AD-A149 343 CONTRIBUTIVE RESEARCH PROGRAM OF AFWAL(U) UNIVERSAL ENERGY SYSTEMS INC DAYTON OH R C DARRAH FEB 83 AFWAL-TR-82-4202 F33615-79-C-5129 1/1

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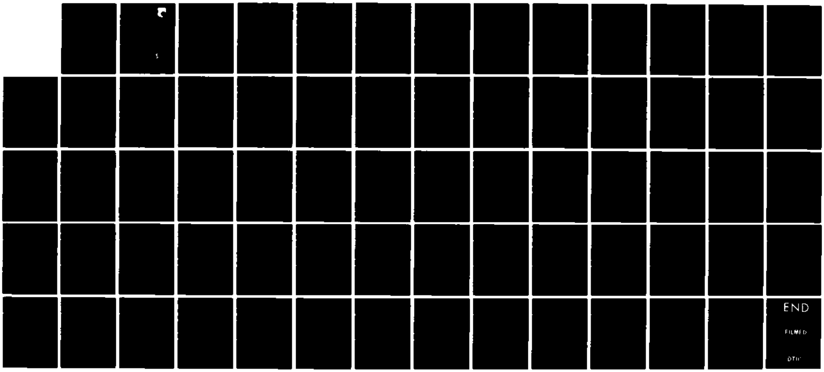

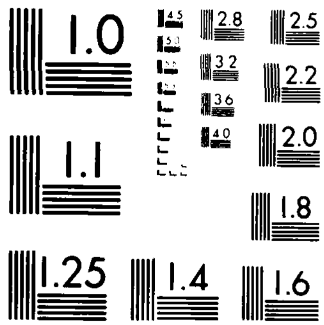

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AFWAL-TR-82-4202

CONTRIBUTIVE RESEARCH PROGRAM OF AFWAL

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4401 Dayton-Xenia Road
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February 1983

Final Report for Period October 1979 - September 1982

Approved for Public Release; Distribution Unlimited

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This technical report has been reviewed and is approved for publication.

WILBERT R. POWELL
Contract Monitor
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GARY K. WAGGONER
Chief, Programs Office
Materials Laboratory

FOR THE COMMANDER

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFWAL-TR-82-4202	2. GOVT ACCESSION NO. AD-A149 343	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) CONTRIBUTIVE RESEARCH PROGRAM OF AFWAL		5. TYPE OF REPORT & PERIOD COVERED Final Oct 79 - Sep 82
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Rodney C Darrah		8. CONTRACT OR GRANT NUMBER(s) F33615-79-C-5129
9. PERFORMING ORGANIZATION NAME AND ADDRESS Universal Energy Systems Inc 4401 Dayton-Xenia Road, Dayton Ohio 45432		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 230X0000
11. CONTROLLING OFFICE NAME AND ADDRESS AFWAL/ GLXPM WPAFB OH 45433		12. REPORT DATE February 1983
		13. NUMBER OF PAGES 68
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Polymers
Mechanics
Metallurgy
Electronics
Optics
Composites

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A description of the work performed under the Contributive Research Program of AFWAL is presented. The scope and objectives of each individual task is reported The work reported consisted of a wide range of individual tasks involving theoretical studies, analytical studies, seminars, diagnostic and measurement techniques, and the evaluation of new ideas, systems, devices and concepts.

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INTRODUCTION

Under the Contributive Research Program of AFWAL, Universal Energy Systems, Inc. (UES) was required to provide the professional effort for investigating, defining, and predicting the basic physical and engineering phenomena occurring in the aerospace environments. UES provided the personnel to perform the basic research in the physical and engineering sciences to accomplish this mission.

In consonance with the broad scope of the AFWAL programs and the AFWAL need for specialist to conduct short-term investigations or present seminars on specific subjects, UES researchers and consultants addressed an omnium-gatherum of technical disciplines under this effort. The work consisted of a wide range of individual tasks involving theoretical studies, analytical studies, seminars, diagnostic and measurement techniques, and the evaluation of new ideas, systems, devices and concepts.

A description of the work performed is presented in this report. The scope and objectives of each individual task is reported. The technical reports, publications and presentations for each task have been delivered to the Government Initiator of the tasks.

