state variable form. Stage 2 involved using a truncated Taylor series to linearize the engine state equations about a succession of engine equilibrium points and solving the linear optimal output regulator problem and the linear optimal tracking problem to minimize a quadratic Performance Index. In stage 3, the engine model was simulated on a digital computer via the MIMIC Simulation Language. The engine control laws were then realized in a FORTRAN function subprogram. The MIMIC engine model was interfaced to the FORTRAN controller. Stage 4 consisted of testing the controlled engine for various throttle demands to verify the satisfactory operation of the controller.

113. A MICROPROGRAMMED STACK MACHINE EMULATOR

Kenneth G. Castor, Capt, USAF — 208p — GE/EE/73A-3
Advisor: Dr. G. B. Lamont — Lab Sponsor: AFAL

The effort which is documented by this thesis has produced a microprogrammed stack machine emulator adapted to the Burroughs Aerospace Multiprocessor. The emulator is written in a symbolic microlanguage, called TRANSLANG, which was developed by Burroughs Corporation. A listing of the microlanguage is not included with the report. The purpose of the emulation is the implementation of an ALGOL capability on the Aerospace Multiprocessor. The emulation is of a pseudo machine similar to the Burroughs B6500 system. The report discusses the structure of the emulated machine pertinent to the emulation. In addition, the structure of the emulator is presented with detailed descriptions of individual routines and their interaction within the emulator.

114. MEASUREMENT OF THE ANISOTROPIC MODULATION TRANSFER FUNCTION OF THE EXTRAFOVEAL HUMAN VISUAL SYSTEM

Ronald I. Cowger, Capt, USAF — 412p — GE/EE/73A-4
Advisor: Prof M. Kabrisky — Lab Sponsor: AMRL

The anisotropy of the extrafoveal modulation transfer function of the human visual system was measured at angles up to 45 degrees of eccentricity. The stimuli consisted of sine wave gratings of four different spatial frequencies which were presented at four different orientations. Six subjects observed the stimuli at five degree intervals along two orthogonal meridians on the peripheral retina. The results are presented as a series of plots depicting contrast sensitivity as a function of stimulus orientation and contrast sensitivity as a function of stimulus position in the visual field. The contrast sensitivity of all subjects was found to decrease more rapidly with increased stimulus eccentricity in the superior direction than in the nasal direction. Also, all subjects exhibited anisotropic MTFs for extrafoveal vision even at spatial frequencies where their foveal MTFs were isotropic. The two predominant anisotropic effects that were observed are designated "oblique effect" and "depressed orthogonal" MTFs. Each type is described in detail and its occurrence analyzed.

115. A COMPUTER FOR AVERAGING TRANSIENTS TO DETERMINE EEG EVOKED POTENTIALS

Frederick Cruger, Capt, USAF — 84p — GE/EE/73A-5
Advisor: Maj Lessard — Lab Sponsor: AMRL

A "Computer for Averaging Transients" (CAT) has been designed, constructed, and tested; the CAT is capable of averaging overall electroencephalogram (EEG) patterns following repeated stimuli, thereby separating the EEG response waveform from the many unrelated signals of much larger magnitude encountered in making EEG recordings. Using an analog multiplexer, the CAT can process up to eight simultaneous analog inputs. Eight fixed-gain EEG amplifiers are included in the circuitry, along with eight analog filters which are used to eliminate extraneous noise at frequencies above 30 Hz. All inputs are converted to digital words, and all internal manipulation of data is executed using standard digital techniques. The CAT provides eight analog outputs for real-time qualitative analysis and a digital output which may be recorded for post-experimental computerized analysis. The CAT has been tested using a small flashing light as the stimulus. The results from five different persons indicate that the CAT performs the necessary averaging task well, and that the device can be successfully employed in future physiological experiments.

116. AN EXPERIMENTAL APPARATUS AND PROCEDURE FOR OBTAINING DYNAMIC SPATIO-TEMPORAL TEMPERATURE MEASUREMENTS IN LASER IRRADIATED MONKEY EYES

Curtis G. Crum, Capt, USAF — 112p — GE/EE/73A-6
Advisor: Maj Lessard — Lab Sponsor: AFSC

The intense light produced by lasers and atomic weapons has spurred current research efforts to determine the minimum light exposure capable of causing injury to the eye. Theoretical thermal models

of the eye have been developed which might predict light exposures causing retinal injury. However, actual temperature measurements in the retina which would validate the existing models have been unavailable due to the considerable technical difficulties involved with taking these measurements. Recent developments in the design and fabrication of a microthermalcouple have led to a totally automated apparatus which is capable of obtaining dynamic spatio-temporal temperature measurements in laser irradiated monkey eyes. Employing the surgical and experimental procedures established for this apparatus, 5000 accurate temperature measurements can be recorded from the retina and choroid of a Rhesus monkey with respect to time and three dimensional space in less than four hours.

117. AN ASSEMBLY LANGUAGE TRANSLATOR, SEL 810B TO HP-2100A

James J. Davis III, Capt, USAF 151p GE/EE/73A-7
Advisor: Dr. G. B. Lamont Lab Sponsor: AFLC

This report describes a method to translate the Systems Engineering Laboratories (SEL) 810B minicomputer's assembly language to that of the Hewlett-Packard HP-2100A. The purpose of this report is to save time and money by rapidly converting proven programs for a SEL 810B minicomputer into programs for an HP-2100A. The method of translation is a minicomputer program, written in the HP-2100A's assembly language, that inputs, translates, and outputs code on a line-by-line basis. Only the more useful and more frequently encountered parts of the SEL language are translated. Several hardware options of the SEL 810B also result in assembly language features that have no equivalent in the HP-2100A's assembly language. The software to activate these features is translatable, but no HP-2100A hardware action results. For simple programs, the translator is a viable alternative to manual translation. For more complex programs, human intervention is required to check and possibly alter the translator produced code. The translated program will run more slowly due to the SEL 810B's shorter cycle time and because of the use of HP subroutines to simulate some SEL instructions. In summary, a semi-automatic method of translating SEL 810B programs for the HP-2100A exists.

118. DETERMINING THE APPLICABILITY OF THE WALSH TRANSFORM IN THE REAL-TIME PATTERN RECOGNITION OF SPOKEN ENGLISH

David P. Durant, Capt, USAF 125p GE/EE/73A-8
Advisor: Prof M. Kabrisky Lab Sponsor: AMRL

The application of Walsh transforms in a real-time word recognition system is demonstrated in this study. Feature patterns for spoken words are obtained on a PDP-12 computer through a KY-585/U vocoder. The feature patterns are then Walsh transformed and filtered. The filtered set of coefficients is used to identify the spoken word and print out the word on the decwriter. Recognition rates of up to 95% for a 10-word vocabulary and 65% for a 40-word vocabulary were achieved by a trained speaker.

119. MACHINE RECOGNITION OF HAND-SENT MORSE CODE USING THE PDP-12 COMPUTER

Joel A. Guenther, Capt, USAF — 153p — GE/EE/73A-9
Advisor: Lt Col T. Purnhagen — Lab Sponsor: AMRL

The purpose of this investigation is to determine an optimum decision algorithm for use in machine recognition of hand-sent Morse code. An extensive analysis of hand-sent Morse code data is presented together with a discussion on the relative merits of several recognition algorithms. A recognition program is developed for use on the PDP-12 digital computer to test these algorithms. Test results are presented for a time duration averaging algorithm which achieves less than a one percent recognition error rate for noise-free Morse code signals.

120. ENERGY SPECTRA FOR FREQUENCY-SHIFT-KEYED SIGNALS TRANSMITTED BY SYNCHRONOUSLY RESONATED, VERY LOW FREQUENCY ANTENNAS

Tee R. Hadley III, Capt, USAF — 90p — GE/EE/73A-10
Advisor: Maj R. Reinman — Lab Sponsor: RADC

Electronic broadbanding is a technique whereby very low frequency (VLF) antennas can be resonated (retuned) synchronously with a frequency-shift-keyed (FSK) signal for transmission of binary data at rates well over 1000 baud. The purpose of this thesis is to investigate the transmitted energy density spectrum for an electronically broadbanded VLF antenna system in which a frequency shift can occur only at the instant of an antenna-current zero-crossing with positive slope. A computer solution shows that the transmitted spectrum is approximately equivalent to the spectrum of an ideal, constant amplitude, FSK signal. A further investigation, again by computer program, shows that if the total frequency shift between the marking and spacing frequencies occurs over a finite period, rather than instantaneously, then the spectrum's sidelobes will be reduced significantly. The spectrum for a 27,000 Hz center-frequency VLF antenna transmitting at 1600 baud by means of electronic broadbanding can be reduced from 3 to 18 dB in the first five sidelobes. No evaluation is made on the detectability of the signal with the non-instantaneous frequency shift. Numerous plots of the computer-generated spectra are included.

121. EXTENSION OF KELLA'S ALGORITHM TO SUBSET-SPECIFIED SEQUENTIAL MACHINES

Gary L. Hill, Capt, USAF — 109p — GE/EE/73A-12
Advisor: Lt Col T. Purnhagen — Lab Sponsor: AFCRL

Purnhagen has developed a new and generalized theory of state-reduction of sequential machines. This theory allows for conditional entries in present state/input cells of the flow table that represents the machine. Such a machine is said to be a subset-specified sequential machine. Purnhagen's state-reduction procedure is based on the closure and covering table method for incompletely-specified machines developed by Grasselli and Luccio. Kella's algorithm uses a new concept for state-reduction of incompletely-specified machines. Since completely-specified and incompletely-specified machines are just special cases of

subset-specified sequential machines, it has been theorized that Kella's algorithm could be modified to take into account the unique features of subset-specified machines. Using the basic ideas behind Kella's algorithm and Purnhagen's theory, the necessary theory and techniques were developed to apply a state-reduction procedure similar to Kella's to subset-specified sequential machines. Once Kella's algorithm was extended to handle subset-specified machines, flow diagrams were developed so that a computer program to implement this algorithm may be readily programmed. A discussion of computer programming techniques accompanies each flow diagram. Many problems were solved by hand using this algorithm, and even the largest problem could be solved by hand (even though CC-table solution was prohibitive).

122. ELECTRODEVELOPMENT OF HIGH-RESOLUTION INTEGRATED CIRCUIT MASKS

Gary L. Hoe, Capt, USAF — 72p — GE/EE/73A-13
Advisor: Prof J. Lubelfeld — Lab Sponsor: AFAL

This report details an investigation of the electrodevelopment process as applied to mask-making. The process places masks and developer in a low power electrolytic cell to remove and neutralize developer byproducts. This method and an older ultrasonic developer agitation method are compared as to developer concentrations and lifetimes, processing times, exposure values and tolerances to exposure ranges, ability to reproduce sub-micron images, image bloom and pinholing, defect densities, and image density. Electrodevelopment is further characterized for electrode compatibility and cell power requirements. Electrodevelopment is found to improve image size stability by reducing bloom of 10-micron images from 12% to 1%. Electrodeveloped images also exhibit density variances of less than 0.08D across the mask. Electrophoretic action of the developer byproducts in the cell eliminates most of the random diffusion of developer molecules that plagues mechanical agitation methods. Electrochemical actions of the cell are shown to increase developer activity by reducing developer byproducts at the cathode. The increased developer activity necessitates a dilution of the developer to control development times, yet image density remains high. Prototype and final electrodevelopment tanks were designed and integrated with the existing mask-making facility. The final design was successfully demonstrated during the fabrication of a number of integrated circuits.

123. VARIABLE ARCHITECTURE MULTIPROCESSOR (VAMP) - PROCESSOR

Gary R. Hurst, 2/Lt, USAF — 147p — GE/EE/73A-14
Advisor: Dr. G. B. Lamont — Lab Sponsor: AFAL

VAMP was designed to provide a capability to operate as an 8, 16, 24, or 32 bit machine, to emulate other computer systems with these word lengths, and to accommodate on a continuing basis a wide range of state-of-the-art computer components with minimum design changes to the basic system. The design of VAMP was broken into three areas of interest: an interlock switch (input/output), the microprogrammable control unit, and a processor. The interlock switch and microprogrammable control unit are the subject of other reports (Refs. 11 and 14). This report presents the

results of the processor designed for VAMP. After a brief overall look at VAMP, a plug board panel is examined. This panel provides the machine with the capability to operate in an 8, 16, 24, or 32 bit configuration and it also controls other variables of the machine. Next, a brief look is taken at the overall front panel design and, then, the processor section of the front panel is examined in detail. A final design is presented for the registers, arithmetic logic unit, bus structure, and high speed memory that constitute the body of the processor. Finally, a brief examination of card layout and power requirements for VAMP is made.

124. A SCANNING AUGER MICROSCOPE FOR THIN FILM ANALYSIS

James M. Kroyer, Capt, USAF — 71p — GE/EE/73A-16
Advisor: Prof J. Lubelfeld — Lab Sponsor: AFAL

A scanning Auger microscope was assembled by a previous AFIT student at the AFAL for spectroscopic analysis of thin films. Previous attempts to operate the system for Auger analysis were incomplete. Modifications were made to the system so Auger analysis could be made on a fixed point. Sputtering facilities were designed and added to the system to provide cleaning and indepth profile capabilities. Problems encountered in obtaining a surface scanned Auger peak presentation were identified and correlated with the overall present sensitivity of the system.

125. AN EEG SLEEP-SCORING ANALYZER BASED UPON ZERO-CROSSING PERIOD CODING TECHNIQUES

Barry L. Mitchell, Capt, USAF — 110p — GE/EE/73A-17
Advisor: Maj Lessard — Lab Sponsor: AMRL — AD 770575

An automatic electroencephalogram (EEG) analyzer was constructed, computer programs were written to process the data produced by the analyzer, and tests were conducted to verify that the analyzer performed as designed. Design concepts for this analyzer have been previously published by C. S. Lessard. Zero-crossing pulses are produced by a Biodata period coder for zero-crossings of one channel of analog EEG data and its first and second derivatives. The zero-crossing pulses for the fundamental analog signal are filtered by a time-domain filter into four frequency ranges: delta, 0.5-3.5 Hz; theta, 3.5-7.5 Hz; alpha, 7.5-12.5 Hz; and, sigma, 12.5-14.0 Hz. The zero-crossing pulses for the fundamental EEG signal, its first and second derivatives, and the zero-crossing pulses from the outputs of the four filters are counted by binary counters for a specific recurring time interval which may be adjusted between one and sixty seconds. At the end of each counting period, the number of zero-crossings in each counter is temporarily stored in memory latches and subsequently recorded on an incremental step recorder in IBM-compatible format. The major advantage of this automatic EEG analyzer over other data reduction schemes is that it performs almost a one thousand to one compression of the data, storing only 96 bits of data per minute at the slowest output rate. This will permit EEG researchers to review continuous EEG records which were previously scored manually.

126. VARIABLE ARCHITECTURE MULTIPROCESSOR (VAMP) - INTERLOCK SWITCH

Russell F. Moody, Capt, USAF 326p GE/EE/73A-18
Advisor: Dr. G. B. Lamont Lab Sponsor: AFAL

An interlock switch for a variable architecture multiprocessor (VAMP) was designed. VAMP is an educational and research tool which will be used to study and evaluate various computer architectures. The interlock switch provides an interface for the basic building blocks of the system which are the processors, memory modules, and devices. The interlock switch also performs functions involved with resource allocation and provides interrupt and direct memory access transfer capability. Through a plugboard control, the interlock switch architecture can be varied. This allows operation of the system as a uniprocessor, multiprocessor, array processor, or multicomputer. The interlock switch also contains a hardware monitor. Test points in the interlock switch are monitored to provide measurement of parameters which are vital for meaningful system evaluation.

127. PATTERN RECOGNITION OF LOGIC DIAGRAMS

Douglas A. Naegele, 2/Lt, USAF 144p GE/EE/73A-19
Advisor: Prof M. Kabrisky Lab Sponsor: AMRL

This paper presents the development of line following and line analysis pattern recognition routines to automatically computer read hand-drawn logic diagrams. The decision criterion used was based on a tree analysis of segmented lines. The logic diagrams were drawn with a flair pen and the computer program analyzed gates and Flip-Flops within squares ranging from 1/2" to 3" in size. All four orientations of the six major logical functions were investigated along with 16 different versions of a J-K Flip-Flop. The output of the program is a series of statements which describe the relationships Gates and Flip-Flops have with each other within a logic diagram. These statements are presented in a form suitable as input statements for a developed Digital Logic Simulation program used at AFIT. If a program as undertaken here could be developed to a 100% effectiveness then the design time for computer networks would be immensely reduced. This program made no mistakes in recognition of the major groups of logic functions considered; that is, Or, And, Inverters, and J-K Flip-Flops; or in the connecting line analysis.

128. AMRL 16-DEVICE X 12-BIT MULTIPLEX CONTROLLER 75 - 300 BAUD

Ronald E. Nystrom, Capt, USAF 88p GE/EE/73A-20
Advisor: Prof M. Kabrisky Lab Sponsor: AMRL

In controlling psychophysical (or other) experiments, it is desirable to control stimuli using a computer. This relieves the experimenter from routine computations and manipulations while speeding the testing for the subject. This report is a technical order for a multiplex controller designed to perform that function; electrically the controller looks like a standard TTY, making the computer interface task straightforward. The controller responds selectively to ASCII 11-unit code and can recognize instructions for any one of 16 buffers while ignoring traffic not addressed to it. Each buffer may contain 4, 8, or 12 bits.

129. DESIGN EXPANSION OF THE D17B COMPUTER FACILITY

Duane B. Reynolds, Capt, USAF | 149p | GE/EE/73A-21
Advisor: Dr. G. B. Lamont | Lab Sponsor: AFLC

Several years ago, the Electrical Engineering Department of the AFIT School of Engineering initiated a research program to investigate and demonstrate the feasibility of converting the Minuteman I ICBM D17B guidance computer into a general purpose minicomputer. This report, as part of a continuing effort to determine the extent to which the capabilities of the computer can be applied to a general-purpose information processing tasks, presents the results of a study of the memory writing circuitry of the machine. The study was conducted to investigate the possibility of installing a two-way Direct Memory Access (DMA) capability in the AFIT D17B. The study forms the basis for a design proposal for such a DMA facility for the AFIT D17B complex. This proposal is fully defined in register transfer language and other logic expressions before being presented in a hardware realization.

130. VARIABLE ARCHITECTURE MULTIPROCESSOR (VAMP) - MICROPROGRAMMABLE PROCESSOR CONTROL

Curtis A. Riggs, 2/Lt, USAF | 216p | GE/EE/73A-22
Advisor: Dr. G. B. Lamont | Lab Sponsor: AFAL

A Variable Architecture Multiprocessor (VAMP) has been designed as a research and educational tool. This digital information transfer system was designed to investigate various computer architectures and to provide a machine with variable word length to emulate other digital systems. The structure and operation of the system are presented as a basis for the development of a microprogrammable processor control unit (MCU). The detailed design and operation of the MCU are presented along with the recommended hardware realization.

131. COMPUTER AIDED LOGIC HAZARD DETECTION

Daniel R. Riley, Capt, USAF | 78p | GE/EE/73A-23
Advisor: Lt Col T. Purnhagen | Lab Sponsor: AFAL

Hazards can be a serious problem in asynchronous logic circuits, particularly asynchronous sequential circuits. They are inherent in a minimal two level sum of products design which is often the most economical. In a large network a long and tedious analysis must be performed to detect hazards. The algorithm developed here is based on an analysis of the Boolean function representing the logic network. The algorithm can detect all types of hazards which can be detected from a delay-free analysis of the function including network instability in feedback circuits. The algorithm is superior to some types of analysis because it does not require the system equations to be put in a standard form and it allows the analysis to be performed by observing only the behavior of the function output. No internal terms of the function need be analyzed. A computer program realization of the algorithm is presented and discussed in order to clarify the ideas presented.

132. CAPACITANCE VOLTAGE MEASUREMENTS FOR DETERMINING BASE WIDTHS IN HIGH SPEED SWITCHING TRANSISTORS

James R. Roy, Maj, USAF — 128p — GE/EE/73A-24
Advisor: Maj P. Sproul — Lab Sponsor: AFAL

The purpose of this report is to investigate the possibility of using capacitance-voltage (C-V) analysis for measuring base widths in high speed switching (microwave) transistors. To accomplish this a model is developed for the junctions of a bipolar microwave transistor. The planar process of manufacturing double diffused microwave transistors is analyzed, the junctions are approximated by "step functions", and the C-V relationship developed. Then a computer program is developed that will draw a doping density profile from the C-V data. The limitations of the "step function" approximation are then discussed, and an attempt is made to quantize and minimize the errors. Several large test transistors and small microwave transistors are tested using differential high-frequency C-V analysis. The base widths are obtained from C-V analysis and from direct measurements on scanning electron microscope (SEM) micrographs. The base widths on the large transistors are also measured using bevel and stain techniques. The base widths obtained from C-V analysis and the SEM, for the microwave transistors, are shown to be very close. However, no definite correlation can be made between C-V analysis and base width. This is because the beveled surfaces that expose the base regions are badly scarred from beveling, making the junctions appear ragged. Also, there is an unknown capacitance that affects the C-V data; the E-B sidewall capacitance.

133. ELECTROMAGNETIC WAVE PROPAGATION IN PERIODIC MEDIA

Ronald L. Sipes, Capt, USAF — 62p — GE/EE/73A-25
Advisor: Prof R. A. Potter — Lab Sponsor: AFAL

This study investigates electromagnetic wave propagation in a rectangular waveguide filled with a medium having permittivity and permeability which are spatially periodic in the direction of wave propagation. It is shown that the field distributions are given in part by the solution to a Hill differential equation. The general solution of this equation is outlined. For the special case where the permeability is constant throughout the structure and the permittivity is square-wave stratified, a characteristic equation is derived from the Hill equation which enables wave propagation characteristics to be predicted. This characteristic equation is analyzed, using digital computer techniques, to obtain propagation characteristics for several experimental structures. In addition, the effects of varying the system parameters are studied. Finally, results of experimental verification of the theoretical predictions are presented.

134. INVESTIGATION OF AN ALGORITHM FOR THE DETECTION OF MAN-MADE OBJECTS IN AERIAL PHOTOGRAPHS

Edward C. Stanke II, Capt, USAF — 109p — GE/EE/73A-26
Advisor: Prof M. Kabrisky — Lab Sponsor: AMRL

An algorithm for the detection of man-made objects in aerial photographs is investigated. The algorithm consists of spatial frequency filtering,

cross correlation with one of three prototypes and boundary tracing of objects detected. The results based on a test set of five optical aerial photographs indicated the potential of a low pass and one particular band pass filter. For a given class of photographs, these filters exhibited a 100% detection rate with a false alarm rate of 18-25%.

135. A METHOD FOR PREDICTING HUMAN PERFORMANCE OF CERTAIN SYMBOL RECOGNITION TASKS

John K. Thomas, Maj, USAF — 57p — GE/EE/73A-27
Advisor: Prof M. Kabrisky — Lab Sponsor: AMRL

The purpose of this study was to model the human performance of a symbol recognition task. An algorithm is developed enabling one to closely model the results obtained from human subjects in a symbol recognition test. This model was then used to predict the human performance of another recognition test conducted by a different group of psychologists using three completely different symbol sets. The model enabled the author to predict the results obtained from human testing with very high accuracy as measured by the Pearson product-moment correlation and Chi-square test. The Chi-square percentile was .0001 for all symbol sets. The author concludes that these results may possibly reduce the necessity for further human testing of the symbol recognition task modeled by this algorithm.

136. REDUCED ORDER MODELING FOR SUB-OPTIMAL FILTERING

John G. Tittle, Jr., Capt, USAF — 71p — GE/MA/73A-1
Advisor: Maj J. Dillow — Lab Sponsor: AFAL

A procedure is developed to give a reduced order model and a set of filter gains to give an estimate of a subset of system states. A computer program is shown to perform an optimization of the reduced order model with respect to the full system. A case study is done for an F-5 lateral motion model. Four reduced order models are compared using a numerical comparison.

137. ORIENTATIONAL CHANNEL DEPENDENCE FOR VISUAL DETECTION OF SINE WAVE GRATINGS

Bruce L. Toy, Capt, USAF — 54p — GE/EE/73A-29
Advisor: Prof M. Kabrisky — Lab Sponsor: AMRL

The detection threshold for a sine wave pattern in the presence of a background pattern of another sine wave can be expressed as a function of two variables, background frequency and relative orientation, when the frequency of the target pattern is not changed. There are many indications that the human visual system consists of independent frequency detecting channels. It has been postulated, that, based on this model, a channel response function may be complex. That is to say, a channel may respond to other frequencies than its basic frequency, if they are oriented at other relative angles to the channel. This theory was investigated using a Maxwellian view apparatus. Results are presented for two orientation angles, 90° and 15°, and a wide range of background frequencies.

138. QUASI-STATIC CAPACITANCE-VOLTAGE CHARACTERISTICS OF MNOS DEVICES

George W. Trever, Capt, USAF — 91p — GE/EE/73A-30
Advisor: Prof J. Lubelfeld — Lab Sponsor: AFAL

The quasi-static (low-frequency) capacitance-voltage (CV) characteristics of MNOS memory devices are shown to exhibit distinguishable properties associated with "memory" and "nonmemory" behavior. Quasi-statiq CV analysis procedures, as developed by Kuhn, are applied to the MNOS "nonmemory" characteristics and reveal that the silicon-oxide interface-state densities are 100 times larger than for comparable "nonmemory" capacitor structures. Substrate surface-potential functions are constructed to model ideal "nonmemory" CV behavior and are used to compare with "memory" CV characteristics. Calculations are performed to show that the switching behavior observed experimentally is consistent with the quasi-static CV "memory" characteristics and with the mathematical models. Also, non-equilibrium quasi-static effects observed for MNOS "memory" transistor structures and deviations in normal quasi-static CV behavior of MNOS "nonmemory" capacitor structures are reported.

139. A CATHODE RAY TUBE DISPLAY SYSTEM FOR A MINUTEMAN I COMPUTER

Thomas N. Trimble, Capt, USAF — 122p — GE/EE/73A-31
Advisor: Dr. G. B. Lamont — Lab Sponsor: AFLC

Since the Electrical Engineering Department of AFIT acquired two of the Air Force's surplus D17B Minuteman I computers June of 1971, considerable effort has been expended toward converting these into a general purpose laboratory computer system. This report describes the considerations which must be evaluated in designing a computer display system. Many of the different types of commercial display systems and how they operate are discussed. The design of an alphanumeric cathode ray tube display system and the reasoning followed during the design effort is presented in this thesis. The logic schematics and the components required for constructing and interfacing this alphanumeric display system with the D17B computer system are included as a part of this project.

140. AN ANALYSIS OF THE DESIGN AND FABRICATION OF DOUBLE JUNCTION CHARGE-COUPLED DEVICES

Robert O. Venes, Maj, USAF — 81p — GE/EE/73A-32
Advisor: Dr. R. E. Fontana — Lab Sponsor: AFAL

Two designs of processed silicon wafers were tested and analyzed to investigate the feasibility of a new concept in charge-coupled device structures. The new concept eliminates the oxide layer from the standard MOS structure by incorporating poly silicon resistive gates and a buried channel mode of operation in the device. Testing of the device wafers revealed a catastrophic processing phenomenon which prevented successful demonstration of the DJCCD operation. Analysis indicated that this failure to operate was a result of enhanced channeling of the implanted gate dopant impurities through the buried channel into the substrate. This channeling is attributed to a random crystallite growth, characteristic of thin film deposited poly silicon which was used as the gate material.

141. THE CONTROL OF A SIMPLE INERTIA

John T. Williams, Capt, USAF 130p GE/EE/73A-33
Advisor: Sqn Ldr McLean Lab Sponsor: AFIT

Three types of controllers were developed in this thesis for use with a position-control system which was characterized by a second- order differential equation. One type of controller was linear and continuous. Both examples of this type of controller were each optimal in the sense that they were designed to minimize a specific performance index. The other types were optimal nonlinear on/off controllers, and a linear on/off controller with an optimal slope for its switching line. Theory is presented in detail for the development of the linear/off controller with optimal slope of its switching line. A specific laboratory servomotor, manufactured by the Electro-Craft Corp., was chosen for use in this research. Each controller was mated to the servomotor and data in the form of performance index measurements were gathered and compared with data from analog simulations of each servomechanism. It is demonstrated in this thesis that theory for the linear on/off controller with optimal slope switching line may be applied successfully to systems which have significant viscous friction present. A future investigation is needed to determine to what extent the theory is sensitive to variations in the parameters of the plant.

142. THE APPLICATION OF ERROR MODELS TO THE DETERMINATION OF ERROR CAUSES IN DIGITAL CHANNELS

Jonathan P. Worthley, Capt, USAF 71p GE/EE/73A-34
Advisor: Maj R. Reinman Lab Sponsor: RADC

The purpose of this study is to determine whether the error cause present in a modem channel can be ascertained using the parameters of matrix and renewal models of the digital channel. Data generated by a modem subjected to three major error causes, impulse hits, frequency offset, and phase jitter, were supplied by the Digital Communications Experimental Facility (DICEF), Rome Air Development Center, Griffiss AFB, New York. A simulator was used to produce the error cause in the modem or channel. The parameters for Fritchman's partitioned Markov chain model, the parameters of the renewal channel model of Muntner and Wolf, and the stationary distribution and stationarity of the transition probabilities for the error-free run model are used to determine the cause of errors. This study indicates that they can be used for this purpose.

143. AN AUTOMATED DIGITAL DESIGN LANGUAGE FOR CLODS

Thomas J. Brown, Capt, USAF | 195p | GE/EE/73S-1
Advisor: Dr. G. B. Lamont | Lab Sponsor: AFIT | AD 768346

Many aspects of digital design have been computerized in the past. Symbolic design, state reduction, state assignment, logic realization and simulation are a few of these individual processes. The Computerized Logic-Oriented Design System (CLODS) is an attempt to consolidate previous individual efforts into an integrated digital design system. This thesis is a study of several symbolic design languages currently available which could be used in the symbolic design phase of an automated design system. One language, the Digital Design Language (DDL), is chosen as the most desirable in terms of conciseness, readability, and flexibility. A translation program, which converts a DDL description into Boolean equations and state tables, is implemented in the FORTRAN language using a previously written program as the basis. The method of translation and the actual programs are discussed in detail. One state reduction program and two state assignment programs are also incorporated into CLODS. The state assignment programs are not the most sophisticated but do provide a necessary link in the overall system.

144. A STOCHASTIC MODELING APPROACH TO AERIAL DUEL DATA ANALYSIS

Roy E. Brunson, Capt, USAF | 111p | GE/EE/73S-2
Advisor: Prof T. L. Regulinski | Lab Sponsor: HQ USAF

A stochastic modeling approach to aerial duel data analysis is described. Time-to-conversion data generated during air-to-air combat engagements between differently configured fighter aircraft is modeled. Eight probability density functions are chosen as possible models. Each density function possesses a location parameter to account for the initial time period of an engagement during which a conversion was not possible. The parameters of the density functions are estimated using the method of maximum likelihood for censored samples. The Kolmogorov-Smirnov goodness of fit test is conducted to determine which models are reasonable representations of the time-to-conversion data. The best model of those passing the Kolmogorov-Smirnov test is selected using the maximum likelihood ratio test. The characteristics of each underlying model are investigated. In particular, the probability of conversion, frequency of conversion, conversion rate, fitted mode, and fitted mean are analyzed. Comparisons between results from the various data samples considered are made. The results indicate that the behavior of the conversion process is described in more detail by the stochastic models than by point probabilities and sample averages alone.

145. MODELING THE DISTINGUISHED VISITOR AIR/GROUND COMMUNICATIONS SYSTEM

Raymond L. French, Maj, USAF | 212p | GE/EE/73S-3
Advisor: Prof T. L. Regulinski | Lab Sponsor: AFCS

A stochastic approach to modeling the Distinguished Visitor Air/Ground Communications System (DV) is described. Time-to-failure data generated by the DV stations, the Defense Communications System (DCS) interstation lines, and the HF radio links are modeled for reliability. Time-to-repair data generated by the DV stations and the DCS lines are modeled for maintainability

Restorability of the secure voice channel on the HF radio link is also modeled. Bit error rate data generated on the DCS lines and HF radio links are modeled. Nine probability density functions are chosen as possible models. The parameters of the density functions are estimated using the method of maximum likelihood for the data samples. The K-S goodness of fit test is conducted to determine which models are reasonable representations of the data under study. The best model of those passing the K-S test is selected using the maximum likelihood ratio test. Thr reliability models are analyzed for various periods of mission time. Availability is used to show the interrelations of system operation and maintenance. Comparisons between results for the various data samples are made. Reliability of the stations was modeled by the Gamma and Weibull densities. The log normal density modeled the station maintainability. The Gamma and log normal densities modeled the reliability and maintainability of the DCS lines. The Weibull density modeled the number of frequencies used in a 24 hour period by a station. The Beta and log normal densities modeled the reliability of the analog and digital voice channels. The Beta and Weibull densities modeled the restorability of the digital voice channel for the modem and vocoder terminals. The BER was modeled by the log normal density. Results of the thesis indicate that the DCS lines were the limiting factor affecting overall system performance.

146. SPACE OBJECT IDENTIFICATION BY FILTERED FOURIER TRANSFORM PATTERN RECOGNITION ALGORITHM

William L. Malinski, Maj, USAF — 102p — GE/EE/73S-4
Advisor: Dr. M. Kabrisky — Lab Sponsor: AFAL — AD 768347

Light intensity signals reflected from three classes of orbiting rocket bodies were analyzed using one-dimensional Fourier transforms. Low-frequency filtering in the transform domain and the Euclidean distance metric were used to classify the signals into the three classes. Using a portion of the data, linear decision boundaries were constructed by an adaptive training algorithm. It was found that the low-frequency filtered one-dimensional Fourier-transform domain gave good separation of the three classes of rocket bodies analyzed. A method of automated space object identification is proposed for non-stabilized satellites. It is suggested that the algorithm used in this study is also applicable to data collected via radar.

147. MULTIPLE-TWO-HYPOTHESIS TESTING - A NEW METHOD FOR DETERMINING SIGNAL CONTENT

John A. Nowacki, Capt, USAF — 110p — GE/EE/73S-9
Advisor: Maj R. Reinman — Lab Sponsor: AFAL — AD 769497

Detecting and classifying overlapping waveforms can be done using M-ary hypothesis testing. A new detection method, multiple-two-hypothesis testing, is developed by minimizing the probability of error for each decision made, and is shown to have computational advantages over M-ary hypothesis testing. A sequential test is developed from multiple-two-hypothesis testing, and it is also shown to have computational advantages over M-ary hypothesis testing. The three detection methods are applied to

the synchronous detection of two signals with no overlap, and their performances are compared. Then M-ary hypothesis testing and multiple-two-hypothesis testing are applied to the synchronous detection of two signals with one overlap and error equations are presented for the two methods. Finally, multiple-two-hypothesis testing is combined with maximum a posteriori estimation to solve nonsynchronous detection problems.

148. A 1 KeV ION PROBE FOR THIN FILM ANALYSIS

Fred H. Porter III, Maj, USAF — 95p — GE/EE/73S-5
Advisor: Prof J. Lubelfeld — Lab Sponsor: AFAL — AD 768348

A 1 KeV ion probe analyzer was designed and assembled for thin film analysis. The major components include a QUAD 250B quadrupole mass spectrometer manufactured by Electronic Associates, Inc., and a Phi 04-131 sputter ion gun manufactured by Physical Electronics Industries, Inc. The distinctive features of the analyzer are its low energy ion source and its ability to sputter and analyze conducting and nonconducting materials equally well. The instrument can resolve impurity densities of one part in 1000 from sputtered secondary ions, and the etch rate achieved is 800 angstroms per hour on a permalloy target. The report contains sample spectra and the necessary details to use it as an operating manual for the analyzer. Recommendations include modifications for improved sensitivity, establishment of measurement standards, and further work for time-of-flight and ion energy measurements.

149. INTEGRAL TRANSFORM TECHNIQUE FOR MONITORING ELECTROCARDIOGRAMS

James H. Reid, Capt, USAF — 100p — GE/EE/73S-10
Advisor: Dr. M. Kabrisky — Lab Sponsor: AFIT — AD 769297

This paper applies time domain and filtered integral transform domain pattern recognition techniques to the problem of locating and discriminating between QRS-complexes and premature ventricular contractions in electrocardiograms. The data set consists of sixteen 100-second single lead electrocardiogram records. Sufficient electrocardiogram and pattern recognition theory is included to explain the technique and the results. Three different integral transforms are evaluated: the discrete Fourier, the Walsh, and an accidentally discovered transform similar to the Walsh. Ninety-seven percent of the QRS-complexes and PVC's in the records evaluated were located correctly The three transform techniques classified between 90.8% and 92.5% of the QRS-complexes correctly and 85.6% and 93.2% of the PVC's correctly.

150. COMPUTERIZED LOGIC-ORIENTED DESIGN SYSTEM

Michael J. Svisco, 1/Lt, USAF — 161p — GE/EE/73S-6
Advisor: Lt Col T. Purnhagen — Lab Sponsor: AFIT — AD 768349

The Computerized Logic-Oriented Design System (CLODS) is a computer program written for the CDC 6600 computer located at WPAFB. The program is intended as an educational tool and as a design aid for the students of the Air Force Institute of Technology. All of the various steps in the digital design process are covered by CLODS and these steps can be accessed either serially or

individually. The major programs used by CLODS are: (1) a higher-order language (DDL) developed by D. L. Dietmeyer, (2) a state reduction program developed by J. P. Rutledge, (3) state assignment programs developed by T. J. Brown, (4) a logic-hardware realization algorithm (GELAS) developed by GE and D. L. Dietmeyer, (5) a logic circuit drawing program developed by L. E. Jennings, and (6) a ditital logic simulator (DLS) developed by J. R. Niederhauser. CLODS essentially controls the execution of the above-mentioned programs. A majority of the programs are written in the FORTRAN Extended Language, however, parts are written in the COMPASS Assembly Language as an attempt to save execution time and core memory. A technique is used in conjunction with the overlay structure of the programs to make the core requirements (of certain sections) variable (dependent upon the amount of core requested by the user). This technique, along with a system user's manual and suggestions for further improvements, is presented in this thesis.

151. CAPACITANCE AND EQUIVALENT AREA OF A HOLLOW SINGLE-GAP PROLATE/OBLATE SPHEROIDAL ELECTROMAGNETIC PULSE SENSOR

Larry W. Wood, Capt, USAF — 88p — GE/PH/73S-1
Advisor: Prof D. G. Shankland — Lab Sponsor: AFWL — AD 761801

Electromagnetic sensors of various geometric configurations are used to measure the nuclear electromagnetic pulse. Certain design parameters exist for these sensors and are so related that if any two are known, the others are also known. For dipole sensors, the two most readily calculable parameters are capacitance and equivalent area. The capacitance and equivalent area are calculated for both prolate and oblate hollow single-gap dipole sensors for various ranges fo eccentricity and gap-size. The method used is a finite difference scheme in matrix form which solves LaPlace's equation in spheroidal coordinates with mixed boundary conditions. The computations are performed on a CDC 6600 digital computer, and a sequence-to-sequence limiting procedure is used to improve the accuracy of the solution. The results are presented in graphical form and the validity of the method is discussed. Recommendations are made for improving the method.

152. FEASIBILITY OF USING CONVERSION ELECTRON MOSSBAUER SPECTROSCOPY FOR CHARACTERIZATION OF SURFACES AND THIN FILMS

Donald G. Allen, Capt, USAF — 72p — GEP/PH/73-1
Advisor: Dr. G. John — Lab Sponsor: AFML — AD 767219

Experimental techniques for the study of surfaces and thin films by the use of Mossbauer spectroscopy requires a detector that can isolate internal conversion electrons with energies of 7.3-keV or less. In addition, if the detector could "energy-discriminate" the electrons, changes occuring in a thin film, as the interface between the film and substrate is approached, could be observed. An electrostatic detector, employing parallel deflector plates and a channeltron electron multiplier, was designed and constructed for the purpose of obtaining Mossbauer spectra by detecting specific-energy electrons. Although the detector was capable of detecting the 7.3-keV, 5.6-keV, and 0.53-keV electrons emitted in the decay of a Co^{57} point source, attempts to obtain Mossbauer spectra were unsuccessful. A flowing-gas proportional

counter, designed to detect internal conversion electrons, was used to obtain several Mossbauer spectra. Absorbers used for these spectra were enriched Fe57 foil, enriched Fe57 oxidized foil, and thin films of enriched and non-enriched Fe57 on stainless steel substrates. Effects of the oxidation on the enriched foil and the Fe57 peaks from enriched films were observed; however, Mossbauer spectra obtained from non-enriched FE57 films on stainless steel showed only the stainless steel peak resulting from the substrate.

153. OPTICAL EXCITATION OF ORGANIC DYE VAPORS

Thomas J. Alpert, Capt, USAF — 39p — GEP/PH/73-2
Advisor: Maj K. Jungling — Lab Sponsor: AFAL — AD 764704

The fluorescence of purified and unpurified Rhodamine B vapors was observed using for excitation all the lines of an argon ion laser. The compound was heated in the side arms of a 43-cm long tube evacuated to $\sim 10^{-6}$ torr. The temperatures of the side arms were varied from 200° to 400°C. The emission band was very broad, characteristic of vapor phase fluorescence and its peak was at ~508-nm. No appreciable fluorescence was detected from either purified or unpurified Rhodamine 6G vapor. Absorption measurements made on this compound indicated that no fluorescence was detected because of self-absorption.

154. HIGH RESOLUTION LOW TEMPERATURE SPECTRA OF Tb^{3t} IN $YAlO_3$

Johnny L. Berg, Maj, USAF — 94p — GEP/PH/73-3
Advisor: Lt Col DeWitt — Lab Sponsor: AFML — AD 766881

Absorption and emission spectra of terbium-doped yttrium orthoaluminate ($YAlO_3:Tb^{3+}$) have been recorded at 77° and 4.2°K. A reduction of data to tables of wavelength has been completed. All spectra were recorded photographically on a 3.4 meter focal length Jarrell-Ash spectograph at a reciprocal linear dispersion of 5A/mm. The wavelength ranges covered were 2000Å-6050Å in absorption and 3500Å-7050Å in fluorescence. Most of the theoretically allowed crystal field levels from 0-37000 cm^{-1} were identified. A free ion calculation has been carried out. The electrostatic, spin-orbit, and configuration interaction parameters that minimize the mean square deviation between the experimental centers of gravity and the calculated free ion energies were determined to be $E^1 = 5993.8\ cm^{-1}$, $E^2 = 29.026\ cm^{-1}$, $E^3 = 598.60\ cm^{-1}$, $\zeta = 1694.9\ cm^{-1}$, $\alpha = 19.159\ cm^{-1}$, $\beta = -557.46\ cm^{-1}$, and $\gamma = 1272.9\ cm^{-1}$. The rms deviation between the sixteen centers of gravity included in the calculation and the theoretical centers calculated with these parameters is $73\ cm^{-1}$.

155. CHARACTERISTIC ENERGY LOSS SPECTRA OF III-V SEMICONDUCTORS

Richard E. Bernard, 1/Lt, USAF — 55p — GEP/PH/73-4
Advisor: Prof R. Hengehold — Lab Sponsor: AFML

The characteristic electron energy losses of III-V semiconductors were examined. The identification of losses associated with interband and d-band transition and surface and bulk plasmons were studied as were the effects of contamination and incident electron energy. The interband and d-band transitions and bulk plasmon losses were found to be in close agreement with earlier reported results. The surface plasmon result was found to vary in position and amplitude and was found to be dependent upon incident energy and surface contamination.

156. BEAM DIVERGENCE: THE MEASUREMENT OF NANOSECOND LASER PULSES

Douglas E. Caldwell, Capt, USAF 94p GEP/PH/73-5
Advisor: Maj K. Jungling Lab Sponsor: AFWL AD 764702

The divergence of a laser beam is a measure of the rate at which the energy in the beam spreads. There are many ways of measuring the divergence of nanosecond pulses. The data reduction needed to gain accuracies of less than ±15% involves the expenditure of considerable time. The methods which give results in a short time generally have accuracies of ±20% or worse. Two of the more accurate methods which are based on photography, the Winer technique and Hartmann method, are compared. Also, a mechanized technique known as SRTLAS, Semi-Real Time Laser Analysis Scanning is discussed. The Winer method uses a multielement lens/filter array to photograph the spot produced in the focal plane of a lens. A Lambertian reflector such as a MgO block is used as a "screen" in the focal plane to provide an image for the film. The Hartmann method makes use of an array of holes, precision drilled and spaced, to divide the beam into a number of beamlets. The pattern of these beamlets is recorded on film at a known distance from the hole array, and a geometrical analysis is performed based on where the images should have been for perfectly parallel light. SRTLAS is basically an electronic Hartmann technique that uses a Silicon diode vidicon and reference mask in analyzing the array of beamlets. The 40 ns pulses measured during the comparison were produced by a Nd:Glass laser operating at 1.06μ. The Hartmann technique yielded a divergence of about 0.8 mr and the Winer technique gave a divergence of about 4.4 mr. SRTLAS divergence measurements indicated a resolution of ±3 μr. Due to installation difficulties, SRTLAS data was not taken for any of the shots reported in this thesis. Data reduction times for the Winer data (8 hours) and the Hartmann data (11 to 24 hours) showed the need for a more rapid measuring technique.