SECTION I

Section 1.0 Materials Laboratory

The description of the tasks performed by UES for the AFWAL/ML is presented in this section.

Task 2 - Synthesis of Organic Compounds

This task was addressed by Dr. Allen B. Conwell, a Contributive Researcher with UES and Dr. Sujan S. Dua, a UES employee.

This research effort was concerned with the synthesis of organic compounds selected from the following classes: nitr[illegible] heterocyclic compounds, highly halogenated aliphatic and aromatic compounds and organo-silicon compounds. Synthesis procedures were developed to provide new organic materials with selected physical and chemical properties. Molecular structure versus physical properties correlations were developed leading to data required for the selection of optimum properties, e.g., liquid range, thermal stability, oxidative and chemical resistance. The synthesis of the above classes of organic compounds included the use of organometallic intermediates as organomagnesium, - lithium and - copper compounds as well as free radical reactions. Free radical reactions were concerned with thermolysis of per-fluoroalkyl iodides and various aromatic and inorganic substrates. The task received additional funding under Tasks 21 and 125.

Task 3 - Silicon Electronic Transport Theory

Dr. Frank M. Madarasz, a Contributive Researcher with UES, was the principal investigator on this task. This task consisted of three parts:

Part 1 - High Purity Intrinsic

A calculation of the relaxation time for phonon-scattering of holes taking into account the nonparabloic nature of the bands and warped energy surfaces was made. The Hole drift mobility as a function of temperature and the Hall mobility were calculated. The Hall mobility was combined with the drift mobility to calculate the r-factor as a function of temperature. The calculated r-factor values were compared to the values that could be obtained experimentally over limited temperature range and the values were extrapolated over the total range of interest.

Part 2 - Intentionally Doped-Extrinsic Silicon

Relaxation time calculations including neutral and ionized impurity scattering of holes were made. The calculation of the r-factor including all scattering mechanisms was made. Data tables that present the r-factor as a function of both dopant concentration and temperature were prepared.

Part 3 - Analysis of Hall Date

The computer program for extracting material parameters from the the experimental Hall date was modified and updated to reflect current state-of-the-art knowledge.

Task 9 - Assessment of Development Potential of Fe_3Al, NiAl, and RSR Alloys

This task was addressed by Dr. James C. Williams, a Contributive Researcher with UES.

The intermetallic compounds Fe_3Al and NiAl have outstanding oxidation resistance and elevated temperature strength. It is necessary to assess the full development potential of these compounds for turbine engine service.

The RSR alloys based on the systems Ni-Al-Mo-X and Ni-Cr-Al-X are being developed to help provide solutions to current turbine engine materials problems. These systems require extensive characterization. This characterization is being accomplished mainly in-house at the AFWAL/ML facilites.

All the above programs require considerable transmission electron microscopy and scanning transmission electron microscopy to be accomplished by scientists skilled and knowledgeable in the area of intermetallic compounds and nickel base superalloys.

Under this task, Dr. Williams provided the TEM+STEM support including preparation and study of various metallic structures off site and the reporting of results at WPAFB.

Task 10 - Characterication of Surface Treatment of Titanium Alloys

Dr. Alain Roche, an employee of UES, was assigned as principal investigator for this task. Dr. Roche conducted experiments at the AFWAL/ML in-house facilities to determined morphological and chemical effects of etchants of titanium alloy surfaces. From this work a data base, for which adhesive bonding of future USAF systems can be reliably applied, was established.

Task 12 - Composite Materials Analysis

The principal investigator for this task was Dr. Rudolfo Aoki, an employee of UES. Dr. Aoki's research under this task involved the design, acquisition, and analysis of experimental data on composite materials under combined stresses. The required test-specimen design and instrumentation was based upon highly advanced mathematical modeling. Dr. Aoki made extensive experimental measurements of composite material and presented a technical report on this subject.