157. PERTURBATION THEORETIC SOLUTION OF THE HARTREE-FOCK EQUATIONS

Richard J. Cook, 2/Lt, USAF 90p GEP/PH/73-6
Advisor: Prof D. G. Shankland Lab Sponsor: AFWL AD 752119

The feasibility of obtaining solutions of the Hartree-Fock equations by perturbation theory was investigated. The perturbation theory used was very similar to Rayleigh-Schrodinger perturbation theory. The solution was carried to the third order of approximation for both the one-particle orbitals and one-particle energies. For application to atoms, a set of nondegenerate one-particle orbitals were developed as a basis for expansion of the perturbation theory. The perturbation theory was applied to a number of simple atoms and ions: He I, Li I, Be I, Li II, Be II, and Be III. The one-particle energies, ionization potentials, and system energies were calculated for these atoms and ions. In addition the energy of the first excited state of He was calculated for both the singlet and triplet configurations. The calculated values for the system energy were found to agree with experiment to within errors ranging from 0.37% to 3.9% and the one-particle energies agreed with results obtained by self consistent solution to within error ranging from 0.1% to 7.0%.

158. SPIN-FLIP RAMAN SCATTERING IN CADMIUM SULFIDE

Terrence F. Deaton, 1/Lt, USAF | 132p | GEP/PH/73-7
Advisor: Dr. R. Hengehold | Lab Sponsor: ARL | AD 764600

Spin-flip Raman scattering from bound electrons in n-type CdS was observed at liquid helium temperature using the 4880 A and 5145 A lines of an argon ion laser. Scattering was observed in Cd- and In-doped samples with carrier concentrations of 7×10^{16} to 4×10^{18} cm^{-3}. The g-factor was determined to be 1.77 ± 0.04 for magnetic fields of 33 to 95 kGauss. The g-factor was determined using a 2-meter Bausch and Lomb spectrograph. A Spex Raman spectrometer was used to determine the relative intensities of the Stokes and anti-Stokes lines and the linewidths of the scattered lines. The linewidths (FWHM) of the Stokes lines were determined to be 0.20, 0.10, and 0.08 cm^{-1} for carrier concentrations of 4×10^{18}, 3×10^{17}, and 7×10^{16}, respectively. The linewidth measurements are consistent with a Lorentzian lineshape for the scattering. The relative Stokes and anti-Stokes intensities were measured at several field strengths, and the results indicate a spin temperature of 4.3°K when the lattice is at liquid helium temperature. The intensity of the scattering as a function of pump power was measured for right-angle scattering with $\bar{q} \cdot \bar{H} \neq 0$. The 5145 A argon ion laser line was focussed to a diffraction-limited spot size in the crystal, producing power densities up to 3 MW/cm^2. At the maximum input power available, no stimulated Raman scattering could be detected at right angles to the incident beam.

159. A STUDY OF THE RELIABLE GENERATION OF ZERO π PULSES WITH A MODE LOCKED CO_2 LASER

John E. Dunkle, Capt, USAF | 105p | GEP/PH/73-8
Advisor: Maj H. Weichel | Lab Sponsor: AFWL | AD 764692

Theoretical advances in the study of the propagation of coherent pulses of electromagnetic radiation have introduced the concept of self-induced transparency. Experimental evidence of this phenomena can be obtained with the pulses from a mode locked CO_2 laser. Maximum output power can be obtained from the laser if the design parameters are carefully considered before construction of the laser begins. Mode locking with sulfur hexafluoride (SF_6) requires a minimum of 10 $watts/cm^2$ of laser output power before saturation of the absorbing gas will occur. The mode locked pulses must be examined with an infrared detector to determine the shape and area necessary to develop self-induced transparency. Room temperature detection of the infrared pulses can be accomplished with a pyroelectric detector or a photon drag detector. Mode locked pulses were not observed during this investigation. Mechanical Q-switching indicated that the two detectors were not fast enough to reproduce pulses with rise times near 50 nanoseconds or less. The detectors were re-designed and further testing will provide the information needed to determine if mode locking with SF_6 did occur. The probability for mode locking will be enhanced if the laser plasma tube is lengthened to increase the output power and if the laser cavity is lengthened to increase the number of modes available for locking.

160. THE ELECTROMAGNETIC FIELDS DUE TO RADIAL CURRENTS NEAR A PERFECTLY CONDUCTING SPHERE

Robert L. Gardner, Capt, USAF | 74p | GEP/PH/73-9
Advisor: Prof D. Shankland | Lab Sponsor: AFWL | AD 753664

The dyadic Green's function technique is applied to the problem of determining the electromagnetic fields due to radial electron emission near a perfectly conducting sphere. The application of the technique results in formal solutions for the surface current on the sphere and the curlless field within the electron cloud which causes the currents. Two electron velocity functions are used. They are the constant velocity case and the case in which the velocity falls off in a central potential. The analysis of the problem is simplified by ignoring electron-electron interactions, electromagnetic field-electron interactions, and the potential due to ions left on the surface of the sphere. Both time domain and Laplace transform domain solutions are obtained. The singularity expansion method is used to determine the inverse transforms of the Laplace domain field expressions. The final field expressions are in formal series form. The series are not summed.

161. UTILITY OF THE METHOD OF STEEPEST DESCENTS IN ANALYSIS OF TRAVELING WAVE INSTABILITIES

David L. Johnson, Capt, USAF | 72p | GEP/PH/73-10
Advisor: Maj C. Case | Lab Sponsor: AFWL | AD 763091

This report analyzes some simple traveling wave instabilities which are mathematically similar to the instabilities found in electron beam tubes. The differential equation describing the system is solved by applying the Laplace transform over time and the Fourier transform over space. The resulting equation in transformed variables is solved algebraically and the inverse double transform obtained to yield the desired solution in space and time. The calculus of residues is used to obtain the inverse Fourier transform. The inverse Laplace transform cannot always be obtained exactly however. When this is the case, the method of steepest descents is used to obtain a closed form approximation to the inverse Laplace transform which will asymptotically approach the inverse Laplace transform for late times. The method of steepest descents not only provides an asymptotic approximation in closed form, but does so in a manner that facilitates a physical interpretation of the results obtained. In each case discussed, three examples of initial perturbation are used to illustrate the methods used. The first two examples yield results that might be expected from the application of stability criteria, but the third example illustrates the fact that the dispersion relation does not solely determine whether or not a system is stable.

162. CATHODOLUMINESCENCE OF ION IMPLANTED ZnS

Sidney L. Johnson, Jr., Capt, USAF | 82p | GEP/PH/73-11
Advisor: Prof R. Hengehold | Lab Sponsor: AFML | AD 767877

Sodium ion implanted zinc sulfide crystals were studied by observing the luminescence produced by incident electrons with energies between 4 and 15 keV. Spectral comparisons were made between 100, 200, and 300 keV sodium implanted, sodium doped, and pure melt grown zinc sulfide crystals. The relative increase in the size of the UV band located at approximately 3450Å was attributed to the presence of sodium. A possible energy level model is discussed.

163. ELECTROMAGNETIC PULSE PROPAGATION IN BOUNDED PLASMAS, ANISOTROPIC PLASMAS, AND LOSSY PLASMAS

John A. Justice, Capt, USAF | 114p | GEP/PH/73-12
Advisor: Maj C. Case | Lab Sponsor: AFWL | AD 768350

The dispersion of electromagnetic pulses in plasmas is considered. Maxwell's equations are used to determine the wave equation in the Fourier transform domain. Thus, the fields in the time domain are determined by inverse Fourier transformations. Asymptotic solutions for the fields are obtained via the saddlepoint method of integration. The investigation considers three different plasma models. The first model is a homogeneous, isotropic, plasma slab with infinitesimal boundaries. The reflection and transmission coefficients are found to be frequency dependent. When an air-plasma-air problem is considered, the transmission coefficient is almost one and the boundary effects are thus negligible. The second model is a homogeneous, anistropic plasma where propagation along magnetic field lines is considered. Responses to both double exponential and delta function initial pulse shapes are obtained. The results show significant transient Faraday rotation, even for weak magnetic fields. The third model is a homogeneous, isotropic, lossy plasma. The Langevin equation (with a viscous collisional term) is used to approximate the effect of sollisions. For large propagation distances the wave is severely damped, even for the weak absorption case. The lower frequency components of the wave are annihilated for low propagation distances. Application of the theory to the propagation of Exoatmospheric EMP through the ionosphere is discussed.

164. THE THEORY OF AN ELECTROSTATIC METAL-PARTICLE SENSOR OPERATING IN A JET ENGINE EXHAUST

Jack A. Labo, Capt, USAF | 62p | GEP/PH/73-13
Advisor: Maj C. Case | Lab Sponsor: AFFDL | AD 768351

An electrostatic probe is studied as a charged metal particle detector in a jet engine exhaust from both a theoretical and experimental standpoint. The theoretical development concentrated on the electrostatic particle-probe interaction problem. The mechanism by which a moving charged particle induces a voltage pulse in a probe sensing circuit is studied and a practical model for the particle-probe system is developed and the resulting voltage pulses are explained by means of a capacitive equivalent electrical circuit. In order to predict the voltage pulse waveform, the changing capacitance, $C_2(t)$, between a moving charged particle and an electrostatic probe is determined, and the predicted voltage pulse is found to depend upon $C_2(t)$, $dC_2(t)/dt$, the particle charge, and the probe sensing circuit. The interaction of an uncharged particle with a biased probe and the jet engine exhaust plasma effects are briefly discussed. A simple experimental setup is used to confirm the predicted voltage pulse waveform. Finally, the predicted voltage pulses and experimental results are compared and are both found to agree with certain voltage pulses observed in actual jet engine exhausts from the older J-57 to the latest F-101 engine.

165. THE MORPHOLOGY OF IONOSPHERIC F-REGION STORMS AT MIDDLE AND LOW LATITUDES

William F. McCullough, Capt, USAF 140p GEP/PH/73-14
Advisor: Prof J. Wilson Lab Sponsor: AFCRL AD 753665

The dependence of the onset time of the F-region electron density disturbance upon the local time of the geomagnetic storm commencement and main phase onset was investigated. Hourly values of the fractional deviations of foF2 from monthly median values at a world-wide network of ionosonde stations were examined during 29 geomagnetic storms occurring between July 1957 and December 1964 with main phase onset time lags of more than 2 hours and K-indices at Fredericksburg of 6 or greater. No general local time effect of the geomagnetic storm commencement or main phase onset upon the onset of the F-region disturbance was found. The relationship between the relative equatorial electrojet strength and the time rate of change of foF2 above Huancayo was investigated during eight geomagnetic storms. The structural morphology of the equatorial anomaly during two geomagnetic storms was also investigated. The equatorial ionosphere was found to be controlled by electrodynamic drifts during geomagnetically disturbed conditions. Physical processes responsible for the F-region storm phenomena were suggested to be increased chemical combination coefficients, due to increased atmospheric heating, and vertical electrodynamic drifts, due to additional fields within the ionosphere.

166. DENSE PLASMA FOCUS X-RAY EMISSION: STUDIES AND APPLICATION

Alan R. Mertz, 1/Lt, USAF 60p GEP/PH/73-15
Advisor: Prof D. Shankland Lab Sponsor: SAMSO AD 761800

X-radiation from a region 4.0-11.0 mm above the anode of a 33kJ plasma focus device was spectrally (1.0-5.0 keV) and temporally resolved. The plasma radiation during the first compression was found to correlate with a thermal plasma bremsstrahlung radiation in the temperature range 0.3-0.6 keV in pure deuterium. Additions of 1-4% argon and other high-z gases enhanced the soft continuum and produced intense line radiation ~20 nanoseconds after the first compression. Copper-zinc line radiation and continuum resulting from an ejected metallic cloud was produced ~150 nanoseconds after the initial compression. The angular photoelectron distribution for oblique, pulsed radiation incident upon a thin foil indicated a peak emission angle of ~30° to ~50° from the axis of incident radiation.

167. ELEMENTAL ANALYSIS OF MATERIALS BY ENERGY DISPERSIVE SPECTROMETRY OF X RAYS PRODUCED BY A FOCUSING ELECTRON GUN

William C. Nielsen, Jr., Capt, USAF 88p GEP/PH/73-16
Advisor: Drs. G. John and R. Hagee Lab Sponsor: AFTAC AD 768352

The construction and operation of a system for elemental analysis of materials by energy-dispersive x-ray analysis are described. The majority of the components are found in most well-equipped physics laboratories while others such as the electron gun are relatively inexpensive to fabricate. The Steigerwalt electron gun provides a beam of electrons which can be varied in diameter from a fraction of a millimeter to several centimeters. Fluorescent x rays from samples

are excited either directly by electrons from the gun or by secondary x rays produced by using the electrons to excite interchangeable thin targets. With electron energies up to 40 keV and beam currents as high as 300μA elemental concentrations as low as 10^{-7}g and less than 10 ppm have been detected with short exposures. The sensitivity of this system is compared to systems which use radionuclides and protons to excite x rays. All x-ray measurements were made with an intrinsic germanium detector with a resolution (FWHM) of 200 eV at 6.4 keV.

168. THERMOPHYSICAL AND OPTICAL EVALUATION OF HEAT PIPE COOLED LASER MIRRORS

David Raspet, Maj, USAF — 157p — GEP/PH/73-17
Advisor: Maj H. Weichel — Lab Sponsor: AFAPL — AD 766883

A concept for cooling laser mirrors with the heat pipe process was evaluated with a 2-inch diameter copper mirror. The mirror was illuminated by a 67 watt/cm^2 incident beam from a 10 kilowatt carbon arc lamp. This beam provides 34.2 watts/cm^2 to the water heat pipe. Reflecting surface temperature distributions were measured to assess heat pipe operation. Reflecting surface distortions were measured from the change in focal length. Despite a problem with obtaining good wetting of the copper capillary structure of the heat pipe by the water, the heat pipe demonstrated the ability to significantly reduce reflecting surface temperature gradients.

169. FEASIBILITY OF A DEEP-SPACE SOLAR ACTIVITY MONITORING PLATFORM WITH VIDEO CAPABILITY

David D. Ratcliff, Capt, USAF — 91p — GEP/PH/73-18
Advisor: Dr. L. Pedrotti — Lab Sponsor: AFAPL — AD 761799

A basic fact of life facing solar forecasters and researchers is that half of the sun is not visible to them. Because of the rotation of the sun, solar activity centers which spawn flares are invisible during part of their lifetime and solar forecasters have only a few days of lead time in their forecasts. This study investigates the feasibility of placing a satellite platform capable of supporting a high-resolution video imaging system on the far side of the sun in the earth's orbit. Other measurements included in the mission are x-ray flux, UV flux charged particle flux, and radio emissions from the sun. The study indicates that the mission is feasible. A design for the vehicle is suggested; proven systems are used in the proposed vehicle with the exception of the attitude control system. Vehicle pointing requirements are met by a proposed attitude control system design which uses radiation pressure torques, optical damping, and a reaction boom to achieve a one-arc-second pointing accuracy for the vehicle.

170. THE PRODUCTION AND EVALUATION OF HOLOGRAPHIC LENSES

Rickey C. Seid, Capt, USAF — 95p — GEP/PH/73-19
Advisor: Maj K. Jungling — Lab Sponsor: AMRL — AD 764701

An experimental study was made to determine the optimum procedure for making both reflection and transmission bleached holographic lenses on Kodak's 649-F plates. Several bleaches were used, with the highest efficiencies (40%) occurring for the transmission lenses. The imaging ability of these lenses was determined by imaging an Air Force Resolution

Chart through each lens and recording this image on 649-F plates. These plates were then scanned with a microdensitometer to determine the square wave modulation response of the lenses. Their performance dropped significantly when the spatial coherence of the reconstructing beam was reduced by placing a ground glass diffuser behind the resolution slide. The low order aberrations inherent in holographic lenses were largely compensated for by rotating the object or image plane about an axis perpendicular to the plane formed by the principal axes of the holographic lens. The transmission lenses were markedly better than the reflection lenses, with their maximum modulation response being 80% and best resolution at the object of 70 lines/mm.

171. EXPERIMENTAL INVESTIGATION OF SOME POSSIBLE APPROACHES TO THE X-RAY LASER

Kenneth E. Siegenthaler, Maj, USAF 95p GEP/PH/73-20
Advisor: Maj H. Weichel Lab Sponsor: AFWL AD 764691

A discussion of the historical development of the X-ray laser and the problem areas preventing its operation is followed by an experimental investigation of some of the most promising approaches to the X-ray laser. An experiment using 66, 40-nanosecond, Nd:glass laser pulses of over 30 joules was unsuccessful in duplicating the Utah X-ray laser experiment. Data was obtained in the experiment through the use of streak pictures, framing pictures, time exposure pictures, closed-circuit television pictures, burn patterns, X-ray detection by film, pumping laser output and transmission energy measurements, and pulse shape measurements of the pumping laser output, reflection and transmission pulses. If the Utah experiment is actually an X-ray laser the author concludes that the key variables remaining to be investigated are the pulse shape, and the criticality of focusing on the gelatin sandwich. An experimental investigation of self-focusing in glass and liquids as a possible X-ray laser was also conducted. An experiment using Lanthanum-doped, optical glass and 10 shots with a 35-joule, 40-nanosecond, Nd:glass laser pulse resulted in no detectable radiation shorter than 5Å. Another experiment using a homogeneous solution of cupric acetylacetonate dissolved in carbon disulfide and 8 shots with a 25-joule, 40-nanosecond, Nd:glass laser pulse resulted in no detectable radiation shorter than 5Å. In future self-focusing experiments a better detector than film should be used.

172. ELECTRIC FIELDS GENERATED BY SYMMETRIC INWARD EMISSION OF ELECTRONS FROM CYLINDRICAL AND SPHERICAL SHELLS

Marcus R. Skeem, 2/Lt, USAF 73p GEP/PH/73-21
Advisor: Prof D. Shankland Lab Sponsor: AFWL AD 753014

Simple analytic models incorporating assumptions based on physical arguments are developed to calculate the electrostatic fields produced inside cylinders and spheres by internal electromagnetic pulse (IEMP). The assumptions are: (a) Both the cylinder and the sphere are evacuated perfectly-conducting shells having no aperatures. (b) The cylinder is

infinite and the photon propagation direction is perpendicular to the axis of the cylinder. (c) Electrons having a known but arbitrary energy spectrum are scattered into the cavities by photons. (d) There is no angular dependence in the electron emission, i.e., the electron emission is uniform around the wall of the cavity. (e) The electrons are emitted radially inward from the shell wall. (f) All electrons are nonrelativistic. (g) The electrons collide only with the shell wall and are then absorbed. (h) A self-consistent steady-state solution approximates the real problem reasonably well. Integral equations for the potentials in the cavities are derived from Poisson's equation and energy conservation and are solved self-consistently for a representative enrgy spectrum. The numerical solutions are checked against analytic solutions in the limit of small space-charge effects and numerical results for the electrostatic potential, electric field, and charge density are presented.

173. ENERGY DISPERSIVE ANALYSIS OF X RAYS PRODUCED BY RADIOACTIVE SOURCES

William A. Swick, III, Capt, USAF | 65p | GEP/PH/73-22
Advisor: Dr. G. John | Lab Sponsor: AFTAC | AD 763728

A system for energy-dispersive analysis of x rays produced by radioactive sources was evaluated in this study. Fe^{55}, Cd^{109}, and Am^{241} were used to produce fluorescent characteristic x rays in a variety of samples. Methods of reducing matrix effects were investigated. Dilution techniques were used to eliminate matrix effects for concentrations below $10^{-3}g/cm^2$. Diluted solutions of metal salts were evaporated to deposit samples of $10^{-6}g$ to $10^{-2}g$ which were irradiated to produce net count rate of K x rays vs weight curves for different elements. Samples of unknown composition were examined and the weights of the elements present in these samples were determined from the net count rate curves. Samples of atmospheric dust were found to contain elements such as zinc, gallium, bromine, lead, calcium, and strontium in microgram quantities. The system was consistently used to detect weights of $10^{-5}g$ to $10^{-6}g$. Elements with atomic numbers as low as potassium were detected. A K-L x-ray coincidence experiment was used to selectively examine the L x-rays of high-Z elements which were masked by the K x rays of low-Z elements. The coincidence mode was also used with samples of mixed high-Z elements to enhanc the L/background ratio of elements whose K x rays were of low intensity or masked by the K x rays of adjacent elements.

174. HOLOGRAPHIC INVESTIGATION OF THERMAL EFFECTS IN NONLINEAR CRYSTALS

Kirby H. Williams, Capt, USAF | 92p | GEP/PH/73-23
Advisor: Maj K. Jungling | Lab Sponsor: AFAL | AD 764703

The thermal response of barium sodium niobate (BSN) and cesium dihydrogen arsenate (CDA) to intra-cavity, Nd:$YALO_3$ laser radiation were studied using holographic interferometry. The laser operated at 1.08μ at an internal power level of 8W. BSN showed a uniform increase of 2.6°c for CW operation without harmonic generation and about 3.1°c for Q-switched operation with harmonic generation. The increased response is believed to be a result of nonlinear absorption at the high peak powers associated with Q-switching. CDA, tested only under CW operation without harmonic generation, showed a gradient of 30°c/cm in the beam spot and a logarithmic decrease across the

bulk of the crystal. Thermal focussing by CDA and its effect on laser operation were observed; a thermal focal length of 46.5 cm was calculated. Thermal conductivities, phase match temperatures, and refractive index variations with temperature were determined. Also, a second harmonic generation test was conducted for BSN; conversion efficiency of 0.2% in CW mode and 5% in Q-switched mode were determined from output power measurements.

175. AN IMPROVED METHOD OF PREDICTING AIRCRAFT LONGITUDINAL HANDLING QUALITIES BASED ON THE MINIMUM PILOT RATING CONCEPT

John D. Arnold, Maj, USAF — 144p — GGC/MA/73-1
Advisor: Maj J. Dillow — Lab Sponsor: AFFDL — AD 764696

A fixed-base simulation of some of the flight tests in the USAF/CAL variable stability T-33 aircraft was performed. The tank was maintaining pitch attitude in the presence of vertical turbulence. The root-mean-square state data and parameters in a linear pilot model were determined from the simulation. These items were correlated with the Cooper-Harper Pilot Ratings. This led to the development of a pilot-rating expression based on rms state errors and pilot workload. This rating expression was used in a digital computer program to accurately predict pilot ratings and rms state errors using only the aircraft stability derivatives, airspeed, and altitude as inputs.

176. POWERED LUNAR RENDEZVOUS GUIDANCE

Lawrence E. Baugh, Jr, 1/Lt, USAF — 92p — GGC/EE/73-2
James E. Leach, 1/Lt, USAF — Lab Sponsor: AFFDL — AD 768355
Advisor: Maj J. Funk

A computer program was developed to simulate the rendezvous of an ascending lunar shuttle on a bielliptic transfer orbit with an earth shuttle on a free-return circumlunar trajectory. The effects of the gravitational perturbations due to the earth and sun on the transfer trajectory were corrected by an equation which predicted these perturbations. Finite burn periods were used for the transfers into the unguided coasting timing semi-ellipses. A previously proposed timing system was developed and refined. Two controllers were investigated for the terminal guidance portion of the rendezvous trajectory. A linearized suboptimal method was developed using a set of Riccati equations and was applied successfully. A "reduced-memory" optimization scheme was also developed, but could not be successfully implemented. Since the optimal control was not achieved by the attempted method, results are presented only for the linearized scheme.

177. SELECTION OF OPTIMAL STABILITY AUGMENTATION SYSTEM PARAMETERS FOR A HIGH PERFORMANCE AIRCRAFT USING PITCH PAPER PILOT

Robert P. Denaro, 2/Lt, USAF — 99p — GGC/EE/73-3
Garrison L. Greenleaf, 2/Lt, USAF — Lab Sponsor: AFFDL — AD 767879
Advisor: Lt Col R. Hannen

Pitch Paper Pilot is a computer program which yields pilot parameters for a pitch tracking task and predicts the pilot rating of the aircraft handling qualities. Using Pitch Paper Pilot, optimal SAS gains are

selected for the fixed form Stability Augmentation System of a high performance aircraft with structural bending. This aircraft was described in the Design Challenge to the 1970 Joint Automatic Control Conference. The final augmented aircraft responses compared favorably with desired normal acceleration response envelopes. The pilot model in Pitch Paper Pilot is modified in this study to include pilot lag and remnant which results in greater rating accuracy, although a few cases still show room for improvement.

178. THE SIMULATION AND ANALYSIS OF A NEW FIRE CONTROL TECHNIQUE FOR LAUNCHING AIR-TO-AIR MISSILES

Cecil D. Haas, 1/Lt, USAF — 110p — GGC/EE/73-4
Lee D. Puckett, 1/Lt, USAF — Lab Sponsor: AFFDL — AD 768353
Advisor: Capt D. DeDoes

Under controlled conditions the air-to-air missile has proben to be an effective weapon. However, this situation changes in the area of hard maneuvering combat where the missile system must perform under more taxing conditions. Techniques to remedy the deficiencies found in current systems range from hardware improvements to computerized methods for predicting missile firing opportunities. This study considers a fire control technique which predicts and displays a missile's maximum off-boresight capability and, in addition, allows the seeker to acquire non-boresight targets. The fire control computer considers such factors as the target's acceleration and range and the missile's performance. The philosophy of this approach is to reduce both the hardware and on-line computational requirements while incorporating pilot judgment as part of the solution to the fire control problem. To test the system's performance, both the target and attacking aircraft have been modeled in three dimensions and programmed for a hybrid computer utilizing an EAI 7800 analog computer and an EAI 8400 digital computer. The simulation is controlled by two pilots who have access to control sticks. The attacking pilot has the capability of launching air-to-air missiles when a firing opportunity is indicated. Both pilots observe their relative positions and accelerations as well as the in-flight missile on the face of a large cathode ray tube. The display is similar to that which would be observed by the attacking pilot through his heads-up display during actual combat.

179. APPLICATION OF THE AVIONICS MULTIPROCESSOR TO INERTIAL NAVIGATION

James A. Haugen, 1/Lt, USAF — 155p — GGC/EE/73-5
Advisor: Dr. G. Lamont — Lab Sponsor: AFAL — AD 768354

The Burroughs Avionics Multiprocessor System was developed as a flexible avionics computer system. Its flexibility was obtained through microprogrammability and modularity. One of its possible application areas is inertial navigation. The goal was to find the best system configuration and to microprogram it for inertial navigation. After examing the system organization and developing application specifications, it was decided that navigation computer emulation was the best way to apply the system to navigation data processing. This emulator is developed and a testing sequence set up. A program which solves the inertial navigation equations is also developed for the emulator. A program test sequence is given, including two simulated test flight paths.

180. OPTIMAL TRUNCATED-POWER-SERIES FOR DIFFERENT REENTRY PHASES

Phillip C. Hollister, 1/Lt, USAF — 72p — GGC/EE/73-6
Advisor: Maj J. Funk — Lab Sponsor: AFAL — AD 768356

The optimal reentry problem is formulated for a phase by phase planar trajectory. The reentry portion of the trajectory for a shuttle type vehicle is divided into two phases and each phase is treated as an individual optimal control problem. Optimization is with respect to (1) peak heat rate for the entry phase. (2) a combination of total control energy, total heat absorbed, and satisfactory end conditions for the glide phase, and (3) a total surface distance. The control for each phase consists of a truncated power series as a function of the system states and the independent variable range. The entry phase ends at pullup and has a single constant for control. The glide phase ends at conditions desired for a transition from a high to a low angle of attack, the transition phase is left for a later study. By process of elimination the glide phase control form is reduced to a constant plus two terms. Searching for the coefficients which optimize the power series is accomplished using Davidon's minimization routine. The optimal open-loop solution is converted to a sub-optimal adaptive controller by making the coefficients functions of phase initial conditions. The sub-optimal adaptive solution using a constant plus two terms is compared to a sub-optimal adaptive solution using a single constant. Results indicated that a constant adaptive controller is a reasonable sub-optimal solution for both phases.

181. PREDICTING PITCH TASK FLYING QUALITIES USING PAPER PILOT

Robert B. Johnson, 1/Lt, USAF — 136p — GGC/MA/73-2
Advisor: Maj J. Dillow — Lab Sponsor: AFFDL — AD 764698

A mathematical model for predicting the pilot rating of an aircraft in a pitch tracking task is described. The model includes: (1) the longitudinal-directional aircraft equations of motion; (2) a stochastic gust model; (3) a pilot model with two free parameters; and (4) a pilot rating expression that is a function of rms pitch angle, rms pitch rate, and the pilot lead time constant. The pilot parameters are then adjusted to provide at least a 20% stability margin, and the adjusted pilot parameters are used to compute a Flypaper Pilot rating of the aircraft/gust configuration. The Flypaper Pilot rating was computed for 32 aircraft/gust configurations. A range of actual ratings from 2 to 8 was encountered and the Flypaper Pilot ratings agree quite well with the actual ratings.

182. DETERMINATION OF REENTRY CORRIDOR WIDTH BASED ON HEATING

John J. Kessler, 1/Lt, USAF — 142p — GGC/EE/73-8
Paul D. Tofte, 1/Lt, USAF — Lab Sponsor: AFFDL — AD 768377
Advisor: Maj J. Funk

This report contains a two-dimensional study of the reentry corridor for lifting body reentry vehicles with available maximum Lift-to-Drag ratios of 1, 1.5, 2 and 3. The initial velocity range investigated is from 7.9 km/sec to 23.7 km/sec which encompasses reentry missions from near earth to interplanetary return. Two studies of the reentry corridor are presented: a constant control study where a specific constant control, angle of attack, was applied from reentry to capture; an optimal control method, Differential Dynamic Programming, was used to determine if the

angle of attack, was applied from reentry to capture; an optimal control method, Differential Dynamic Programming, was used to determine if the corridor width could be extended from that determined by the constant control by applying an optimal time varying control from reentry to capture. The results of the two studies show that the constant control window is a good approximation of the optimal control window. The boundaries of the reentry corridor are defined by capture and heating rate constraints. The capture constraint defines the overshoot boundary and is determined by an initial depression angle which allows the vehicle to reenter without exceeding a specified free flight apogee radius. The heating rate constraint defines the undershoot boundary and is determined by an initial depression angle which allows the vehicle to reenter without exceeding a specified maximum value of heating rate. A qualitative comparison between the optimal and constant control results is presented along with the results obtained by each method.

183. PRECISION RADAR POINTING AND TRACKING USING AN ADAPTIVE EXTENDED KALMAN FILTER

Raymond L. Kolibaba, 1/Lt, USAF — 85p — GGC/EE/73-9
Advisor: Lt Col R. Hannen — Lab Sponsor: AFAL — AD 768378

An Adaptive Extended Kalman Filter technique was developed to improve the tracking capabilities of an airborne tracking system. A maneuver determination technique was developed as well as an adaptive technique for the probability model of target acceleration. The computer simulation was run using four different types of data. Computation of the acceleration state was inaccurate due to imprecise modeling of the acceleration states. The adaptive technique reduced the range error of the non-adaptive filter. A maneuver was determined when a bias was detected on the range measurement residual.

184. BALLISTIC SKIP GUIDANCE FOR ATMOSPHERIC REENTRY

Melvin L. Nagel, 1/Lt, USAF — 48p — GGC/EE/73-10
Advisor: Maj J. Funk — Lab Sponsor: AFFDL — AD 768379

The feasibility of a reentry guidance scheme that utilizes ballistic flight to attain a variable surface range is investigated. The equations of motion are derived, and the reentry trajectory is divided into four phases: pull up, skipout, ballistic, and terminal. The pull up, skipout, and terminal phases are within the atmosphere, while the ballistic phase is outside the atmosphere. The conjugate gradient optimization method is used in the skipout phase to determine the reentry vehicle control needed to achieve the desired initial ballistic phase conditions. The cost functions uses the errors between the actual trajectory and a reference trajectory which is obtained by projecting a ballistic path into the atmosphere. The equations for the reference trajectory are presented. Ballistic theory is discussed and a parametric selection technique is presented as a means of determining the ballistic parameters needed for a specific range. An optimal control solution is found for one set of ballistic initial conditions.

185. BALLISTIC ENERGY PARAMETER CONTROLLER FOR ATMOSPHERIC REENTRY OF A LIFTING BODY

Dennis Navin, 1/Lt, USAF | 69p | GGC/EE/73-11
Advisor: Maj J. Funk | Lab Sponsor: AFFDL | AD 768380

A preliminary investigation was conducted on the usefulness of the non-dimensional ballistic energy parameter Q in a control scheme for the atmospheric reentry of a lifting body with a maximum L/D of 2. A feasible control scheme was developed that allowed onboard calculation of the angle of attack which was used as the control. The control scheme was used over a wide spread of surface ranges while still meeting criteria on heating rate, deceleration and obtaining a desired final velocity. The final altitude was near that desired. The control scheme is flexible in that it has the capability of updating itself continually as its states become better known and if the control becomes saturated for a part of the reentry trajectory the scheme will pick up again when the vehicle returns to a controllable state. The development was in two dimensional space and comparisons were made with desireable reference trajectories.

186. LANDING APPROACH AUTOMATIC FLIGHT CONTROL SYSTEM DESIGN VIA REDUCED ORDER OPTIMAL CONTROL LAW

Jerry D. Pfleeger, 1/Lt, USAF | 74p | GGC/MA/73-3
Advisor: Maj J. Dillow | Lab Sponsor: AFFDL | AD 760125

A set of optimal feedback gains is used as a basis for designing a practical longitudinal automatic flight control system for the landing approach task. A procedure is developed to give a good first-cut design. The procedure is systematic and straightforward. The procedure is used to design two control systems for a DC-8 aircraft. In one case it is assumed that pitch, pitch rate, normal acceleration, and longitudinal airspeed are continuously measured on board the aircraft. The second system is similar to the first with the exception that longitudinal airspeed is deleted as one of the measured variables. These systems are compared with a high-performance automatic flight control system that was designed using classical control techniques. The procedure is also used to design two control systems for a hypothetical aircraft with direct lift control capability.

187. ORBITAL PARAMETER DETERMINATION BY WEIGHTED LEAST SQUARE ERROR AND KALMAN FILTERING METHODS

Joseph J. Pollard, Capt, USAF | 145p | GGC/EE/73-13
Advisor: Lt Col R. Hannen | Lab Sponsor: NORAD | AD 757880

The Extended Kalman Filter and Weighted Least Square Error filtering techniques are used to determine estimates of the classical orbital parameters of a passive near-earth satellite. Modelling of the geopotential is complete through $J_{6,6}$. Modelling of the earth's atmosphere includes day-night variations as well as altitude variations. Kalman smoothing is also performed. Both filter techniques were used on a simulated orbit as well as a polar circular orbit and a low perigee eccentric orbit obtained from actual radar data. The determination of the orbital parameters of the simulated orbit yielded an absolute as

well as a relative comparison of the filter techniques. The analyses of the orbits determined from actual data yielded a relative comparison of the filter techniques. Comparable results were achieved with both filter techniques. Analyses include discussion of orbital perturbations as well as mean orbital elements. All orbits considered were multi-pass with a limited number of observations per revolution.

188. AN APPLICATION OF OBSERVERS TO LINEAR SYSTEMS WITH REDUCED STATE MEASUREMENT

Charles P. Pritzlaff, Capt, USAF — 262p — GGC/EE/73-14
Advisor: Capt D. deDoes — Lab Sponsor: AFAL — AD 768383

The problem considered in this report was the synthesis of control laws when all states of a system could not be measured. The study was restricted to linear, deterministic, and time-invariant systems. The problem was solved by the design of observer systems to estimate a linear functional of the full-state feedback control. Three distinct algorithms for designing an observer were tested. The first was a direct solution of the observer design equations and involved setting as many gains as possible to unity. The second algorithm minimized a cost function which was related to the magnitudes of the gains associated with the observer system. The final algorithm was designed to minimize the effect of known errors in the basic state equations on the accuracy of the observer design. Three different test systems were used to evaluate the performance of the algorithms and to investigate the effects of variations in the observer design parameters. As a final evaluation, the algorithms were applied to a system of current interest in the Air Force (C-130 Gunship). The following criteria were used to compare the observer systems: (1) magnitudes of the gains of the observer systems; (2) transient responses of the observer-augmented systems; and (3) locations of the closed-loop poles of the observer-augmented systems. It was found that observer-augmented systems, which performed satisfactorily when compared to the full-state feedback systems, could be designed by computer algorithms. Furthermore, the roots of the observer system could be specified by the designer. System gains were found to increase in magnitude as the root(s) of the observer were made more negative. Such large magnitude gains were found to be related directly to larger transients in the response of the observer-augmented systems. The following techniques were found to be successful in producing an observer design with lower magnitude gains: (1) changing the set of measurements; (2) increasing the number of measurements; (3) increasing the order of the observer; (4) changing the form of the matrix of the observer system (in which the observer roots were specified). It was determined that Algorithm II (minimized observer system gains) was the most effective of the design techniques because of the importance of reducing the gains in the observer system. Several modifications were proposed in the final chapter to improve the performance of the two computerized design algorithms. These recommendations are based on problem areas which were discovered in the course of designing observers for the test systems.

189. A STATE-VARIABLE DESIGN APPROACH FOR A HIGH-PERFORMANCE AEROSPACE VEHICLE PITCH ORIENTATION SYSTEM WITH VARIABLE COEFFICIENTS

Richard A. Ray, 1/Lt, USAF — 124p — GGC/EE/73-15
Advisor: Prof C. Houpis — Lab Sponsor: AFFDL — AD 761493

The purpose of this thesis is to design a simple state-variable feedback system to control a linear plant with variable coefficients. The solution of the problem was to determine the values of the constant feedback gains

based on a desired transfer function. This transfer function met all required time responses. One of the state-variables is an internal state and not available for measurement. This state is reconstructed using a minor-loop feedback circuit. A nominal set of conditions was selected for the plant and the feedback coefficients of the desired transfer function. Using the values of feedback coefficients determined above, the response of the control system was simulated at several flight conditions. The result and conclusion is that an insensitive state-variable system capable of handling large variations in plant dynamics may be successfully designed.

190. A SECOND ORDER METHOD FOR COMPUTING AN OPTIMAL REENTRY TRAJECTORY USING NUMERICAL DERIVATIVES

David Richards — 91p — GGC/EE/73-16
Advisor: Maj J. Funk — Lab Sponsor: AFFDL — AD 768381

The primary purpose of this study was to investigate a second order method using numerical derivatives to converge to an optimal set of initial costates that would produce an optimal reentry trajectory. A secondary objective of the research was to test the computational method by computing a minimum total heat input trajectory (two dimensional) for a lifting. It was assumed that the vehicle could attain a maximum lift-to-drag of 2.0 during its descent from a near earth orbit. The initial states are known, the initial costates are unknown, and only the final altitude at a fixed final range is specified. The second order method uses the first and second difference equations to iterate on corrections to an arbitrarily chosen set of initial costates. The corrections are based on minimizing a scalar terminal error function. The results indicate that the numerical integration errors limit too severely the accuracy to which the second partials of the terminal errors with respect to the initial costates could be estimated. Consequently, for the reentry problem considered the second order method did not show improvement over first order methods. But for similar reentry problem involving different boundary conditions and cost function and using a more accurate integration routine the method might prove worthwhile. Also, developing and applying an optimal stepping scheme could improve the convergence rate.

191. APPLICATION OF THE AEROSPACE MULTIPROCESSOR TO THE A-7D FLIGHT CONTROL SYSTEM

Robert R. Summers, Maj, USAF — 99p — GGC/EE/73-17
Advisor: Prof G. Lamont — Lab Sponsor: AFAL — AD 768382

The application of the Aerospace Multiprocessor as the flight control computer for a digital fly-by-wire control system for the A-7D aircraft is described. First a brief discussion of the evolution of flight control systems, ranging from mechanical to digital fly-by-wire, is presented. Next, the topic of digital computers for aircraft flight control is covered. First general computer characteristics are discussed. This is followed by an extensive discussion of Aerospace Multiprocessor characteristics and principles of operation. The present analog flight control system for the A-7D aircraft is described. Various methods of

digitizing the A-7D flight control system are considered. The Tustin method of digitization is covered at length, and difference equation derivations are shown in detail. The flight control microprogram written for the Aerospace Multiprocessor is described at a flowchart level. A multiply subroutine, written during this study, is described in detail. Then a description is given of the laboratory tests that were made with the Aerospace Multiprocessor programmed for flight control. Test results are discussed. Finally, the Aerospace Multiprocessor is evaluated regarding its suitability for use in a flight control application.

192. DESIGN AND INVESTIGATION OF A WIND-SHEAR-PROOF CONTROL SYSTEM FOR AUTOMATIC LANDING

Louis G. Trivett, 1/Lt, USAF — 78p — GGC/MA/73-4
Advisor: Maj J. Dillow — Lab Sponsor: AFFDL — AD 764697

An analog computer simulation of the longitudinal portion of an All-Weather Landing System is presented. The linearized longitudinal equations of motion of a DC-8 aircraft during landing approach are converted to state-variable form to facilitate the analog simulation. An Advanced Automatic Flight Control System is added and the approach phase of an automatic landing is simulated. A severe turbulence atmospheric environment consisting of wind gusts and wind shears is an integral part of the simulation. A systematic method is presented for developing a Kalman Filter based wind-shear-proofing system to reduce deviations from glide slope caused by wind shears. Performance of the All-Weather Landing System both with and without the wind-shear-proofing system is evaluated and a comparison of the results shows that the wind-shear-proofing system reduces deviations from glide slope due to wind shear up to 70%.

193. PILOT PARAMETER IDENTIFICATION VIA THE EXTENDED KALMAN FILTER

Stephen A. Walker — 123p — GGC/MA/73-5
Advisor: Maj J. Dillow — Lab Sponsor: ASD — AD 764694

The extended Kalman filter was used to estimate three pilot parameters, a pilot gain, lead time constant, and pure time delay. These parameters were estimated by defining them as states in an augmented state vector. The pilot model used consisted of a pilot gain, first order lead, and a Pade approximation of the pure time delay. The aircraft model consisted of the longitudinal short period equations plus a wind gust term. The accuracy of the estimated pilot parameters was determined by numerically comparing the true and estimated parameters and by model matching, that is, by comparing the transient responses of the pilot aircraft model containing the estimated pilot parameters with the pilot-aircraft model containing the true values of the parameters. The result of the study was that the good pilot parameter estimates could be obtained without good apriori estimates of the pilot parameters.

194. PASSIVE DETECTION AND RANGING OF A GROUND RADAR FROM AN AIRCRAFT USING AN EXTENDED KALMAN FILTER

David H. Watjen, 2/Lt, USAF — 102p — GGC/EE/73-20
Advisor: Maj P. Sproul — Lab Sponsor: AFAL — AD 760764

The dynamic equations between a moving aircraft and a stationary ground based radar transmitter are used to design an extended Kalman filter for determining the location of the transmitter with respect to the aircraft. Emphasis is

placed on obtaining the range of the transmitter from the aircraft. The only inputs available to the filter are the velocity and attitude of the aircraft and the bearing and elevation angles which the transmitters radar beam makes with the aircraft. The filter is implemented on a digital computer and its performance is observed for various flight paths of the aircraft. The time for the error in the estimate in range to decrease to specified values is tabulated for comparison.

195. NUCLEAR THERMAL VULNERABILITY OF HONEYCOMB RADOME MATERIALS

Michael V. Bell, 2/Lt, USAF — 83p — GNE/PH/73-1
Advisor: Prof C. Bridgman — Lab Sponsor: AFWL — AD 753666

The thermal vulnerability levels of honeycomb sandwich radome panels were determined by using quartz iodide lamps to irradiate the panels in a wind tunnel. The lamps and wind tunnel simulated a thermal pulse on a flying aircraft. The radome panels were tested with lamp-black, neoprene, and polyurethane coatings. The pulses delivered the thermal energy of up to 29.9 cal/cm^2 sec peak flux and 94.3 cal/cm^2 total fluence. The double honeycomb panel with polyurethane coating withstood a thermal pulse of 94.3 cal/cm^2 total fluence before the polyurethane coating had ablatted and the top layer of the radome panel had delaminated. The double honeycomb panel was still structurally sound, and the radar signal transmission was not seriously retarded. The single honeycomb radome panel withstood a thermal fluence of 59.9 cal/cm^2. The effects of this pulse were the same as the double honeycomb panel. A computer code using temperature independent properties was programmed and compared with the experimental tests. This code predicted the material's temperatures to within 5% until the material reached temperatures which melted the panel's resins.