Task 17 - Pole-Figure Analysis of Ordered Polymers

Dr. P. Galen Lenhert, a Contributive Researcher with UES, was assigned as principal investigator for this task. Dr. Lenhert conducted a study to determine the polycrystalline nature and preferred orientation of rod-like, para-configured, heterocyclic polymers (here-after referred to as ordered polymers). Expendable samples of ordered polymers in the form of fibers and films were furnished by the government. The technique used for this study was x-ray diffraction pole-figure analysis, as carried out on a Picker FACS-a Automated Diffractometer located at AFWAL/ML. This study was divided into two parts.

a) The first part was to devise and modify the existing control codes, government furnished, of the Picker FACS-1 operating system and the associated data analysis program in order to provide for the acquisition of accurate and reproducible pole-figure data sets.

b) The second part was to perform pole-figure analyses upon ordered polymer samples. The ordered polymer samples were supplied by the government. The results determined from these pole-figure analyses included the degree of crystallinity and the orientation factors for the polymers samples.

Required reports included a laboratory notebook used to record daily progress and to identify experiments carried out and a summary report to describe the results obtained during the period of research. These were delivered to the Task Initiator.

Task 18 - Prediction of Dynamic Stresses in Blades

Control of combined high level static and dynamic stresses in bladed disks has become very important from the point of view of preventing high cycle fatigue. Since the stress field is critically dependent on the detailed mechanical interactions at the blade/disk interface, this investigation was aimed to analyze discrete element and finite element models of a blade/disk system, allowing for slip at the blade/disk interface and the effects of rotation. Combined static/dynamic stress levels were sought, in accordance with the selected model, and an effort was made to identify the parameters of the model from tests on blades and disks, and finite element analyses of linear response. The aim of this exploratory investigation was to increase the understanding of interface effects, such as slip, on the dynamic mechanical coupling between blades, through the disk. UES assigned Dr. Agnes Muszynska, a participant in UES' Exchange Visitor Program to addressed this effort. The results of this work were reported to the Task Initiator.

Task 21 - <u>(See Task 2)</u>

Task 22 - <u>Review of the State-of-the-Art of Adaptive Control for the Gas Tungsten and Plasma Are Welding Processes</u>

Dr. Richard W. Richardson, a Contributive Researcher with UES, was assigned as principal investigator on this task. Generally, adaptive welding involves the sensing of welding variables or weld groove characteristics at or near the point of welding. The sensed information is processed by suitable means and, via feedback, used to control the welding process in real time. The sensing and control functions can be separated into three relatively distinct areas:

1. Sensing of the location of the groove for automatic guidance of the welding torch, commonly referred to as seam tracking.

2. Sensing and control of the proximity of the welding torch to the workpiece.

3. Sensing of characteristics of the groove ahead of the point of weld or sensing process variables for the purpose of adjusting process parameters to obtain acceptable weld properties.

Many and varied control methods have been developed over the years in these areas, however, with little general success due to the inherent complexity of the welding process. The emerging availability of computing power for control applications, as furnished by the microcomputer, is leading to an improved climate for success in these areas of adaptive control and makes a state-of-the-art review timely.

In the course of this review, the above areas were broken down into a structured organization from which specific current and past developments were classified and evaluated. Material for the review was drawn from the technical literature, from welding equipment developers, and from communication with experts in the field. To the extent possible, the review considered worldwide developments. An interpretation of the state of the art in the various areas was presented, together with projections and recommendations for future developments. A technical report on this effort was delivered to the task initiator.

Task 26 - Optical Properties of Thin Oxide Layers

The principal investigator for this task was Dr. Izhar Bransky, an employee of UES. Under this task Dr. I. Bransky investigated the optical (IR) properties of thin oxide layers of materials with well-known physical properties. Materials of interest for coatings were selected from the group of compounds exhibiting phase transformations associated with metal to insulator or metal to semiconductor transitions. Various methods were tried to produce the coatings such as vapor deposition, sputtering, and ion melting. Measurements included reflectance and transmittance. Stoichiometry was controlled so that transitions could be studied. Effects of phase change on the index of refraction, reflection, and electrical conductivity were studied. A technical report of this work was prepared and delivered to the task initiator.

Task 27 - NDE Techniques for Multilayered Media

The problem of locating and measuring defects in multilayer structures, using ultrasonic techniques, is one that has been recognized for many years. Unfortunately, the complicated resonance and absorption properties of these structures has made progress very difficult.

Current in-house research efforts at AFWAL/ML are directed toward the development of an ultrasonic NDE technique utilizing reradiated surface waves (leaky waves) to detect cracks both at the surface and also buried under a coating. A great deal of prior research in this area was conducted at several universities where the fundamental properties of these waves were experimentally and theoretically determined.