196. DIFFUSION THEORY - A COMPARISON WITH TRANSPORT AND EXISTING CODES

Leonard A. Butler, Maj, USAF — 57p — GNE/PH/73-2
Advisor: Prof C. Bridgman — Lab Sponsor: AFWL

This report is an analysis of a computer code which uses diffusion theory to predict scattered neutron and gamma fluences in an exponential atmosphere for source altitudes between 7 and 100 kilometers. The diffusion theory results, or P_1 approximation, were obtained by separating the scattered and unscattered particles. The unscattered solution is exact, whereas the scattered solution is an approximation. The validity of the code was checked by comparison with some higher order methods of solution; namely, Straker's ORNL 4464, an $S_{16}P_5$ discrete ordinates solution; Webster's UCRL 50570, a Monte Carlo solution; and SMAUG and ATR, two direct look codes which use ORNL 4464 as a data base. Since ORNL 4464 and UCRL 50570 are based in an infinite homogeneous atmosphere, mass-integral scaling techniques were used in SMAUG and ATR to convert from an exponential atmosphere to the infinite, homogeneous medium. This report also contains an analysis of the mass-integral scaling techniques. Additionally, a particle conservation check was made on the diffusion calculations. Its purpose was to insure the accountability of all neutrons emanating from a point source. The analysis of this code found it to be within a factor of 2 when compared to the higher order methods out to a range of 12 mean free paths. Also, it did not contain the 25 kilometer restriction imposed by mass-integral scaling.

197. A CODE FOR ANALYSIS OF NUCLEAR EFFECTS AND SYSTEMS SURVIVABILITY

Harold E. Meisterling, Capt, USAF 326p. GNE/PH/73-3
Advisor: Prof C. Bridgman Lab Sponsor: AFWL AD 767888

This report contains the description of a computer code which calculates effects due to a nuclear burst, and determines the survivability of up to 100 selected vehicle positions. The effects calculated are those due to X-rays, neutrons, gammas, induced gammas, blast, and thermal. The code accepts as input: (1) the number and spectra of the nuclear bursts; (2) the vulnerability of the vehicles (one type at a time) to the various effects; and (3) the mission profile (initial positions and velocity vectors). The code then computes the level of each effect from each burst at each target position. If any effect level exceeds the vehicle's given vulnerability, that vehicle is assumed to be killed. In the case of blast only a probability of survival may be computed rather than a kill/no kill determination. The code is written in FORTRAN Extended for the CDC 6600 computer located at WPAFB. The code requires 290 seconds of computer time for each burst to be analyzed, and a central core of 156000 octal regardless of the number of bursts. This report is divided into five volumes. A user's guide to the code is presented in Volume I. Volume II presents a listing of the code and a brief description of each subroutine. Volumes III through V contain detailed descriptions of the calculation of effects due to blast and thermal, neutrons and gammas, and X-rays respectively.

198. DETERMINATION OF STABLE ELEMENTS IN AIR POLLUTION PARTICULATES BY NEUTRON ACTIVATION ANALYSIS

Jimmy A. Richardson, LtCol, USAF 101p GNE/PH/73-4
Advisor: Prof's J. Hagee & G. John Lab Sponsor: AFTAC AD 764715

Neutron activation analysis was used to determine the quantities of 13 elements in samples of atmospheric particulate matter. Quantities ranged from 0.35 micrograms of Se to 34 milligrams of Ca, which were 0.0002% to 15% of the samples by weight. Twelve other elements were identified, but not quantified. An 80-cm^3 lithium-drifted germanium detector with a resolution of 2.2 keV (FWHM) at 1.33 MeV and a 4096-channel analyzer were used for detection and counting of gamma radiation. Data were analyzed by SAMPO, a CDC 6600 computer program; details on the use of SAMPO are included. Techniques and methods of sample collection, sample preparation in quartz and polyethylene ampoules, and data reduction are reported. Procedures were developed for AFIT students to perform neutron activation analysis as a laboratory exercise. The importance of uniform neutron flux, absence of contamination, and accurate, known standards is emphasized. The spectra obtained by the Ge(Li) detector is compared to that from a 3" x 3" sodium iodide detector when samples were irradiated by fast neutrons produced by a 150-keV Cockcroft-Walton accelerator.

199. THE DESIGN AND TEST OF A HIGH-TEMPERATURE X-RAY SENSOR

Charles M. Snow, Capt, USAF 66p GNE/PH/73-5
Advisor: Prof G. John Lab Sponsor: AFFDL

A design and experimental study was made for a high-temperature application of an ionization chamber for the detection of low-energy (8-12 kev) x-rays. In the design of such an ionization chamber, particular attention was given to materials, vacuum integrity (necessary for application, but not for concept checkout), insulators, windows, size, electrode spacing, and filling gases.

Tests were conducted to determine saturation levels, leakage currents, response times, and ionization currents at temperatures up to 500°C. These tests demonstrated that such an ionization chamber is feasible although not all objectives were attained. Insulators used proved to be inadequate. Vacuum integrity was poor and leakage current exceeded the ionization current of 2.5×10^{-10} amps above 450°C. The response time of the chamber met expectations and was 0.3 ms @ 500°C, with 190 volts applied, and 785 Torr of argon. The response time was only 1 ms @ 25°C, but this larger value was mainly due to the increased density at this temperature (pressure was held constant at all temperatures, but density would be held constant in application). The steady state ionization current decreased with increasing temperature, but with constant pressure the density also decreased in about the same proportion, thus a decrease in ionization current was expected.

200. A DEVELOPMENT OF DETERMINISTIC AND STOCHASTIC TRANSFER PRICING MODELS AND THEIR APPLICATION TO DOD

James D. Bain, Capt, USAF — 63p — GSA/SM/73-1
Advisor: Prof Enzer — Lab Sponsor: AEDC — AD 769155

Attempts to initiate user funding at Arnold Engineering and Development Center (AEDC) in the 1968-1971 time period were very unsuccessful. At that time much of the failure was attributed to the uncertainty of demand for the facility's services. This thesis first examines the origination of profit centers and transfer pricing in the private sector of the economy and the manner in which these concepts precipitated user funding in DOD. Next it presents mathematical formulations of optimal transfer prices under static and deterministic market conditions. Conditions of stochastic market demand and cost are then applied to those formulations to provide optimal transfer prices using maximization of expected profit as the decision criterion. Finally the stochastic demand model is applied to a simplified Test and Evaluation environment in order to determine the form of the optimal transfer price at AEDC. Consideration is also given to the conditions surrounding use of transfer prices to improve efficiency and resource allocation in the government sector of the economy.

201. AN ANALYSIS OF THE PHASED INSPECTION SYSTEM FOR B-52H AIRCRAFT

Barry L. Barnes, Capt, USAF — 110p — GSA/SM/73-2
Advisor: Capt R. Tripp — Lab Sponsor: AFLC — AD 769154

An analysis of the phased inspection system was conducted for B-52H aircraft assigned to the 17th Bombardment Wing, WPAFB, based on 1972 historical data. The results indicated a wide interval variability between phased inspections for various aircraft, when the interval was measured in flying hours, calendar days, or sorties between phases. Certain performance measures were identified, such as code 2 and code 3 system malfunctions, late take-offs, mission cancellations, inspect and repair manhours, and aircraft nonavailability. These operational measures were generally found to be constant, regardless of interval length between phased inspections. Specifically, the per cent of code 2 and code 3 equipment malfunctions did not differ for various intervals between inspections. Based on the analysis, total costs of phased inspections could apparently be reduced, without a loss of system reliability, by increasing the number of flying hours between inspections.

202. A PROPOSED METHODOLOGY FOR WEAPON SYSTEM DEVELOPMENT RISK ASSESSMENT

Herbert L. Bevelhymer, Capt, USAF | 129p | GSA/SM/73-3
Advisor: Maj J. Hobbs | Lab Sponsor: ASD | AD 766885

Formal risk analysis has become a required part of the weapons acquisition process since 1969. Many methods of quantitative risk assessment require extensive data collection solely for risk purposes. Frequent assessments thus become costly. This thesis proposes a risk assessment methodology that uses contractor-reported data extracted from the standard Cost Performance Report and Schedule Status Report. A graphical network of a project is constructed using the symbology and logic available with the Venture Evaluation and Review Technique (VERT) computer routine. Each network arc is made to correspond with a contract work breakdown structure element. The marginal probability density functions of the network arcs are assumed to be Beta distributed. The parameters of each arc's time and cost distribution are determined using the contractor's monthly revised estimates for work breakdown element costs and completion dates and applying the method of moments. A test application on a weapons system currently in full-scale development was conducted. The test results, although inconclusive, did tend to show promise and merit further application of the methodology.

203. AN ANALYSIS OF THE EFFECT OF AIR CREW FACTORS ON B-52 BOMBING RESULTS

Kenneth H. Biehle, Maj, USAF | 55p | GSA/SM/73-4
Advisor: Lt Col C. Doryland | Lab Sponsor: SAC | AD 766887

This study examines the effect of aircrew and equipment factors on bomb scores achieved by electronically simulated bomb releases in B-52 aircraft. A total of 260 low level, synchronous releases performed by one SAC squadron over a six-month period were analyzed. Multiple linear regression analysis was used to analyze the effect of 16 crew factors and two equipment factors on bomb scores. At a .05 level of significance, no single crew factor was found to consistently affect bomb scores. It was also found that certain of the aircraft have a greater effect (either positive or negative) on bomb scores than any of the crew factors which were studied.

204. ESTIMATION OF AN AERONAUTICAL EQUIPMENT MISSION RELIABILITY

Robert N. Cockburn, Capt, USAF | 72p | GSA/MA/73-1
Advisor: Prof A. Moore | Lab Sponsor: ARL | AD 766886

This thesis develops methods for estimating the probability that an aeronautical equipment will operate satisfactorily for the duration of a specific mission. The failure times are modeled by exponential and Weibull densities. The parameters are estimated from multiple independent grouped and censored samples. Several estimation methods are developed for each model. In addition, the equations to obtain maximum-likelihood estimates are derived. However, they would have to be solved iteratively. Monte Carlo simulation is used to compare estimates with the data grouped and with the failure times known.

205. A METHODOLOGY FOR DEVELOPING SENSITIVITY ANALYSIS ON SPECIFIED DOD LOGISTICS SYSTEMS

Jerry M. Figgins, Maj, USAF — 204p — GSA/SM/73-7
Steven A. Thompson, Capt, USAF — Lab Sponsor: DOD — AD 766880
Advisor: Lt Col C. Doryland

This study adapts a location-allocation algorithm to assist in the economic analysis of (1) DOD depot storage policy and (2) optimum sizes and locations of depots. The model is unique in the manner in which it combines the parametric analysis of a DOD general depot storage system with optimization techniques to determine the most economical system under a given set of conditions. Input data is parameterized to allow the study of the effect of policy decisions on cost, as well as the tradeoff of inbound and outbound transportation costs with depot fixed and variable costs in determining an optimum. The model was applied to the Air Force distribution system on a short range time basis. The results were then used as the input data for example case studies to illustrate a methodology for using these results to provide information to decision makers. The model was also used in a study of the entire DOD general depot system. This analysis was a long range study to determine the possible optimum distribution system configurations in number, sizes and locations for varying levels of demand as well as varying patterns of production and demand distribution. The results of the study indicate that the model and methodology can provide information vital to effective utilization of the logistics dollar; however, the magnitude of the DOD supply effort is such that any continuous study demands the undivided attention of a full time analysis staff.

206. A CASE STUDY AND COST OF OWNERSHIP ANALYSIS OF THE USAF AN/APN-59B AIRBORNE RADAR REPLACEMENT EFFORT

Gary W. Holtz, Capt, USAF — 164p — GSA/SM/73-8
Advisor: Lt Col R. Lucas — Lab Sponsor: AFLC — AD 766884

This is a case study dealing with the USAF effort to provide improved navigational radar capabilities on aircraft currently employing the AN/APN-59B Radar Set. Two primary procurement alternatives were considered: (1) replacement of the present system with a newly developed configuration, designated the APQ-122(V)5, and (2) an update of the current system employing solid-state components, designated the AN/APN-59X. A brief history of the rationale and development efforts for each alternative was presented, along with an analysis of a field operational evaluation of the APQ-122(V)5 system. A comparative cost of ownership analysis has been conducted to determine the feasibility (from an economic viewpoint) of replacing the APN-59B system on the Air Force's fleet of KC-135's, C-130's, and C-141's with either of the two alternative proposals. This comparison was based primarily on APQ-122(V)5 performance data gathered during the field evaluation and historical data for the APN-59B supplied by Air Materiel Areas and Air Force maintenance records. Based on this analysis, the APN-59X update proposal appeared to be more cost effective, whereas the APQ-122(V)5 could not be justified for a total fleet retrofit. A similar cost of ownership study was also conducted to determine the feasibility of replacing the APN-59B system on only the Military Airlift Command fleet of C-141 aircraft. The

results of this study also showed the APN-59X to be generally superior economically to that for the APQ-122(V)5. General conclusions of the study, in addition to recommending the APN-59X proposal be adopted, were (1) that the rationale and methodology as applied to the APQ-122(V)5 field evaluation provide meaningful baselines for comparison in subsystem procurement efforts; (2) that the APQ-122(V)5 radar might be a desirable radar system for future weapons systems, providing the mission requirements were such as to justify its sophistication; (3) that much uncertainty exists over the criteria to be used for determining justification of airborne systems retrofit; and (4) that additional consideration should be given to improving the methodology for both gathering aircraft system sustaining costs and for its use in conducting future cost analyses.

207. ROBUST ESTIMATION OF LOCATION AND SCALE PARAMETERS

Loren W. Jorgenson, Capt, USAF — 95p — GSA/MA/73-2
Advisor: Prof A. H. Moore — Lab Sponsor: ARL — AD 766882

A Monte Carlo analysis was performed to determine the efficiency of the Harter robust estimators of the scale and location parameters of double exponential, normal, and uniform distributions relative to the maximum-likelihood estimators. Two modifications were made to the Harter estimators which increased the relative efficiency except when the underlying population was uniformly distributed. The modified estimators were then designated the Moore estimators and the Jorgenson estimators. Tables were prepared comparing the relative efficiencies of the Harter, Jorgenson, Moore, Hogg, Hodges-Lehmann, and the Switzer robust estimators of the location parameter for the double exponential, the normal, and the uniform distributions for samples of size 12 and 24. Two types of figure of merit were define for a robust estimator. The choice of the best robust estimator is a function of sample size and the criteria used.

208. A COST EFFECTIVENESS ANALYSIS OF AN AIR COMBAT SIMULATOR

Donald Z. LaRochelle, Maj, USAF — 84p — GSA/SM/73-10
Advisor: Prof Enzer — Lab Sponsor: AFLC — AD 770577

This study provides a general description of the design and features of the Simulator for Air to Air Combat (SAAC). The limitations of the research in transfer of training prevent the prediction of the effectiveness of a simulator, but a qualitative technique (Stimulus-Response Analysis) does point to the existence of positive transfer in the SAAC. The cost effectiveness analysis is carried out with the transfer of training treated as a variable. The results of the investigation indicate that the exact measure of transfer is not essential to the training device.

209. A SIMULATION STUDY OF THE FORCE MIX PROBLEM IN CLOSE AIR SUPPORT OPERATIONS

Dennis K. Leedom — 210p — GSA/SM/73-11
Arnold R. Thomas, Capt, USAF — Lab Sponsor: ASD — AD 766879
Advisor: Maj J. R. Hobbs

A computer program was designed and constructed which simulated the operation of a single combat aircraft squadron in a close air support situation. The simulation model was specifically designed to highlight differences in

effectiveness, vulnerability, availability, and cost between two aircraft with two different degrees of avionics sophistication. A weather model included in the simulation was based upon an analysis of long-term climatological records compiled from hourly weather observations at Bitburg Air Base, Germany. A hypothetical example was used to demonstrate the utility of the simulation model. Specifically, two different types of aircraft were postulated and used in the close air support squadron. Results of this example showed that the increased costs of advanced avionic equipment can be justified on an attrition cost per target killed basis. Furthermore, the use of a mixed aircraft squadron was shown to result in higher target kill rates under certain conditions. Weather conditions were shown to have a significant effect on squadron performance with attrition costs rising during bad weather conditions. An analysis of the simulation model along with the results of the hypothetical example led to the conclusion that the model could serve as a useful tool for studying the close air support problem. Specific areas capable of being addressed by the simulation model are (1) force-mix studies, (2) avionic equipment tradeoff studies, and (3) sensitivity studies examining particular portions of the close air support operation. Finally, the Markovian model developed from historical weather data provided a good representation of the weather throughout the simulation experiments.

210. RISK ASSESSMENT

Hamilton T. Lenox, Maj, USAF | 169p | GSA/MA/73-3
Advisor: Prof A. H. Moore | Lab Sponsor: ASD | AD 767871

Risk assessment became an integral part of the DOD system acquisition process in 1969 as a result of various letters and directives. An extensive literature search was conducted and the past efforts to define or derive a valid risk assessment program were reviewed. Literature of a general nature but applicable to the techniques used in assessing risk is compiled in a general reference bibliography. The primary effort of this paper was directed at exploring past attempts to quantify risk, and while the qualitative measurement of risk is mentioned, it is not explored in any depth. An attempt is made to define or describe the manner in which risk analysis varies throughout the system acquisition life cycle and a methodology using Bayes' Theorem is presented for the quanitfication and updating of risk in an on-going program. The uncertainties associated with the acquisition process are discussed in some detail. These uncertainties must be recognized and accurately transmitted through the estimates used in the risk analysis if it is to result in a valid assessment which can be used by the decision maker. The methods of estimating parameters and their usefulness in a formal analytical process are discussed. The probability density function best transmits the uncertainty associated with an estimate and lends itself more readily to the analytical techniques than other methods of estimation.

211. AN ANALYSIS OF THE RELATIONSHIP BETWEEN TECHNOLOGY AND COST OF AIRBORNE COMMUNICATIONS SYSTEMS

Michael J. McEuen, Capt, USAF | 87p | GSA/SM/73-13
Advisor: Prof Enzer | Lab Sponsor: AFAL | AD 766888

Statistical cost estimating techniques are used to analyze the relationship between technology and cost of airborne communications systems. The basic model examined is a two-stage model developed at the Rand Corporation for aircraft turbine engines. Multiple linear regression is used to initially develop a technological index for each system; and then this index is included in the cost equation to determine if the index improves the cost model to a significant degree. The technological index used is the date an airborne communications system can be expected to be operationally available. This date is calculated by regressing technical variables, which are meant to describe the technology of the system, on the actual date that the system is in use in the field. The actual date is the date of the basic Technical Order of each system, from which the technical data were gathered. The results are inconclusive, as high coefficients of determination are not obtained. The mere addition of the actual date at which a system is available in the field to the cost equation improves the statistics of the cost model more than the technological index. This may be due either to the effect of learning on more recent systems or to the effect of non-technological factors.

212. TACTICAL FIGHTER/SRAM WEAPON SYSTEM DESIGN STUDY

Michael P. Bess, Lt, USAF, Julian H. Chockley, Capt, USAF, Bill Elsner, Ronald R. Grawert, Lt, USAF, Donald J. Kosco, Lt, USAF, Iowa H. Lynn, Lt, USAF, Donald W. Montgomery, Capt, USAF, Donald L. Newman, Lt, USAF, Norris O. Olson, Maj, USAF, Thomas M. Palmer, Capt, USAF, Gary E. Rosing, Lt, USAF, James A. Saber, Maj, USAF, Robert G. Schwartz, Maj, USAF, L. V. Seeber, Lt, USAF, Marvin Spector, T. N. Stierman, Capt, USAF, R. M. Teitel

Advisor: Dr. L. E. Wolaver | GSE/SE/73-1 | Lab Sponsor: ASD
AD 527595L (Vol I) | AD 527596L (Vol II) | AD 527597L (Vol II

The integration of the Short Range Attack Missile (SRAM) with fighter aircraft for use in the tactical nuclear environment is investigated in three general areas: (1) The proposed designs and major engineering problems identified for each of three fighter aircraft (F-111D, A-7D, and F-4D). (2) A comparison of the relative merits of the three fighter/SRAM systems. The results of the mission analysis and the five decision variable studies--range performance, survivability, reliability, weapons effects, and cost--were used to formulate a comparative analysis. (3) Related considerations. This includes comparison of SRAM to nuclear bomb delivery and the effect of equipping the SRAM with a terminal guidance device. The fighter/SRAM system is a viable system for use in the tactical nuclear environment. The information contained in this report should provide the decision-maker with the facts necessary to evaluate procurement of a fighter/SRAM system.

213. A COMPARATIVE ANALYSIS OF THE PROPOSED NEW MILITARY NONDISABILITY RETIREMENT SYSTEM

Darrell L. Anderson, LtCol, USAF — 136p — GSM/SM/73-1
Advisor: Col R. Yantis — Lab Sponsor: DOD — AD 770573

Considerable pressure is being brought to bear on the Department of Defense to lower the level of military spending. One aspect of this spending which has become very visible recently, and which is considered excessive by critics of military spending , is the military retirement system. In an effort to devise a system which will maintain the desired motivational effects while reducing the expenditure for retirements, the DOD Retirement Study Group has developed the New Revised Military Nondisability Retirement System. If this system is adopted, the Study Group claims that it will produce a dramatic reduction in expenditures. The objective of this thesis is to make a comprehensive evaluation of this Proposed System and compare it to other retirement systems. Judgements about the merits of the various characteristics of the systems studied will be from the individual's standpoint. That is, characteristics of the system are judged solely upon their advantages to the individuals subject to the system. The bases for comparison of the system are (1) eligibility requirements, (2) contributions, (3) vesting, (4) early retirement, and (5) retirement benefits. The other systems with which the Proposed System is compared are the Extant System, the Civil Service system, and retirement systems available to airline pilots, policemen, firemen, and members of the Canadian and German military establishments. No universally acceptable overall evaluation of the Proposed System can be made as a result of this study. Within the framework of values possessed by the writer, however, the Proposed System is judged to be superior to all other systems studied except the Extant System and the airline pilot's system.

214. A STUDY OF THE PERSONAL VALUE SYSTEMS AND OPERATIVE GOALS OF MINUTEMAN MISSILE OPERATIONAL CAREER FIELD.

Larry C. Bagley, Capt, USAF — 215p — GSM/SM/73-2
Advisor: Maj R. Manley — Lab Sponsor: HQ USAF — AD 773797

The primary objective of the research was to gain insight into personal values and goals of Minuteman Operational Officers. Of the 653 questionnaires distributed, 392 were returned with usable data. Thirty nine percent of the sample had a Moral-Ethical primary orientation (POR), 32% a Mixed POR, 24% a Pragmatic POR, and 5% an Affect POR. The POR percentages were similar to those observed in studies of New York Telephone Managers, College Seniors, and Union Leaders. The hierarchy of values and of goals for Minuteman officers reflect internalization of the official goals and primary mission of SAC by the personnel. There were indications that "mission" oriented official goals receive less support than "personnel" oriented official goals. The apparent lower level of support for the "mission" goals was viewed as probably being more a result of the perceived level of military threat than a real lack of support. Contingency table analyses of the personal and organizational variable classifications, and the behavioral relevance of

values and goals revealed 308 differences at the 0.05 level of significance. The majority of the differences centered about age-related variables, career intentions, Regular or Reserve Commission, job satisfaction scores, and POR. The variable POR accounted for the greatest number of significant differences. The study of the personal values of Air Force personnel can provide valuable information to the Air Force decision makers. With this information, decision makers may be better able to assess the impact of, and response to Air Force decisions, policies, programs, and goals.

215. PERSONAL VALUE SYSTEMS AND CAREER OBJECTIVES OF MEN VIS A VIS WOMEN AIR FORCE OFFICERS

Charles W. Bartholomew,LtCol,USAF 282p GSM/SM/73-3
Advisor: Maj R. Manley Lab Sponsor: HQ USAF AD 769932

Basic objective of this research was to compare the personal values and career objectives of Air Force women to Air Force men. The research used a personal values questionnaire to establish which values and objectives were most likely to be translated into behavior. Values and objectives of 307 women officers and a control sample of 323 men were analyzed using chi-square contingency table analyses. Women were found to take a more normative, less pragmatic approach to their jobs. "Conventional wisdom" that women do not seek careers or responsible jobs was refuted. Both men and women were found to value enriched, responsible jobs. Women appeared to be at least as positively career inclined and more dedicated to their organizations than men with the same time in service. Implications were found for policy improvements concerning participative management, personnel system flexibility, and consideration in recruiting and assigning Air Force couples. Equal sex opportunity and continued availability of quality, low-cost medical care were also highly valued by respondents.

216. AN ANALYSIS OF SUPERVISORY PERCEPTIONS REGARDING THE ADVANCED ACADEMIC DEGREE MANAGEMENT SYSTEM

Danny A. Beam, Capt, USAF 66p GSM/SM/73-4
Advisor: Col R. Lucas Lab Sponsor: HQ AFSC

This research effort is devoted to an analysis of supervisory perceptions regarding the effectiveness of the Advanced Academic Degree Management System (AADMS) used by the Air Force. This research examines the perceptions of supervisors working in the Scientific and Developmental Engineering area in six AFSC organizations at WPAFB, Ohio. This study contains background material on past Air Force programs for the management of advanced degree resources. The study also contains a review of the current Air Force advanced degree management system, AFM 36-19, upon which this study is based. The results of the analysis of the perceptions of supervisors who had and had not used the AADMS showed that the system was only partially effective. It was judged to be less than totally effective because of the number and significance of the problems revealed by the supervisory perceptions. The problem areas of the AADMS were: (1) the objectives; (2) the policies; (3) the criteria for identifying advanced degree requirements; (4) identification of future requirements; and (5) satisfaction of supervisory manning needs.

217. A REVIEW AND ANALYSIS OF TRAINING PROGRAMS USED BY INDUSTRY AND THE U.S. AIR FORCE FOR THE FIRST-TIME SUPERVISOR

Stanley K. Burghardt, Maj, USAF — 179p — GSM/SM/73-5
Jessie J. Lundy, Capt, USAF — Lab Sponsor: AFLC
Advisor: Dr. R. Klug

The primary purpose of this study is to compare and contrast the first-time supervisory training programs of the Air Force with the supervisory training programs of civilian industrial firms, professional management associations, and other government agencies. The information is categorized into three main classifications: (1) Management Fundamentals; (2) Human Relation Fundamentals; and (3) Supervisory Skills and Techniques. Each of the classifications are presented and discussed as to the topical areas presented, and an analysis of the responses is accomplished in order to compare and contrast Air Force programs of the other respondents. The Air Force programs reviewed were determined to provide the first-time supervisor with an adequate background as compared to the majority of others reviewed. There were deficiencies noted in the Air Force programs in certain topical areas as to the subject material covered. Recommendations are made to correct the deficiencies that were noted. The recommendations suggest that a specific supervisory program be studied for possible inclusion into Air Force programs.

218. A STUDY IN AIR FORCE SUPERVISION - AN ANALYSIS OF THE PROBLEMS ENCOUNTERED IN THE TRANSITION FROM OPERATIVE EMPLOYEE TO SUPERVISOR

James W. Coffman, Capt, USAF — 110p — GSM/SM/73-6
Roger G. Longenbach, Capt, USAF — Lab Sponsor: AFLC — AD 769503
Advisor: Dr. R. Klug

Supervisors are often considered to be the keystone of an effective organization. A concern of the writers was that many Air Force personnel may be placed in an initial supervisory assignment with inadequate supervisory skills, knowledge, or understanding of personnel supervision and management. The purposes of this study are to examine the nature of the first supervisory assignment of Air Force personnel and the transition from worker to supervisor. Areas examined include the training and preparation received or recommended for the initial supervisory assignment; the supervisory skills, techniques, and practices applied; the amount of time allocated to supervision; and the problems, difficulties, and frustrations encountered. Data for the research were gathered through face-to-face interviews administered to a total of 264 WPAFB personnel, categorized as either potential, first-time, or experienced supervisors. The respondents were military and civilian employees assigned to AFLC; 2750th ABWg; ASD; ARL; AFIT; FTD; and the 17th Bomb Wing, SAC. Open-ended questions, which addressed the objectives of the study, enabled the subjects to add any thoughts or comments not covered in the specific questions. The category of "Human Relations" was considered by the respondents to be the most important area of supervisory skills and problems.

219. FROM MIS TO MBC: AN INVESTIGATION INTO WHY ONE CORPORATION ELIMINATED ITS COMPUTER-BASED MANAGEMENT INFORMATION SYSTEMS

Dennis L. Constant, Maj, USAF — 205p — GSM/SM/73-7
Advisor: Lt Col C. Doryland — Lab Sponsor: AFIT — AD 770574

The early management of the Aerojet-General Corp. was technically oriented. As the corporation grew in size, the technically-oriented managers slowly drifted from a collegial style of management toward a more centralized style of management. Beginning in 1964 the military market of Aerojet began to rapidly disappear as national priorities changed. As a result of this diminishing market, the corporation began to seek new markets while becoming increasingly more standardized in management procedures and while increasing its use of computer-based management systems. By 1969 the corporation was spending approximately $10 million annually on computer support, while corporate sales and profit plummeted downward. In November 1969, a new management structure was established within the corporation. The new structure centers around a decentralized approach to management, based on the concept of management by objectives. Additionally, the computer-based management systems were eliminated as managers gained exposure to the new management style. Since 1969 the financial performance of the corporation has improved dramatically. In the opinion of the writer, there are important lessons to be learned from an analysis of the experiences of the Aerojet-General Corp. These lessons relate to management perspectives on the role of computers in decision-making, MIS design, the need for a periodic management audit of a corporation and the practice of management by objectives

220. AN EXPLANATION AND COMPARISON OF THE ZERO-ONE INTEGER PROGRAMMING ALGORITHMS OF BUSH, BALAS, AND HEALY AS USED ON A PARTICULAR RESOURCE ALLOCATION PROBLEM

Nicholas R. Duva, Capt, USAF — 82p — GSM/SM/73-8
Advisor: Col R. Yantis — Lab Sponsor: AFIT — AD 773796

Problem manipulation has been defined as the restatement of a mathematical programming problem in an alternative, but essentially equivalent form, more amenable to solution than the original. Richard L. Bush was interested in a particular type of problem manipulation which resulted in an equivalent knapsack problem form for a mathematical programming problem. His algorithm for solving knapsack problem is a zero-one integer programming algorithm which he called a "single branch implicit enumeration." Stanley Zionts' modification of Balas' method of implicit enumeration minimizes zero-one integer programming problems with "less than or equal to" constraints. The program translates any problem submitted into an equivalent problem with non-negative coefficients in the objective function. The drive of the algorithm is toward feasibility. The Healy algorithm is applicable where variables must be either or one, and the variables are divided into integer sets such that the variables in each set sum to unity. The basis for the algorithm is the generation of new constraints for a linear programming problem, which are based on changes which will occur in the value of the objective function if the different variables within an integer set are set equal to one. The writer presents a detailed explanation and comparison of these algorithms as used on a particular resource allocation problem.

221. THE CIVILIAN INDUSTRY PROGRAMS TO COMBAT TECHNICAL OBSOLESCENCE: APPLICATIONS TO THE MILITARY COMMUNICATIONS FIELD

Heiki Ellermets, Maj, USAF | 146p | GSM/SM/73-9
Advisor: Col R. Lucas | Lab Sponsor: AFSC | AD 768384

This study was performed to determine how an industry, comparable to the Air Force communications field, addresses the potential technical obsolescence problems within management personnel in similar positions to the Communications Systems Staff Officers (AFSC 3016). The lessons learned from this closely related civilian industry (Bell System) have been combined with parts of existing USAF training programs to construct a model for an alternate technical training progression for officers in the 30XX career field. Six areas have been adapted from the Bell System for inclusion in the alternate training model, providing for: (1) A change to shorter training periods but including participation by more officers. The training periods would be divided over a longer period of time during the individual's career. (2) A change from generalized training to a more task (job) oriented training. This feature would prepare the 30XX officer for the current job after each change of assignment. (3) A change from ECI to self-study programs. These would provide for more personal contact between trainee and instructors and more frequent updates for the course. (4) Task oriented course development program. Under this concept a detailed study of the tasks and information on accomplishment of these provides the basis for the course curriculum. (5) A pre-testing program. Prior to the attendance of each training course, each trainee would be tested and locally trained to the course entry prerequisite level. (6) USAF sponsored membership in professional associations. This membership would assist in an exchange of ideas at the technical level and receipt of new information concerning changes in the C-E specialties. It is anticipated that use of the technical training program proposed in the model would result in a lesser degree of technical absolescence as the officer progresses through the company grade ranks and while performing duties as a Communications Systems Staff Officer.

222. APPLICATION OF SERVICE FUNDING IN USAF RESEARCH AND DEVELOPMENT SUPPORT FACILITIES: A CHRONOLOGY

Harley P. Garrett, Jr., Maj, USAF | 159p | GSM/SM/73-10
Advisor: Lt Col C. Doryland | Lab Sponsor: AEDC

Between 1968 and 1971 the Air Force installed a service fund at Arnold Engineering Development Center (AEDC). Under the service fund the costs for performing developmental testing for projects such as B-1, F-15, etc. were passed on to the system program offices (SPO's). The SPO's were required to budget and pay for the tests they needed at AEDC. The requirement for a service fund was based on improving the effectiveness and efficiency with which the AEDC resource was allocated and used. The objective of this thesis is to examine the issues which impacted on this efficiency and effectiveness. Using contract costs with ARO Inc., the local contractor who operates the AEDC, as input measurements and using test cell occupancy hours and annual projects tested as measures of output, the writer concludes that a decrease in efficiency took place during the service fund years. Effectiveness, however, as measured by the surrogate criterion for measuring mission accomplishment was the annual number of

projects tested. The decreased efficiency caused by the service fund was largely a result of reduced test requirements by the major SPO's. These reduced requirements were primarily due to the fact that the SPO's were obliged to include cost of testing as a criterion in decisions regarding AEDC testing. The increase in effectiveness of mission accomplishments, as shown by the increase in projects serviced, was the result of a common base for competion (e.g. costs) established by the service fund.

223. PROBLEMS ENCOUNTERED IN IMPLEMENTING DESIGN TO A COST IN MAJOR AIR FORCE WEAPON SYSTEM ACQUISITION PROGRAMS

Stephen A. Hamer, Maj, USAF — 103p — GSM/SM/73-11
Advisor: Col R. Lucas — Lab Sponsor: ASD — AD 769912

Increasing pressure to reduce defense spending has encouraged new approaches to managing weapon system acquisition and ownership costs. The design to a cost concept is one of the newest approaches to cost reduction in DOD. Design to a cost is the process of controlling cost by treating in established cost target as a parameter of equal importance with system performance. The SCAD program attempted to incorporate design to a cost in its full scale development contracts through the changes clause but found the cost prohibitive. Since the contracts had been signed, the SPO was negotiating with sole-source suppliers. The A-X program implemented design to a cost in the competitive prototype phase. The target cost was set at $1.4 million unit production flyaway cost. The Fairchild-Republic A-10 was selected as the winning design. The contractors design to a cost program met the cost target and encountered minor problems in its operation. The AMST is a prototype program with a design to a cost target of $5 million unit production flyaway cost. McDonnell-Douglas and Boeing are in the design phase with their individual proposals. Both contractors are operating within budget constraints but are vigorously pursuing the design target cost. Some problems in communication of the priority to be given to cost had to be overcome, but serious problems in operating with design to a cost have not been encountered by either AMST contractors.

224. A COMPUTER SIMULATION STUDY OF ANNUAL OPERATING PARAMETERS OF CURRENT AND FUTURE DOD STORAGE FACILITIES

Robert A. Liske, Lt Col, USAF — 208p — GSM/SM/73-12
Lawrence R. Hubbard, Lt Col, USAF — Lab Sponsor: DOD — AD 773795
Advisor: Lt Col C. Doryland

This research is a part of the effort to understand current warehousing and storage facilities of DOD in an attempt to project the likely outcome of future policy decisions. Automation and aggregation are key ideas. To assist in the study of these ideas this research was directed toward the formulation of a computer simulation of the warehousing facilities as they existed in 1970 and of the facilities of the near future as envisioned by the Task Group 5-70 Phase II report. The 1970 version was termed "manual" and the Phase II projection was termed "automated." The simulation used Federal Stock Numbers (FSN) stocked as the measurement of facility size. Thus this FSN level dictated the activity level in terms of line items, pieces and packages handled which are the parameters used to determine direct manhours required for daily operations of the facility. An analysis of several operating parameters of the "manual" facility are made and compared to those same parameters of the "automated" facility of the same FSN level.

225. A COMPUTER SIMULATION EVALUATION MODEL FOR UNITIZED, CONTAINERIZED CARGO TRANSPORT SYSTEMS

Harold F. Kelley, Capt, USAF | 121p | GSM/SM/73-13
Advisor: Capt R. Tripp | Lab Sponsor: AFLC | AD 770572

The economic advantages of cargo containerization are such that incomplete utilization of the container internal volume for source-to-user shipments is practicable. From this basic hypothesis, a decision criterion is developed for selecting cargo transportation containers or families of containers which best satisfy the various system cargo transportation characteristics. The methodology uses a computer simulation model to economically compare alternative containers when consideration is given to the specific container type, the network travel paths, destination cargo item characteristics, and the destination demand differences. Selected transportation expenses are accumulated by the simulation model when the alternative containers under consideration are employed in a daily destination resupply operation. In determining daily destination cargo transportation costs, a capability exists to define for each destination the expected cargo item density, length, width; the destination fractional depot demand; and the destination distance from the depot. As individual destination demands are allowed to increase, a level is attained where it becomes economically feasible to use a larger container for that destination fractional depot demand. This level, called the economic break-even point, is expressed in the required destination cargo usage of the larger containers' internal volume.

226. COST EFFECTIVENESS ANALYSIS FOR DRONE TACTICAL AERIAL RESUPPLY SYSTEMS

Michael K. Kelly, Capt, USAF | 100p | GSM/SM/73-14
Advisor: Lt Col C. Doryland | Lab Sponsor: TAC | AD 772240

This study develops a simulation model which can be used to assist in making decisions among competing aerial delivery systems for emergency resupply. It is the result of a request by Tactical Air Command for an examination of the possible use of drone systems for the resupply role. Although the examples covered are concerned with drone type systems the simulation model can easily handle manned systems. The methodology involves the use of a cost structure which can and should be altered to fit the simulation under investigation. The simulation model uses the operational characteristics of the competing systems and characteristics of the scenario to provide information required for use with the cost structure. Analysis of the results indicates that the choice of the most cost or exclusion of replacement costs. Other critical parameters were survivability, payload weight and drop accuracy of these survivability is the most difficult to obtain and the most essential for a meaningful analysis.

227. THE TRANSITION OF F-111 INTERMEDIATE LEVEL AUTOMATIC TEST EQUIPMENT SOFTWARE RESPONSIBILITY FROM AFSC to AFLC: A CASE DESCRIPTION & ANALYSIS

Frank T. Kimball, Maj, USAF | 185p | GSM/SM/73-15
Advisor: Col R. Lucas | Lab Sponsor: AFLC | AD 916530L

This thesis is an investigation into the F-111 intermediate level automatic test equipment (ATE) software transitioning problem which is unresolved at the time of this writing (July 1973). The nature

and purpose of transition is discussed with emphasis on the current transition environment that exists within AFSC and AFLC. A comprehensive description of F-111 intermediate level ATE software and software management tasks is presented. The development of this software transitioning problem is described from its earliest symptoms to its present proportions. With the aid of an open-ended questionnaire, the writer has identified and analyzed the basic causes and contributing factors. A possible immediate solution to this particular F-111 transitioning problem is presented. Finally, several major recommendations are offered covering the central themes of inadequate knowledge of ATE software, the deficiencies of the current transition process, and new procedures for handling ATE software during the five phases of the weapon system acquisition process.

228. A COST EFFECTIVENESS APPROACH FOR AIRCREW TRAINING WITH LASER GUIDED TACTICAL WEAPONS

Claude G. Kincade, Maj, USAF	179p	GSM/SM/73-16
Advisor: Prof J. Cain	Lab Sponsor: ASD	AD 916531L

This study is directed toward development of a methodology to help identify optimal aircrew continuation training systems for use in the tactical air forces. The area of training for employment of laser guided weapons was selected to provide a realistic example for an illustrative cost effectiveness analysis. Data combined from interviews with fourteen aircrew members with laser combat experience were used to establish estimated aircrew continuation training requirements for five mutually exclusive alternative methods of training for employment of laser guided weapons. The main criterion used to evaluate the effectiveness of a proposed aircrew training system was whether or not it was judged by the individuals interviewed to be capable of maintaining an acceptable level of combat readiness for the tactical air forces. Ten sub-criteria for tactical aircrew training systems were developed and applied to the five alternative training systems. Examples of the estimated economic costs of the resources required for each alternative to produce the required level of combat readiness were provided for purposes of cost comparison of the alternatives. Further study is suggested for a satisfactory method of measuring the effectiveness of laser tasked aircrews.

229. A MONETARY REPAYMENT MODEL FOR RECOUPMENT OF THE EDUCATIONAL COSTS OF AIR FORCE SPONSORED GRADUATE EDUCATION IN LIEU OF COMPLETION OF AN ACTIVE DUTY SERVICE COMMITMENT

Sanford D. Mangold, Capt, USAF	154p	GSM/SM/73-17
Advisor: Col R. Lucas	Lab Sponsor: AFIT	AD 768385

This study develops a model which enables the Air Force to initiate recoupment action against any officer, who is separating from active service prior to the completion of a graduate education ADSC. It is set up to determine the amount of money owed by the early exiting officer, at any point in the ADSC. The recoupment model is placed into the framework of the average annual wage rates commanded by individual graduate degrees in the civilian work environment. This wage data is derived from the 1970 Census of the United States population. The procedure is to measure the average wage rate of specific graduate and undergraduate degrees, and to calculate the

difference between them. This difference is assumed to approximate an economic measurement of the additional work productivity, that the Air Force can expect from an officer by virtue of his graduate education. This differential amount is then placed into a recoupment scheme, whereby an officer repays the cost of his USAF sponsored graduate education in monetary form, if separated prior to ADSC completion. During a sample application of this model, it was discovered, that while the model appears workable for officers who have attained USAF sponsored Masters' Degrees, more analysis will be required to make the model applicable to those who have earned PhD's. (Exception: The model appears workable when applied to most medical related graduate degrees). The model estimates total amount owed by an early exiting officer, as a function of the following variables: the direct cost to the Air Force of the officer's graduate education; the amount of time served in the associated ADSC; the type of graduate degree earned at Air Force expense; and the type of degree possessed by the officer prior to graduate school attendance.

230. GOAL PROGRAMMING

Ronald J. Marini, Capt, USAF	94p	GSM/SM/73-18
Advisor: Col R. Yantis	Lab Sponsor: AFIT	AD 773037

A tutorial development of goal programming is presented. Special emphasis is placed on model formulation and the nature of the weighting factors in the objection function. Several solution techniques are discussed and a method for utilizing a conventional linear programming computer solution package for goal programming is presented.

231. ANALYSIS OF PERSONAL VALUE SYSTEMS AND OPERATIVE GOALS OF SAC MINUTEMAN MISSILE MAINTENANCE OFFICERS

Dennis F. Markisello, Capt, USAF	224p	GSM/SM/73-19
Advisor: Maj R. Manley	Lab Sponsor: SAC	AD 769931

The objectives of this study are to establish hierarchies of personal value concepts and operative goals of missile maintenance officers, to compare and contrast official and operative goals, and to find if the valuations vary with demographic variables. These are all accomplished. This thesis utilizes the methodologies of Dr. England and Dr. (Major) Manley concerning personal value systems and operative goals respectively. Five Minuteman missile wings were polled with 97 out of 168 questionnaires returned. The primary orientation of missile maintenance officers is decidedly moral-ethical with a greater than expected proportion of respondents having mixed orientations. A hierarchy of 77 personal value concepts is presented with "integrity" ranked first and "change" ranked last. This hierarchy is compared to an Air Force pilot study hierarchy. The questionnaire's 33 goals are classified as to mission related and mission ancillary official goals and unofficial goals. These are presented in a hierarchial form showing the maintenance officers' greatest concern to be to complete maintenance on time and in an orderly manner to fulfill mission requirements. Compared to the SAC IG hierarchy, there are only two differences implying conflict; maximum availability of personnel and maintenance quality at the expense of missile down time. The contingency table analysis shows 197 out of 2970 possible differences related to the demographic variables at the 0.05 level.