For this effort UES assigned Dr. Laszlo Adler, a Contributive Researcher with UES, to supply the AFWAL/ML Engineers with fundamental background information, which was necessary to maximize the effectiveness of the ML effort in this area. Specifically, Dr. Adler provided detailed information on the results of his own research, as well as the identification of those aspects of the leaky wave problem which require more experimental or theoretical effort. Dr. Adler presented seminars at the ML concerning this effort.

Task 38 - NDE for Multilayer Structure

In a similar effort as Task 27, Dr. Richard Claus, a Contributive Researcher with UES, made a trip to the AFWAL/ML to present a seminar to the laboratory engineers, outlining his work in this area.

Task 39 - Weathering of High Solids and Waterborne Coatings for Aircraft

Dr. S. Peter Pappas, a Contributive Researcher with UES, was assigned as principal investigator for this task. Dr. Pappas obtained information for this task by consulting with coating companies, users, supplies and research institutes and companies which evaluate weatherability of coatings. Dr. Pappas presented a summary report to the AFWAL/ML engineers detailing information on weathering characteristics, test methods and techniques for assessing weatherability, and additives and stabilizer systems for enhancing the weatherability of high solids-and waterborne coatings suitable for aircraft applications, with emphasis on the following concerns: a) correlations between weathering characteristics and coatings composition, including a comparison of high-solids and waterborne coatings, b) correlations between accelerated weathering and outdoor exposure, c) potential utility of short periods of outdoor exposure, coupled with sensitive techniques such as FTIS, UV and visible spectroscopy for early detection of weathering and prediction of long-term weathering performance, and d) indentification of additives and stabilizer systems for high-solids and waterborne coatings systems being developed under the AFWAL/ML in-house and contractural aircraft coatings exploratory development research program.

Task 46 - Liquid-Solid Partical Erosion Correlation in Transparent Materials

Dr. Joseph Zahavi, an employee of UES, was principal investigator for this effort. Dr. Zahavi conducted experiments utilizing the AFWAL/ML rotating arm rain erosion apparatus at velocities appropriate to provide direct comparison with sand erosion experiments conducted on an apparatus at the Technion in Israel. Multiple impact rain erosion experiments were conducted on poly-methylemethacrylate, polycarbonate and glass-epoxy composite materials which are identical to those being investigated in the sand erosion nozzle apparatus.

Characterization of the eroded specimens was conducted by use of optical microscopy, scanning electron microscopy and transmission measurements. Correlations with materials strength properties, including notch impact, elongation, hardness and other appropriate properties were developed and contrasted for multiple liquid impact and multiple solid-particle impact.

Task 48 - Statistical Analysis of Failure of Composite Materials

For this task, UES assigned Dr. Won J. Park as principal investigator. Using data supplied by the AFWAL/ML, Dr. Park developed calculator programs for statistical analysis as applied for failure processes in composite material.

Task 49 - Effect of Cooling Rate on Ti-Alloy Weldment Microstructures

This work involved a study of nonequilibrium solid-state phase transformations in welded Ti-Corona 5 (an advanced, high-toughness alloy) and

Ti-5522 (an advanced, high-temperature alloy). Dr. Warren F. Savage, a Contributive Researcher with UES was assigned to undertake this effort. The effect of nonequilibrium phase transformations on microstructural characteristics of both as-welded and heat-treated weldments was investigated with particular emphasis on the influence of weld cooling rate. The study required simulated weldment production, light microscopy, and thin-foil characterization.

Task 50 - Seminar on Raman Scattering from NbO_2

Dr. Mohammed Nasar, a Consultant to UES, presented a seminar at the AFWAL/ML concerning his work with NbO_2.

Task 52 - Slow Strain Rate Embrittlement of Tantalum Due to Oxygen

Dr. Ana Estela Diaz, a Contributive Researcher, with UES was assigned as principal investigator. Dr. Diaz reviewed the pertinent literature and presented a summary lecture discussing the mechanisms of embrittlement.

Task 53 - Acetylene Terminated Resin Toughening Mechanisms

This task was assigned to Dr. Joe Ham, a Contributive Researcher with UES. The objective of this effort was to develop a method for toughening Acetylene Terminated Resins for use as adhesives. Dr. Ham participated in technical discussions and conducted an effort in the topic area of tough high-temperature adhesives. Dr. Ham investigated and developed methods for toughening brittle, high-temperature resins, identified and used experimental procedures for quantizing the significant polymer behavior and related these procedures to AF personnel. Dr. Ham presented his developments and findings in a brief in formal report.

Task 54 - Crack Growth Rate Determination from Displacement Measurements

Crack growth under sustained load at elevated temperature is an important part of the damage accumulated under spectrum loading in engine components. At low stress intensities, relatively slow crack growth rates are encountered which are difficult to measure accurately because of the small magnitudes involved and the lack of precision in conventional crack measurement techniques. Furthermore, the surface crack measurements are misleading as measures of crack extension because of tunneling. This investigation addressed the determination of crack extension through the use of accurate displacement and compliance measurements in conjunction with mathematical analysis to infer the amount of crack extension under sustained load. Laser interferometric displacement measurements with sub-micron resolution were utilized to obtain precision displacement and compliance measurements in creep crack growth at low growth rates. Finite element analysis using realistic consititutive models were utilized to determine crack extensions from the experimental data obtained. Dr. William N. Sharpe, a Contributive Researcher with UES, was assigned as principal investigator, Dr. Sharpe submitted a summary report of his work to the AFWAL/ML initiator.

Task 55 - <u>Mechanisms in Elevated Temperature Crack Growth Modeling</u>

Crack growth in nickel base superalloys at elevated temperature is controlled by both mechanical effects such as creep, plasticity, stress relaxation, etc. as well as environmental degredation of the material. In addition; three-dimensional effects, such as variations from plane stress to plane strain as well as plastic zone size, influence the growth rate of fatigue cracks under spectrum-type loading. This investigation addressed the formulation of crack growth models, in terms of the fundamental mechanisms which govern the behavior, and considered both mechanical and environmental factors. Data for IN-100 were utilized as a basis for model development. Fractographic studies were performed to assist in the model development. Dr. Hao-Wen Liu, a Contributive Researcher with UES, was assigned as principal investigator.

Task 56 - Spectrum Loading Models for Crack Growth at Elevated Temperature

Dr. John J. McGowan, an employee of UES, was assigned as principal investigator for this task. Crack growth in typical engine components is influenced by loads, temperature, and environment. The loading phase in typical turbine engine disks involves low-cycle fatigue of variable amplitude and frequency, as well as sustained loads leading to creep crack growth. This investigation addresses the development of cumulative damage or spectrum loading crack growth models which incorporate the effects of cyclic frequency, amplitude, and hold times, as well as interaction effects including effects of overloads causing retardation. In addition, three-dimensional aspects such as thickness effects in laboratory testing were investigated. The material modeled, was IN-100.

Task 58 - Organic Polymer Synthesis

Dr. James J. Kane, a Contributive Researcher with UES, investigated the synthetic parameters of the Glazier Oxidative Coupling reaction in an effort to obtain high-molecular-weight ploymeric materials and synthetically tailored these polymers to provide materials with improved thermal-oxidative stability. Dr. Kane studied thermal-induced cure reactions of such materials in the solid state.

Task 60 - TEM of Hydrovac Specimens

Dr. J.C. Williams, a Contributive Researcher with UES performed fine structure TEM evaluation of Hydrovac Specimens for phase relationship determination.

Task 62 - Electron Microscopy of Ordered Compounds

Dr. Dan Shechtman, an employee of UES, was principal investigator for this effort. Dr. Shechtman was required to perform highly specialized studies in transmission electron microscopy and to present an advanced level course of transmission electron microscopy to scientists and engineers of the AFWAL Materials Laboratory.

A critical electron microscopic study was required to assess the influence of various alloying additions to a diversity of extremely complex developmental materials. All of these materials possess an ordered structure of atoms, are based on stoichiometric compounds, and have been alloyed to such a degree that while the basic structure remains, the fully ordered atomic arrangements have been altered.

It is necessary to assess not only the influence of alloying on the structure at the electron microscopic level of perception, but also to relate this structure to the changes in mechanical and physical properties of the materials.