232. A PROCUREMENT VIEW OF THE SYSTEMS ACQUISITION PROCESS: AN EFFORT TO PROVIDE PROCUREMENT RESEARCH OBJECTIVES

Leland A. Osburn, Lt Col, USAF | 271p | GSM/SM/73-20
Advisor: Lt Col C. Doryland | Lab Sponsor: DOD | AD 773798

A procurement view of the Systems Acquisition Process is shown in a procurement model within the systems acquisition environment. This model is developed by integrating the systems acquisition activities of the Systems Acquisition Process and the generic procurement activities of the Procurement Process into a Procurement Process Framework. The procurement model is used as an aid in identifying critical factors which affect systems acquisition activities and impact on the Procurement Process, causing problems in procurement. These critical factors are: the objectives of the particular system acquisition program; the policies used to direct, guide, and control acquisition and procurement activities; the participants; the informational inputs; the available resources; and considerations of cost, schedule, and performance. The procurement model is also used as an aid in identifying systems acquisition problems during a field study at the Aeronautical Systems Division of the Air Force Systems Command. Procurement research objectives are stated in 12 topic areas and 41 subtopic areas associated with problems identified during the field study. These objectives indicate study needed to gain greater insight and understanding into the causes of procurement problems and to develop means for reducing the negative effects of these problems. Recommendations are made for research topics which should be initiated immediately and those topics which may need to be delayed before they can be adequately pursued. Recommendations are given for DOD-wide coordination of procurement research and for development of an overall framework of procurement research objectives in all aspects of DOD procurement.

233. PERSONAL VALUES OF R&D PROFESSIONALS AND OPERATIVE GOALS IN R&D ORGANIZATIONS AN IN-DEPTH ANALYSIS OF ONE LABORATORY

Eugene W. Pittenger, Lt Col, USAF | 200p | GSM/SM/73-27
Advisor: Maj R. Manley | Lab Sponsor: AFCRL | AD 769190

Purpose of study was to add to understanding of organizational goals of R&D organizations and of personal value systems of professional personnel in R&D organizations. The approach was to: develop a set of value concepts meaningful to R&D professionals; develop a set of goals potentially important to R&D organizations; incorporate value concepts, goals, and demographic variables in a questionnaire and administer the questionnaire to professional members of the AF Cambridge Research Laboratories (AFCRL); determine primary orientation of professionals through analysis of ratings given value concepts and use primary orientation and importance ratings to determine value concept with behavioral relevance to professionals of the organization, and determine operative goals of the organization; and compare operative goals with formal goals. Completed questionnaires were received from 65 percent of the R&D managers, scientists, and engineers. Results of analysis included rankings in hierarchy of behavioral relevance of 82 value concepts and of 40 operative goals. Significant differences were found in rank and in behavioral relevance of personal values and operative goals among managers, scientists, and engineers, as well as for other demographic variables. Normative descriptions of R&D professionals from the literature in many instances did not agree with finding for this one organization. It appeared that normative studies of R&D professionals should be made by organization and by professional area. Operative goals were compared to official goals (taken from

AF regulations). Some cases of low behavioral relevance of goals were identified, as were areas of potential goal conflict. Studies of the type made appear to offer a good starting point for Organizational Development (OD) and Management by Objectives/Results (MBO/R) programs. Application of similar studies to other R&D organizations was recommended.

234. CONTINGENCY TABLE ANALYSIS OF DOD LOGISTIC FACILITIES MODERNIZATION DATA

Maynard E. Spotts, Maj, USAF — 51p — GSM/SM/73-22
Advisor: Lt Col C. Doryland — Lab Sponsor: DOD

Task Group 5-70 of the Logistics Systems Policy Committee collected Fiscal Year 1970 data from thirty-three continental United States Department of Defense logistics depot. This data served as the basis for evaluating a method of providing a logistic planner with a forecasting tool for resource allocation. The quantity and category of Federal Stock Numbers managed by a depot were assumed to be a decision guide input for this allocation. Contingency table analyses were examined to find meaningful relationships between the stock numbers, hours worked, and production outputs of seventeen specified depot work functions. The variables being analyzed were compared with each other two at a time. The results were hypothesized to be independent of each other and rejection of this hypothesis was established as proving dependence. Of 241 comparisons made, 90 showed to be dependent at a predetermined level of significance of .05. Usefulness of the resultant information as a planning tool was found to be minimal. At best it could only be considered as an exploratory tool and of very little help to the logistics decision maker.

235. A SURVEY AND ANALYSIS OF FACTORS INVOLVED IN THE COST OF OPERATING AIR FORCE AERO CLUB AIRCRAFT

Richard L. Trail, Maj, USAF — 92p — GSM/SM/73-23
Advisor: Dr. R. Klug — Lab Sponsor: AFIT

This research study is a survey and analysis of the direct cost of operating the light aircraft that were utilized by Air Force aero clubs. The need for the study was made evident in the wake of recent closures of aero clubs due to financial difficulties. The modus operandi of the writer was to gather actual data from aero club records and then to analyze the information which had been derived by electronically processing those data. The results obtained were then compared with information gathered from other operators using the same types of aircraft as did the aero clubs. The writer suggests that the enclosed tables, compiled to show the direct cost of operating each type of aircraft utilized by the Air Force aero clubs, will be the most useful portion of this report. Of all the aircraft types utilized by the aero clubs, the Cessna 150 had the lowest direct costs of operation. The Cessna 150 also was shown to have the highest rate of use. The writer concluded that factors other than direct operating costs influence the selection of aircraft used by the aero clubs. It was further

concluded that the financial accounting system, which is by directive employed by the aero clubs does not provide the manager with adequate information upon which to base management type decisions. In a comparison with other flight operations, areo clubs compare favorably in terms of lower direct operating cost per flight hour. The favorable comparison is due in part to volunteer labor for maintenance.

236. AN EVALUATION OR ORGANIZATIONAL DEVELOPMENT AS APPLIED TO THE AIR FORCE MATERIALS LABORATORY (AFML)

Tommy J. Trask, Capt, USAF	163p	GSM/SM/73-24
Advisor: Maj R. Manley	Lab Sponsor: AFML	AD 773038

This study attempts to determine if Organizational Development (OD) as applied to the Air Force Materials Laboratory (AFML) was effective in improving the health of the organization. The "health" of AFML was ascertained through the measurement of internal variables with a Questionnaire constructed around five improvement goals. This Questionnaire was used to survey the entire organization to collect current data, and, since pre-OD or baseline data had not been collected, to collect baseline data. Every one of the nineteen questions on the Questionnaire measured statistically significatn improvement. Improvements appeared to be achieved in spite of three characteristics of AFML's OD process which detracted from its results. These characteristics were a belated and incomplete application to the lower line levels, lack of a systematic application, and a failure of the OD participants to communicate with others. These characteristics were probably responsible for the high correlation between attitude toward OD and participation in OD as well as between attitude toward OD and job satisfaction. OD did appear to improve the health of the organization. This improvement was, however, largely limited to the participants in formal OD activities.

237. A STUDY OF THE PERSONNEL PROBLEMS IN A U.S. AIR FORCE MATRIX

Wilfred S. Tsukamoto, Capt, USAF	61p	GSM/SM/73-25
Advisor: Col R. Lucas	Lab Sponsor: ASD	AD 769171

This study explores the differences in perceptions of personnel problems that exist in an Air Force matrix organization between the engineers assigned to functional organizations and the engineers administratively assigned to functional organizations, but temporarily located in a program organization. The sample consisted of Civil Service engineers assigned to the Deputy for Engineering at ASD, WPAFB, Ohio. Using a formal questionnaire, responses to eleven specific problem areas were solicited along with comments concerning collocation and management in a matrix organization. The eleven problem areas covered concerned project phase-out, dual authority, make-work, job status, loyalty, job ambiguity, career development, organizational conflict, specialization, management layering, and military-civilian work force. In contrast with a study conducted in civilian aerospace companies, which did not include the military-civilian work force, nine out of ten of these problem areas showed no significant differences in perception existed between the functional and collocated engineers at ASD. This suggests that results of studies conducted in civilian industries be carefully examined as to their direct applicability to the Civil Service environment. The one problem area that did coincide with the civilian industry study was on the

similarity of perception between engineers on the problem of job specialization. Two problem areas not included in the questionnaire, but addressed by many of the respondents as areas of concern are the length of collocated tours and the lack of communications between System Program Offices and the Deputy for Engineering on technical matters.

238. THE AEROSPACE CORPORATION: PAST, PRESENT, AND FUTURE

James F. Wheeler, Capt, USAF | 114p | GSM/SM/73-28
Advisor: Maj R. Manley | Lab Sponsor: SAMSO | AD 768386

The Aerospace Corporation was created in 1960 to provide General Systems Engineering and Technical Direction services to the U. S. Air Force and its contractors in support of national space and missile programs. As the priorities associated with these programs have changed in the intervening thirteen years, the role of Aerospace has changed considerably. Today, Aerospace is pursuing an active diversification program and has gained de facto independence of its founder and primary sponsor, the U. S. Air Force. The contemporary situation needs close examination by a competent agency to determine if the management concept embodied in Aerospace is still the best way to obtain these services and if national security interests are being served adequately.

PART III

ABSTRACTS OF DOCTORAL DISSERTATIONS

239. OPTIMAL INCOMPLETE FEEDBACK CONTROL OF LINEAR STOCHASTIC SYSTEMS

Robert E. Heath, II, Capt, USAF — 152p — DS/MA/73-1
Advisor: Maj J. Dillow — Lab Sponsor: AFFDL — AD 766878

The problem of incomplete feedback control of stochastic linear systems is considered. The system is modeled by an uncertain parameter linear differential equation driven by Gaussian white noise and an incomplete observation which is a linear transformation of the states. The optimal control is the linear transformation which minimizes the expected value of a quadratic performance index. For both the finite and infinite time problems, necessary conditions that the optimal control law must satisfy are derived. Time varying and constant gains are considered for the finite time problem. For the infinite time problem only time invariant gains are considered. The gradient derived for the infinite time problem is applied to a flight control design problem. This problem concerns finding feedback gains to improve the lateral handling qualities of an F-4 at two different flight conditions. The resulting control laws give quite adequate aircraft handling qualities for the aircraft at both flight conditions.

240. DIFFERENTIAL GAME BARRIERS AND THEIR APPLICATION IN AIR-TO-AIR COMBAT

Urban H. D. Lynch, Maj, USAF — 237p — DS/MC/73-1
Advisor: Maj G. M. Anderson — Lab Sponsor: AFFDL — AD 766890

The mathematical theory of perfect information, zero-sum, differential games is used as an analytical tool to learn as much as possible about the one-on-one, air-to-air combat problem and the problem parameters which have major effect on its outcome. The primary emphasis is on differential game Barrier theory and the application of the Barrier as an analytical tool for air-to-air combat analysis. A series of progressively more complex air-to-air combat models is developed and solved in such a way that the solution results of a given model have direct input to the more complex model that follows and learning from one model to the next is accumulative. The importance of the Barrier, its shape and its sensitivity to aircraft design parameters is discussed and demonstrated. Barrier sensitivity analysis of the models shows that given the opportunity to increase a fighter aircraft's air-to-air combat capability with either improved turning gs, weapons system, or thrust to weight ratio, increased thrust to weight ratio yields the greatest improvement in this capability. Barrier results of the model are designed into a workable computational technique to relatively evaluate the air-to-air combat capability of a series of fighter aircraft. This is the first known practical application of differential game theory to an air-to-air combat problem of real importance to the Air Force. A general zero-sum payoff function is also developed which allows the roles of the players to be an inherent decision in the model itself based on terminal state.

241. TIME-DEPENDENT TRANSPORT VIA THE CONTINUED FRACTION APPROXIMATION

William A. Yingling, Maj, USAF 125p DS/PH/73-1
Advisor: Dr. C. J. Bridgman Lab Sponsor: AFWL AD 766889

The time-dependent neutral particle transport problem of an isotropic Green's function source in homogeneous, isotropic, spherically symmetric media is examined using the infinite set of time-dependent P-N equations and integral transform techniques. The approximate Green's function solutions in transform space for the all angle flux corresponding to the P-N approximation of order N are determined to order P-9, and demonstrate a multiple wave nature upon inversion. An examination of the set of P-N solutions leads to the development of the complete (P-∞) continued fraction solution in transform space. For pure absorbing media the continued fraction is related to an analytic function which, upon inversion, yields the exact analytical solution. For cases with low order scattering moments the continued fraction yields closed form functions in transform space, but these do not yield to useful inversion. However, a continued fraction approximation technique is developed and yields simple closed form approximation solutions for the case of isotropic scatter. Simply stated, in this technique we approximate the portion of the complete (P-∞) solution in transform space which would otherwise be discarded in the standard P-N technique. The approximate solution, when inverted, is simple in form but shows remarkable spatial and temporal resolution when compared to discrete ordinate and other results. Useful particle conservation is shown for weakly absorbing media. The similar time-dependent plane source problem is also examined and similar results obtained. Finally, the steady state problems in both spherical and plane geometry yield simple approximate solutions from the continued fraction technique, and these solutions compare well with Case's exact solution for the asymptotic portion of the flux.

242. CUMULATIVE IONIZATION AND EXCITATION OF MOLECULAR NITROGEN METASTABLES BY ELECTRON IMPACT

Peter D. Tannen, Maj, USAF 165p DS/PH/73-2
Advisor: Prof D. Shankland Lab Sponsor: ARL AD 774446

The purpose of this study was the measurement of electron impact ionization cross sections of metastable-molecules of N_2. Metastable N_2 was created by intersecting a cold molecular beam with a modulated beam. The $A^3\Sigma_u^+$ metastable was preferentially excited by operating this electron gun at the approximate energy. The molecular beam, including the metastables, then flowed into the region of a second electron beam ionized the metastables at a lower electron impact energy than the ground state molecules. The ionized molecules were detected by observing modulated optical emissions from excited states of the iron. No emission from the First Negative System of N_2^+ was observed, implying that the cumulative cross section for a single vibrational level of the $B^2\Sigma_u^+$ state is less than $10^{-17}cm^2$. Observation of emission from the Meinel (3,1) band indicates that the cross section for the cumulative excitation to this state is approximately $5 \times 10^{-16}cm^2$ at 25 eV. This further implies that the cross section for the cumulative excitation of the entire $A^2\Pi_u$ state is approximately $10^{-15}cm^2$. Poor signal-to-noise ratios prevented a complete verification of these results. Cumulative cross sections

243. METAL-SEMICONDUCTOR JUNCTIONS ON CLEAVED CADMIUM SULFIDE

Charles E. Ehrenfried, Maj, USAF 245p DS/PH/73-4
Advisor: Dr. R. L. Hengehold Lab Sponsor: AFML AD 774439

Diffused metal-semiconductor junctions were measured and compared to a theoretical model to obtain a better understanding of the barrier mechanisms after having first formed controlled Schottky barriers. Contacts of gold, silver and copper were deposited in situ on vacuum cleaved surfaces of cadmium sulfide. The barrier parameters were determined from analysis of differential capacitance and current-voltage measurements. All experimental data was taken in the dark at both room temperature and near 100°K. The results which were interpreted in terms of the simple Schottky theory, gave value for the barrier height, ϕB_n, of 0.82 ±.04 volt, for the Au, 0.59 ±.03 volt for the Ag and 0.40 ±.06 volt for the Cu contacts using the differential capacitance data while the current-voltage method generally indicated lower values by 0.1 to 0.2 volts. The barriers were heat-treated at various temperatures between 140°C and 250°C for 5 minutes. The results are compared with those for the unheated barriers. A theoretical model which included a semi-insulating layer and a linearly graded region was used to derive capacitance-voltage relations. A parametric computer study of the model was done and the experimental data for several heat-treated barriers agreed favorably using this model.

244. CONSTRAINTS UPON GROUP-TO-GROUP SCATTER COEFFICIENTS USED WITH TRANSPORT CALCULATIONS

Joseph B. Webster III,Capt,USAF 146p DS/PH/73-5
Advisor: Dr. C. J. Bridgman Lab Sponsor: AFWL AD 774445

A set of constraints were formulated to test the higher order coefficients of a Legendre polynomial expansion for the angular dependence of the differential cross section which describes the scattering of X-ray energy photons with non-stationary electrons. Prior workers have developed numerical methods which generate these coefficients for both discrete and groupwise treatments of radiative energy transfer. Such coefficients were constrained to obey the principles of conservation of total cross section and detailed balance at equilibrium. This conservation principle provided a test only for the zero order coefficients and left the accuracy of the higher order coefficients to chance. By generalizing the conservation principle to apply to higher order coefficients, and providing the necessary values of averaged polynomials for given initial photon energies, the author developed a method for testing these higher order coefficients. These generalized constraint tests were applied for a four term expansion with a 134 group structure. The results of applying these constraints were evaluated and compared with a set of 134 group uncorrected coefficients. Further, the adequacy of using the fine group set of corrected coefficients for situations where the photon and electron fields were not in thermodynamic equilibrium was evaluated over the temperature range from 0.5 to 20 KeV. The accuracy of one group averaged coefficients in the stated temperature range was found to be within two percent for the values obtained from the set of corrected 134 group coefficients.

245. IDENTIFICATION OF RADAR TARGETS BY PATTERN RECOGNITION

William B. Goggins,Jr., Maj, USAF — DS/EE/73-1
Advisor: Dr. M. Kabrisky — Lab Sponsor: AFCRL — AD 764713

The problem of identifying radar targets without predetermined knowledge or measurements of their aspect angle is examined. The proposed solution is to use radar magnitude and phase versus frequency data in the resonance region as input data for pattern recognition techniques. Practical methods are developed for measuring radar phase and dealing with polarization effects. Pattern recognition algorithms that optimize separation between pairs of input data are developed. These algorithms are based on digital spatial frequency filtering of curves of the radar return versus the radar frequency. The technique is simulated on a ditital computer for three objects-a cylinder, a cone, and a step cylinder-all of about the same size. Results show that at most aspect angles, satisfactory recognition is attained at moderate signal-to-noise ratios.

246. REAL-TIME OPTIMAL GUIDANCE WITH APPLICATION TO LIFTING RE-ENTRY VEHICLES

David J. South, Maj, USAF — 202p — DS/EE/73-2
Advisor: LtCol R. A. Hannen — Lab Sponsor: AFFDL

A real-time optimal guidance scheme based upon the "variation of extremals" algorithm for obtaining optimal trajectories was formulated in two phases and applied to a planar lifting re-entry problem. First the variation of extremals algorithm was formulated and used in conjunction with a flexible prediction technique to construct an algorithm for rapidly generating optimal trajectories. Then, based also upon the variation of extremals algorithm, an en route optimal guidance algorithm was developed for guiding a vehicle to desired terminal conditions in the presence of perturbations. The optimal guidance scheme was assessed by digital computer simulations of the algorithms applied to a re-entry problem for which the integral of a function of convection heating was being minimized. The algorithm for rapidly generating optimal trajectories permits trajectories to be quickly found for initial re-entry states lying within a large re-entry window. Simulations at the en route optimal guidance algorithm indicate that the algorithm permits attainment of desired re-entry terminal conditions in the presence of initial state and en route control errors, but performance is degraded somewhat if atmospheric and vehicle modeling errors exist in the guidance equations. However, desired terminal conditions are achieved if modeling errors are corrected during guidance, assuming improved estimates are made available.

PART IV

ABSTRACTS OF FACULTY PUBLICATIONS

247. LEGENDRE POLYNOMIAL EXPANSION OF THE KLEINNISHINA FORMULA FOR MAXWELLIAN ELECTRONS

Charles J. Bridgman 2p
J. B. Webster III, B. G. Stephan

Transactions of ANS Vol. 16, No. 2, pp 574-575, November 1973

This paper presents energy integrated coefficients for a Legendre expansion of the angular dependeance of the differential cross section which describes Compton scattering from nonstationary electrons. The electrons are assumed to have a Maxwellian velocity distribution and an analytic fit is presented for the dependence of these coefficients on photon energy and electron distribution temperature.

248. APPROXIMATE FUNDAMENTAL FREQUENCY OF NONCIRCULAR RING MEMBRANES

Franklin E. Eastep, Maj,USAF

Published in Journal of the Acoustical Society of America, Vol. 53, No. 2, February 1973

An exact solution for the frequency of a ring membrane can be obtained when the inner and outer boundaries are concentric circles or confocal ellipses. If either boundary has some other shape, approximate methods must be used. This paper presents a simplified approximate method for determining the fundamental frequency of ring membranes whose boundaries deviate only slightly from circular. This method was initially used by Rayleigh in his investigation of simply-connected membranes. The radius of both bounding curves are approximated by truncated a Fourier series. The membrane transverse motion, which is written as a superposition of the modes of a circular ring membrane, is forced to vanish on the approximated boundaries. A characteristic equation is obtained from which the approximate frequencies may be found. This technique is used to determine the fundamental frequency of the following: (1) Elliptical ring membrane with the inner and outer ellipses being confocal, (2) square membrane with a centered circular hole, (3) square ring membrane, and (4) an eccentric annulus. Comparisons with exact solutions, when known, are given.

249. JET-DRIVEN CYLINDRICAL CAVITY OSCILLATORS

Milton E. Franke 8p
G. Jones III, W. A. Olsen

Published in the Journal of Dynamic Systems Measurement and Control, Transactions of the ASME, Vol. 95, Series G, No. 2, pp 125-132, June 1973

The effects of cavity diameter, jet-exit distance, and flow rate on the performance of a jet-driven cylindrical cavity oscillator are investigated experimentally in this study. The cavity oscillator is driven by an air jet that enters the cavity radially through a nozzle located on the periphery of the cavity. The air leaves the cavity perpendicularly to the entering flow through a tube that has its axis parallel to the axis of the cavity. The operating frequencies are found to agree with the eigenfrequencies of the cavity; however, the regions of operation at these frequencies are shown to depend on the flow rate and to exhibit characteristics similar to those of a multistage, jet-edge resonator. The results for several cavity diameters are correlated in terms of a dimensionless

frequency and a cavity Reynolds number. Schlieren still photographs and high-speed motion pictures are used to observe the motions of the jet.

250. SUFFICIENT STATISTICS AND REPRODUCING DENSITIES IN SIMULTANEOUS SEQUENTIAL DETECTION AND ESTIMATION

Jurgen O. Gobien, Capt, USAF 9p
Theodore G. Birdsall

IEEE Transactions on Information Theory, IT-19:6:760-768, November 1973

The doubly-compound hypothesis detection problem with finite-dimensional parameter vectors is treated in a general context. It is shown that estimation and detection occur simultaneously, with the detector using the a-posteriori densities generated by two separate estimators, one for each hypothesis. No assumptions are made on the estimation criterion, and very loose assumptions on the detection criterion. If sufficient statistics and hence natural conjugate densities exist for the unknown parameters, the procedure is quite tractable. In this case, the optimal detector partitions in such a way that the primary processing can be done without knowledge of the a-priori parameter distributions.