The materials considered were Silicon Nitride modified by additions of Boron Nitride, Titanium Carbide modified by the addition of Al, Nb, and/or Sn, and the Iron Aluminide, Fe_3Al, modified by the addition of Al, Mn, Ni, V, and/or N.

It was necessary for Dr. Shechtman to prepare and present individualized modules which described, and allowed 10-15 scientists and engineers to practice, several necessary advanced techniques in transmission electron microscopy. This course followed naturally from a basic course presented last year and was aimed specifically at techniques appropriate to the study of ordered intermetallic compounds.

Task 63 - Relating Chemical Quality Assurance to Composites

The principal investigator for this task was Dr. Anthony Wereta, a consultant to UES. The objective of this effort was to assimilate and analyze the data resulting from Chemical Quality Assurance and Environmental Fatigue Testing of Graphite Epoxy Components materials.

Dr. Wereta presented technical discussions to Air Force personnel, analyzing test data available from recent characterization experiments on Epoxy Resin Variates and composite materials. The data was evaluated, certain conclusions drawn, and the results documented in a report.

Task 66 - Magnetically Changed Optical Properties

Dr. Judith Bransky, an employee of UES, was principal investigator for this task. Dr. J. Bransky performed a literature review to survey for optical materials with magneto-optic properties. The size of the effect, relationship on important dependent properties such as magnetic field, temperature, pressure, deposition techniques, and laser power were noted.

Proposed magneto-optical effects studies were made for both theoretical and experimental. Experimental work was limited to the available equipment at AFWAL/ML. At the end of the work the following was reported:

a) Prioritized list of possible magneto-optical research topics to be pursued.

b) An assessment of the feasibility of using magneto-optical effects in practical applications.

c) Proposed future investigations. Suggestions for additional equipment, prices, and other insights facilitating the work.

Task 67 - See Task 18

This was a continuation of the effort undertaken in Task 18.

Task 68 - Theoretical Transport Data Analysis

Dr. J.E. Lang, a Contributive Researcher with UES, was the principal investigator for this effort. Dr. Lang designed and optimized computer curve fitting techniques for temperature-dependent electrical transport data from semiconductors, both n- and p- type, and developed and validated an algorithm for accurately extrapolating between the voltage-temperature calibration points of a Si diode thermometer over the temperature range 4.2 - 400K.

Task 68(a) - Analysis of Laminated Fiber Reinforced Composites

This task involved the mechanics of fiber-reinforced composites, including a major thrust concerning stress analysis of laminated fiber-reinforced composites. Dr. Som Soni, an employee of UES, was assigned as principal investigator for this task. Dr. Soni's research involved the computer modeling of stress analysis of laminated composites. Specifically this work entailed the stress analysis of laminated materials by solving boundary valve problems employing computer finite element techniques.

Task 69 - Elastic-plastic Finite Element Stress Analysis of Short Cracks

Short cracks in turbine engine components grow under cyclic loading and eventually will grow to a catastrophic size. In life prediction analysis, a major part of component life is in the slow-growth-rate regime while the crack is small. The prediction of the growth rate of small cracks is thus an essential part of life prediction. In turn, this requires a detailed knowledge of the material behavior near the tip of a short crack. Finite element modeling is an appropriate tool for developing crack-growth models. Because of the inelastic behavior of material near the crack tip, it is necessary to develop elastic-plastic finite element computer code capability and apply this to problems of small cracks. It was the purpose of this task to develop such a computer code capability by modifying existing inelastic computer codes and utilizing it to evaluate crack-growth criteria based on existing experimental data. Dr. Jalees Ahmad, an employee of Battelle Columbus, was employed on this task. The computer code was delivered at the completion of the effort.

Task 79 - Two Photon Absorption

Dr. Vaidva Nathan, an employee of UES, presented a seminar to the AFWAL/AL concerning a survey of Laser Hardened Materials. A briefing concerning two photon absorption was given.

Task 80 - Processing Science Project

A seminar on Processing Microstructure Control was presented. Dr. Roger N. Wright of the Materials Engineering Department at Rensselaer Polytechnic Institute, Dean George E. Dieter of the College of Engineering, University of Maryland, Dr. Rishi Raj of Rockwell International Science Center, and Dr. Hans Conrad of the College of Engineering Department of Metallurgical Engineering Materials Science, Lexington, participated in the seminar.

Task 81 - See Task 80

Task 82 - NDE for Multilayer Structures

Dr. Ori Ishai, an employee of UES, was principal investigator for this task. The problem of locating and measuring fracture critical defects in composite materials has been recognized for many years. Unfortunately, the large attenuation and complex geometries encountered in composite structures makes inspection using traditional ultrasonic methods difficult to impossible.

Current AFML in-house efforts are directed toward the development of new ultrasonic methods for the inspection of these structures. The overall objective of this research is to achieve the capability to detect and assess the gradual in-service degradation in these structural materials.

Under this request Dr. Ishai, provided insight into potential methods suitable for the inspection of composite structures.

Specifically, Dr. Ishai drew upon his own experience to provide suggestions for new research directions and presented a report outlining his research efforts

Task 83 - Material Behavior Modeling

For this effort Dr. Shmuel Nadiv, an employee of UES, was assigned as principal investigator. Dr. Nadiv evaluated the current approach to characterizing hot-worked microstructrues as a function of process parameters such as temperature, effective strain and strain rate to determine adequacy to satisfy the goals of the program. The review pointed out potential problem areas, and it provided guidance for achieving a useful solution for the problem. Dr. Nadiv also summarized the experimental work and developed a material behavior model that described the observations.

Task 85 - Organic Polymer Synthesis

Dr. Tonson Abraham, an employee of UES, was principal investigator for this program. Dr. Abraham investigated novel intramolecular cyclization (IMC) concepts leading to thermooxidatively stable polymers for high temperature resin application. The research included pertinent literature surveys necessary for the origination of novel IMC concepts as well as related model reactions to determine their feasibility. The requisite monomer synthesis was performed and the subsequent polycondensation reactions carried out to give high-molecular-weight polymers. Preliminary polymer characterization to determine polymer solubility, solution viscosity, infrared and ultraviolet-spectra were performed.

Task 86 - Microstructural Stability in Aluminum RSP Alloys

Aluminum alloys produced from rapidly solidified particulate (RSP) constitute a new and exciting class of aerospace materials with extremely promising potential. The technology is quite new and requires extensive research to acquire sufficient understanding for fruitful and timely application. It is known that the useful engineering properties of RSP aluminum alloys are highly sensitive to thermomechanical processing history. This investigation addressed the effect of temperature, strain, and strain-rate on the microstructure of the RSP alloys and the relationships between the microstructures attained and the various mechanical properties of interest. The program emphasized the integrity of inter-particle bonding, propensity for grain growth and recrystallization, and dispersoid particle size, distribuiton, and growth as functions of thermo-mechanical processing parameters. The work required extensive application of metallography, scanning electron microscopy and scanning transmission electron microscopy. Dr. Young W. Kim, an employee of UES, was the principal investigator for this task.

Task 89 - Laser Induced Optical Material Effects

Dr. Vaidya Nathan, an employee of UES, was principal investigator for this task. Dr. Nathan investigated laser-induced damage mechanisms and their effects on various laser-hardening schemes including effects of ambient pressure on surface breakdown, brillouin and enhanced Raman scattering, effects of focusing in liquids, and matrix isolation filters. Dr. Nathan also developed theoretical models for the evaluation of laser-hardening schemes from an understanding of fundamental physical properties.

Task 90 - See Task 80

Task 91 - See Task 80

Task 97 - Integrated Decision Support System

Mr. Robert Marcus, a Contributive Researcher with UES, was the principal investigator for this program. Mr. Marcus, conduced research with ICAM Integrated Decision Support System to provide user enhancements in the area of data type declaration for literal string variables and in the provision of a "case" primitive for using those variables in the user definition of decision logic.

Task 102 - Intramolecular Cyclization Concepts

The principal investigator for this task was Dr. Chen-Cheu Yu, a Contributive Researcher with UES. Dr. Yu investigated novel intramolecular cyclization (IMC) concepts directed to thermooxidatively stable polymers for high temperature resin applications. The research included pertinent literature surveys necessary for the origination of novel IMC concepts as well as related model reactions to determine their feasibility. The requisite monomer synthesis was performed and the subsequent polycondensation reactions carried out. Preliminary polymer characterization was performed.