251. WAVE PROPAGATION AND OTHER SPECTRAL PROBLEMS IN A BINARY GAS MIXTURE AS DESCRIBED BY KINETIC MODELS TO THE BOLTZMANN EQUATIONS

David E. Greene, Maj, USAF

PhD Dissertation, August 1973

A system of integro-differential equations, which as a structure similar to the Boltzmann equations for a binary gas mixture and which qualitatively describes wave propagation, is investigated. The Oppenheim model is used and a one-dimensional linear initial value problem is considered. The model is shown to satisfy an H-theorem and to generate the conservation equations. The initial value problem is proved to be well-set mathematically with certain specifications on the initial distribution functions. Justification is made for the use of Fourier-Laplace transforms. A discussion is made of the dispersion relation and its analytic continuation. The roots $\sigma(k)$ of the dispersion relation are shown to be bounded by $-1 + \delta(\mu) < \mathrm{Re}\ \sigma \leq 0$ under the assumption of plane wave solutions. It is established that the continuous spectrum for the model consists of the lines: $\mathrm{Re}\ \sigma = -\mu$ and $\mathrm{Re}\ \sigma = -1$. An asymptotic study of the dispersion relation is carried out. The roots $\sigma(k)$ of the dispersion relation lie in three distinct regions of the σ plane: the hydrodynamic region, the semihydrodynamic region and the rarefied region. In the hydrodynamic region four propagation modes and two dissipation modes appear. The hydrodynamic modes and a spray from $\sigma = -\mu$ are present in the semihydrodynamic region. The spray from $\sigma = -\mu$ intersects a spray from $\sigma = -1$ in the rarefied region. A theory consistent with the model is developed for a gas mixture composed of a hydrodynamic gas and a rarefied gas. The dependence of the solution on the cross-collision frequency and the initial data is considered.

252. NON-LINEAR MODEL OF A PENDULUM VARIABLE RELUCTANCE-AC BRIDGE VELOCITY GAUGE

Jerry L. Hanson, Lt Col, USAF 16p

Proceedings, Symposium on Advancements in Instrumentation for Civil Engineering Applications, October 1973

A theoretical model is developed for a pendulum - variable inductance - AC R-L bridge type velocity gauge. LaGrange's equations and an extension of a solution to a restricted form of Navier-Stoke's equations are used to develop the mechanical-fluidic portion of the model. Amperes circuital law and Kirchoff's laws are the basis for the magnetic-electrical portion of the model. State variables are defined and the overall model state equations written. A computer simulation of the model compares favorably with experimental results for the unforced case. The simulation also illustrates non-linear damping effects as well as maximum and linear operating ranges for the gauge.

253. RELATIONSHIP BETWEEN CONVENTIONAL CONTROL THEORY FIGURES OF MERIT AND QUADRATIC INDEX IN OPTIMAL CONTROL THEORY

Constantine H. Houpis 5p
C. T. Constantinides

Institute of Electronic Engineers, Stevenage, England, January 1973

The paper presents a correlation between the figures of merit used in conventional-control-design theory and the elements of the Q matrix in the quadratic performance index that is utilized for an optimal-control-design theory of single-input/single-output systems. This correlation results in a design procedure that utilizes a set of curves (M_p,t_p,t_s and ω_d against q_{nn}) for determining the elements of the Q matrix. In addition to the design procedure, the paper presents an analysis of the steady-state error for ramp inputs; the condition that the dominant roots are the same for any nth-order system, whereas the nondominant root for a specified plant is given by $s \sim -K\sqrt{q_{nn}}$ (under the reproducibility condition defined in the paper) and the necessary conditions for an accurate solution of the Riccati equation.

254. ON THE ASYMPTOTIC BEHAVIOR OF SOLUTIONS OF THE DIFFERENTIAL EQUATION $(r(x)y'(x))' + p(x)y(x) = 0$

John Jones, Jr. 6p

Rendiconti Del Circolo Matematico Di Palermo, 21:1-2:168-173, January 1973

Let $r(x)$, $p(x)$ be positive continuous functions whose product is non-decreasing, unbounded and of class C^1 $[0,\infty]$,

$$\int_0^\infty p(x)dx = \int_0^\infty \frac{dx}{r(x)} = +\infty,$$

$$\lim_{x\to+\infty} \frac{r(x)}{p(x)} = 0, \quad \lim_{x\to+\infty} \int_0^x \frac{\{|[r(t)p(t)]'| - [r(t)p(t)]'\}}{r(t)p(t)}\,dt$$

exists and is finite, then there exists a nonidentically zero solution $Y(x)$ of $[r(x)y'(x)]' + p(x)y(x) = 0$ which tends to zero as $x\to+\infty$.

255. NUMERICAL SOLUTION OF MIXED BOUNDARY VALUE PROBLEMS USING NUMERICAL GREEN'S FUNCTIONS

Bernard Kaplan 5p
T. Y. Edwards

International Journal for Numerical Methods in Engineering, Vol. 5, pp 517-521, 1973

Numerical experiments were conducted to investigate the numerical determination of Green's functions for the two-dimensional steady-state heat transfer problem with constant heat generation and mixed boundary conditions. The discrete Green's functions were then employed to obtain numerical solutions by matrix multiplication for Poisson's equation for rectangles subject to Dirichlet boundary conditions on two sides and Neumann boundary conditions on the other two sides. Accuracy and time requirements were compared for solutions to the above problems obtained with discrete Green's functions and the more conventional successive over-relaxation iterative method. The results of the study indicate that the use of numerically determined Green's functions can be advantageous over conventional numerical techniques for Poisson's equation with mixed boundary conditions if certain restrictions are observed. The time restriction concerns a minimum number of problems which must be solved for a given geometry and the accuracy restriction concerns the relative magnitudes of the Neumann boundary conditions to the Dirichlet boundary conditions and the differential equation inhomogeneity. The time results obtained from this study compare favorably with the time results obtained from a previous study involving strictly Dirichlet boundary conditions, but the accuracy is somewhat poorer when Neumann boundary conditions were introduced.

256. SINGLE POINT SOLUTIONS OF DIRICHLET BOUNDARY VALUE PROBLEMS BY MONTE CARLO AND SUCCESSIVE OVER-RELAXATION

Bernard Kaplan 2p
J. T. Tills

International Journal for Numerical Methods in Engineering, Vol. 6, pp 448-449, 1973

In an effort to determine an optimal method for computing the numerical Green's functions or probability functions, a numerical investigation was conducted for the Laplacian operator defined on both square and cubic grids. The point iterative methods, Gauss-Seidel and successive over-relaxation were employed with an iterative limit of 10^{-4} percent. The Exodus method, which is a modified Monte Carlo technique, was programmed using a termination limit, 'percent particles remaining', of 0.1 percent. An accuracy study was conducted by comparing numerical results to analytical solutions for Green's functions obtained using a Fourier expansion. It was determined that, at least, for square and cubic regions, numerical Green's functions can be computed by successive over-relaxation in less time and with as good or better accuracy than the statistical method, Exodus. As a consequence it seems quite reasonable to conclude that for a class of boundary value problems (square/cubic geometry, Dirichlet boundary conditions, Laplacian operator) a point iterative method is more attractive than a Monte Carlo method for the task of repetitive single point solutions.

257. A SIMPLE YET THEORETICALLY BASED TIME DOMAIN MODEL FOR FLUID TRANSMISSION LINE SYSTEMS

James T. Karam, Jr., Capt, USAF 6p
R. G. Leonard

Journal of Fluids Engineering, Transactions ASME, 35:1:4:498-504, December 1973

A simple, theoretically based time domain model for the propagation of small, arbitrary signals in a finite, circular, fluid transmission line is developed. A recent simple theoretical solution for the step response at a downstream point in a semi-infinite fluid line is combined with a two-port representation of a finite line. The major feature of this finite line model is two "filters" which represent a convolution of their arbitrary inputs with the unit impulse response at the equivalent location in a semi-infinite line. Experimental tests are reported which further verify the simple semi-infinite line solution and verify the response of several example systems containing finite lines. The models developed herein show good agreement with experiment. The major anomaly noted was an amplitude dependence in the experimental response for signals larger than one percent of the bulk modulus of the fluid. Since the theory represents a linearized, small perturbation model, such disagreement might have been anticipated and is viewed as a limitation, rather than invalidation, of the model. Finally, quantitative comparisons are made between the proposed model and those in current use.

258. a. BASIC GRAPHICAL KINEMATICS (2nd Edition) b. PROBLEMS IN BASIC GRAPHICAL KINEMATICS (Plus Solutions Manuals)

Harold B. Kepler

Textbook, Copyright Date: 1973, Library of Congress Cataloging QA841.K4 1973 621.8'11 72-10890 ISBN 0-07-034171-0, McGraw-Hill Book Company, NY

The purpose of this book is to present a practical textbook in basic kinematics (or mechanisms). It is designed to fill the gap between the physics and mechanics courses (which are necessarily general in nature) and the mechanical design courses (such as machine design) which are oriented toward mechanisms, and machinery. The approach used in this book is primarily graphical. The graphical approach provides methods and techniques which are quite practical and effective and which complement the methods presented in the physics and mechanics courses. The scope of this book is limited to the study of displacements, velocities, and accelerations as applied to planar mechanisms. Except in the case of cams and gears (Chpaters 10, 11, and 12), the scope is intentionally limited to the analysis rather than the synthesis of mechanisms. This is felt to be desirable, if not necessary, in a basic text. The topics covered include vectors, basic motion concepts, kinematic drawing and displacements, centros (instantaneous centers), velocities in mechanisms, accelerations in mechanisms motion curves, cams, gear trains, belts, chains, and cams.

259. MALE VIS A VIS FEMALE MANAGERS: IS THERE A DIFFERENCE?

Robert J. Lucas, Col, USAF 19p
T. Roger Manley, Maj, USAF

Proceedings, Second Annual National Management Conference of the American Institute of Industrial Engineers at Denver, Colorado, 8-9 Feb 73, pp 1-19, February 1973

The data offered in this paper are drawn from two recent studies: one from industry and the other from the U. S. Air Force. The methodology used in analysis is an adaptation of that developed by Professor George W. England of the University of Minnesota. Essentially, the methodology consists of the categorization of an individual's personal value system through the use of a carefully specified set of value concepts. These categories are then used to valuate the individual's ranking of specific value concepts and his/her organization's goals. The specific objective of this paper is to highlight some differences which were found between male and female managers. In view of the preliminary nature of this research, the authors have avoided definitive conclusions or perscriptions. Rather, the focus is on exposition of the observed differences. The authors also speculate on the possible significance of the findings for supervisors who are presently utilizing both male and female managers or will be employing female managers in the future.

260. AUTHORITY PERCEPTIONS OF AEROSPACE PROJECT MANAGERS

Robert J. Lucas, Col, USAF

Proceedings, National Aerospace Electronics Conference, 1973

The task of prescribing formal authority parameters for project managers remains one of the most difficult problem areas associated with the use of matrix organizations. Empirical studies have shown that attempts by management to specify the division of authority between project and functional managers has been largely unsuccessful and frequently at odds with effective project decision making. This paper reports on a recent research effort in which aerospace project managers identified the relative importance of both de jure (formal) and de facto (informal) sources of their authority in dealing with project and support personnel. The findings suggest that project managers employ their various facets of authority based upon an assessment of situational factors surrounding each decision. Results of this empirical investigation with thirty-four project managers from Massachusetts, New York and California based aerospace companies have implications for both top management as well as project managers who are working in the dynamic and challenging project setting.

261. THE PROJECT MANAGER'S LAMENT: "IF ONLY...."

T. Roger Manley, Maj, USAF 5p

Published in the National Aerospace Electronics Conference (NAECON) Record, pp 108-112, May 1973

Project organizations, although used for a number of years, are considered a relatively recent innovation, and are being adopted at an increasing rate throughout government and industry. The adoption of project teams by an organization often represents a radical departure from past management practices. Such an organization normally finds itself confronted with an entirely new set of problems. In this paper a number of such problems are examined as are their probable causes. Although the focus of the paper is on government and government contractor project organizations, the content can be applied to any organization using or contemplating the use of the project approach.

262. FILTER DESIGN FOR A TACAN-AIDED BARO-INERTIAL SYSTEM WITH ILS SMOOTHING CAPABILITY

Peter S. Maybeck, 1st Lt, USAF 66p Lab Sponsor: AFFDL

Air Force Flight Dyanamics Laboratory Technical Memorandum

The objective of this report is to develop prospective designs of an on-line filter for combining data from a baro-inertial attitude and heading reference system with measurements from (1) a TACAN system during the cruise portion of flight and (2) an ILS system during the descent and final approach phase. In the cruise segment of flight, the filter will enhance the attitude and position information accuracy by weighting each data source heavily in the frequency regime where it provides good information and suppressing it in regions where it is in error. The inertial system provides good high frequency information, but it drifts slowly and therefore exhibits poor low frequency performance. On the other hand, TACAN data is good on the average, but subject to high frequency noise. Thus, the filter will use the good low frequency TACAN information to damp out the slowly growing errors inherent in the inertial systems. A similar frequency division can be expolited in combining inertial and ILS information. At present, ILS localizer and glide-slope deviation signals are displayed to the pilot to aid him in final approach and landing. However, these signals are corrupted by biases and high frequency noises. By combining these signals with inertial data, the filter is able to provide the pilot's displays with signals that have not only been smoothed, but compensated for biases as well.

263. LINEAR ESTIMATION OF THE SCALE PARAMETER OF THE FIRST ASYMPTOTIC DISTRIBUTION OF EXTREME VALUES

Albert H. Moore 6p Lab Sponsor: ARL
H. L. Harter, Capt J. W. Shelnutt

IEEE Transactions on Reliability, R-22: 259-264, December 1973

A Lagrange multiplier technique is used to obtain linear, minimum-variance, unbiased estimators for the scale parameters of the first asymptotic distributions of smallest and largest values with known mode.

Coefficients for multiplying ordered observations are computed for complete and censored samples of size n - 1(1)15. Each sample of size n is censored from above and all m-order-statistic estimators are obtained where $m \leq n$. Then the smallest subset of ℓ order statistics from the set of m available order statistics is found which yields a 99% efficiency relative to the m-order-statistic estimator. The Cramer-Rao lower bound for the variances of the estimators for complete samples is derived and tabled for n = 1(1)15. For censored samples the asymptotic variances of the maximum-likelihood m-order-statistic estimators are presented for comparative purposes.

264. FINITE ELEMENT STRUCTURAL ANALYSIS OF LOCAL INSTABILITY

J. S. Przemieniecki 7p Lab Sponsor: AFSC

AIAA Journal, Vol. 11, No. 1, pp 33-39, January 1973

A finite element analysis is presented for predicting local buckling in plates, stiffened panels, and thin-walled columns for which the cross section is made of thin flat plates. The analysis leads to the formulation of the elastic and geometrical stiffness matrices appearing in an eigenvalue equation used to determine the buckling stress. The stiffness matrices are derived from the exact sinusoidal lengthwise variation of displacements. The resulting sinusoidal stiffness matrices depend on the wavelength of the buckled pattern, but this dependence is of a very simple form, since all stiffness coefficients contain the buckling wavelength as a common factor. Examples are given to illustrate application of the method to several typical aircraft structural components.

265. ON MODELING HUMAN PERFORMANCE RELIABILITY

Thaddeus L. Regulinski 2p Lab Sponsor: AMRL

IEEE Transactions on Reliability, pp 114-115, New York, August 1973

Human performance reliability models of systems scientists, behavioral scientists and cyberneticists are discussed and compared. The influence of academic discipline on model formulation, points of view, and on modeling processes is described. General review is given of ten papers appearing in the Special Issue on Human Performance Reliability, in light of the points of view held by the different disciplines.

266. FAST SPECTRAL ANALYSIS OF LINEARLY SWEPT SIGNALS

Donn G. Shankland 36p Lab Sponsor: AFCRL

Air Force Cambridge Research Laboratory, Technical Report 73-0121, February 1973

An Algorithm is developed for computing the cross correlation between a given digitally recorded signal and a set of standard signals of the form $S(\omega,\alpha,t) = \exp [i(\omega t + \alpha t^2)]$, corresponding to a signal whose frequency varies linearly with time. A code is presented for the CDC 6600 computer, and discussed sufficiently to enable programs to be written for other machines. Text data is included for debugging purposes.

267. PRESSURE WAVES IN A FLUID LAYER

Peter J. Torvik
J. R. Easter, Capt, USAF

Lab Sponsor: AFFDL

Journal of the Acoustical Society of America, 53:1:375, January 1973

The pressure field in a layer of compressible inviscid fluid between two parallel elastic plates is considered. Each plate is described by the Timoshenko-Mindlin plate equation, and a point, time-harmonic force is assumed to be applied normally to one plate. The method of solution parallels that previously applied to a semi-infinite fluid bounded by one plate [Feit, JASA 40, 1489-1494]. The Hankel transform was applied to the plate equations and the wave equation for the fluid, with the pressure and normal velocity at the interfaces being equated. The resulting inverse Hankel transform was evaluated both by numerical integration and by an approximation using the method of steepest descent. Separate expressions were developed in each case for results near the axis of symmetry and for large distances from that axis. Results for ten microsecond pulses were also obtained by the superposition of steady-state results for twenty frequencies. Satisfactory argument between the two methods was obtained.

268. THE REDUCTION OF IMPACT INDUCED PRESSURES IN FUEL TANKS

Peter J. Torvik
J. W. Clark, Maj, USAF

6p

Lab Sponsor: AFFDL

43rd Shock and Vibration Bulletin, Part 2, pp 203-208, June 1973

The use of porosity to reduce the pressures generated by projectile impact was considered both theoretically and experimentally. Flame retardant polyurethane foam was found to give some improvement, attributed to the casual introduction of air. A freon-filled dacron material (not suggested for actual application) shows that significantly greater attenuations can be achieved.

269. PRESSURE DISTRIBUTION IN A FLUID LAYER BOUNDED BY ELASTIC PLATES

Peter J. Torvik
J. R. Easter, Capt, USAF

7p

Lab Sponsor: AFFDL

Journal of the Acoustical Society of America, 54:4:1045-1051, October 1973

Pressures are determined in a layer of fluid bounded by two parallel elastic plates, one of which is harmonically excited at a point. The response of the coupled plate-fluid system is obtained for infinitesimal displacements in both the plate and the fluid. The pressures are obtained through a numerical integration of the inverse Hankel transform along an approximation to the steepest descent path. Some numerical results obtained for frequencies both above and below the coincidence frequency are given. These show a complex spatial variation in pressure in addition to that on the scale of the wavelength in the fluid.

270. SOME FURTHER NUMERICAL STUDIES OF LASER INDUCED MELTING AND VAPORIZATION

Peter J. Torvik 33p

Air Force Institute of Technology Technical Report, AFIT TR 73-1

A method for predicting the melt through time for a metal sheet subjected to a continuous laser beam of Gaussian distribution of arbitrary size and peak intensity is given. The effect of completely retained and instantaneously removed melt layers on the melt through time are considered. It is shown that melt through time and the influence of retained melt are dependent on the value of a dimensionless variable representing power per unit thickness. The partial melting and vaporization of sheets by a large single pulse is also discussed and compared with ex experimental results.

271. THERMAL RESPONSE CALCULATIONS AND THEIR ROLE IN THE DESIGN OF EXPERIMENTS

Peter J. Torvik 51p Lab Sponsor: AFWL

Air Force Institute of Technology Technical Report, AFIT TR 73-6

The prediction of temperatures and the times required for complete melt through in metal sheets subjected to continuous laser irradiation is considered. Analytical and numerical methods for predicting the thermal responses are discussed and applied so as to obtain general conclusions on the influence of radial conduction, vaporization, and melt removal mechanisms on the melt through time. The ratio of beam power to thickness, rather than intensity or some strictly geometrical parameter, is shown to determine the significance of radial conduction. At low powers, the predicted time to melt through with a fully retained melt is shown to be little more than if the melt is assumed to be removed as it forms. At higher powers, retention of the melt leads to significant increases in the melt-through times as some fraction of the beam energy is then wasted in heating and vaporizing the molten material. Skin friction drag and gravity are considered as mechanisms for the removal of the melt and are shown to be of consequence in some cases. Radiation and convection losses to the surroundings are considered and shown to be of significance only for very low values of absorbed intensity. Some results from a recent series of experiments are presented and interpreted. Absorptivities of bare titanium and stainless steel at two intensities, together with the absorptivities of painted samples of titanium, stainless steel, magnesium and aluminum are all determined by two methods and the results compared. A comparison between experimental and computed data suggests the presence of several interesting phenomena, worthy of further study. Mass removal before complete melting can lead to lower melt-through times for extremely thin sheets than might otherwise be expected. The data also suggests the possibility of sufficient energy being released due to the burning of paint to be of significance at laser intensities of one kilowatt per square centimeter, or less.

272. PRESSURE DISTRIBUTION IN A FLUID LAYER BOUNDED BY ELASTIC PLATES

Peter J. Torvik
J. Russell Easter

9p

Journal of the Acoustical Society of America, September 1973

Pressures are determined in a layer of fluid bounded by two parallel elastic plates, one of which is harmonically excited at a point. The response of the coupled plate-fluid system is obtained for infinitesimal displacements in both the plate and the fluid. The pressures are obtained through a numerical integration of the inverse Hankel transform along an approximation to the steepest descent path. Some numerical results obtained for frequencies both above and below the coincidence frequency are given. These show a complex spatial variation in pressure in addition to that on the scale of the wavelength in the fluid.

273. ELASTIC WAVE PROPAGATION IN INHOMOGENEOUS BARS OF SEVERAL SECTIONS

Peter J. Torvik
J. E. Wade, Maj, USAF

5p

Lab Sponsor: AFFDL

Journal of Applied Mechanics, 40:4:1050-1054, December 1973

An approximate method is given for analyzing the propagation of low-frequency wave trains in prismatic bars of cross sections which can be approximated through subdivisions into rectangular elements. The method may be applied to inhomogeneous (composite) bars, for it is not required that each such element have the same properties. Results from the new method compare favorably with results previously obtained for a rectangular bar. Frequency spectra for several composite bars, including a bar of thick angle section, are given.

274. AN ECONOMIC ANALYSIS OF THE MULTI-MODAL TRANSPORTATION COMPANY: A SIMULATION APPROACH

Robert S. Tripp, Capt, USAF
Norman L. Chervany, Frederick J. Beier

25p

This paper presents a methodology which can be utilized to examine the economic consequences of establishing multi-modal transportation companies. Using this methodology, an economic analysis which compares the operations of a transportation company consisting of both rail and trucking modes with the operations of single modal carriers in these modes is presented.

PART V

INDEX OF SPONSORING ORGANIZATIONS

AFIT SCHOOL OF ENGINEERING

CONTRIBUTIONS TO AIR FORCE

RESEARCH AND TECHNOLOGY

Technical Report AFIT TR 74-1

October 1974

ABSTRACT

This report contains abstracts of Master of Science Theses, Doctoral Dissertations, and selected faculty publications completed during the 1973 calender year at the School of Engineering, Air Force Institute of Technology, at Wright-Patterson Air Force Base, Ohio.