Task 111 - Optical Properties of Magneto-Optical Materials

The principal investigator for this task was Dr. Judith Bransky, an employee of UES. Based on the findings of prior theoretical studies (see Task 66) experiments were conducted on promising magneto-optical materials with selected properties large enough to be potentially useful for Air Force applications. Experiments were confined to materials, supplies and equipment available within the time defined. Synthesis experiments were performed on magneto-optical single crystals such as CoO or NiO, with and without doping. Characterization experiments were performed on these crystals, such as Faraday Effect, Voigt Effect, room temperature conductivity versus temperature, infrared and/or visible transmission and reflection, electric field effects. Alternative synthesis methods, such as RF sputtering or ion beam deposition, were investigated. An informal technical report was submitted.

Task 116 - Prediction of Dynamic Stresses in Blades

Preliminary computer analyses of discrete model of a bladed disk system led to promising results from the point of view of understanding the phenomena controlling dynamic stress levels (see Tasks 18 and 67). A perametric investigation had been conducted which relates the results of experimental data, in order to ultimately predict dynamic response behavior under combined static/dynamic loads, and hence to control high cycle fatigue. Further efforts to complete the investigation were performed by Dr. Muszynska under this task. A draft technical report was produced.

Task 117 - Composite Material Design

Design of composite materials must be based on some statistical methodology so that the margin of safety can be rationally determined. Current methodology is very primitive and is generally limited to simple loading applied to idealized laminates. The purpose of this work was to explore the theoretical foundation of extending the state-of-the-art to include laminas under combined stresses. The objective was to establish the reliability and optimization of laminates by judicious choice of stacking sequence. Dr. Won J. Park, a Contributive Researcher with UES, addressed this effort.

Task 118 - Integrated Decision Support System

This was a continuation of Task 97.

Task 119 - VHSIC/VLSI

Dr. Eugene E. Jones, a consultant to UES, presented a seminar to the AFWAL engineers, presenting, technical and administrative liasion for implementing a viable research and development program. Dr. Jones provided much-required liasion between Tennessee State University and Georgia Tech University on specific efforts involving VHSIC/VLSI application.

Task 120 - Polymer Mechanical Study

The principal investigator for this effort was Dr. Ching-Chi Kuo, an employee of UES. Dr. Kuo investigated acetylene-terminated resins' mechanical properties during cure and after cure. The temperature and moisture effects on the properties were characterized.

Task 122 - Spectroscopy from Polymer Fracture

Dr. L. Dale Webb, a Contributive Researcher with UES, was the principal investigator on this program. The objective of this effort was to explore the feasibility and assess interim progress in using the fracture process to interrogate the morphology of advanced polymers

Dr. Webb participated in technical discussions with Air Force, university, and industry personnel, explored the literature, and assessed the state-of-the-art in the spectroscopy of polymer fracture.

Task 123 - Acetylene-Terminated Resins

This was a continuation of Task 53. Dr. Ham investigated and developed methods for toughening brittle, high-temperature resins and identified and used experimental procedures for quantizing the significant polymer behavior and related these procedures to Air Force personnel in a brief informal report.

Task 124 - Characterization of Electronic Materials

In order to achieve the high speeds, high densities, and reduced costs required for the next generation of electronic devices to operate AF systems, new materials as well as new forms and processing techniques of materials are being explored.

Accurate characterization must also progress along with material development as a central element in both gauging improvements and settling new directions. New characterization tools must be created and existing tools refined.

The task required the UES investigator to build and test a prototype facility for high-sensitivity electrical transport measurements of bulk semiconductors based upon a new two contract a.c. (alternating current technique) evaluate the feasibility of employing a contactless variation of the a.c. method for rapid measurement of the silicon layers in SOS (silicon on sapphire), modify and improve the presently used d.c. techniques for evaluation of thin layer semiconductors; and use the available methods for evaluation of electronic device grade silicon materials. Dr. Iman Maartense, a UES employee, was the principal investigation for this task.

Task 125 - Synthesis of Organic Compounds

Dr. Sujan Dua continued the work undertaken in Task 2 for this effort.

Task 126 - Organometallic Intermediates

Dr. Young C.S. Yang, a Contributive Researcher with UES, presented a seminar to the AFWAL/ML engineers concerning his research efforts in the synthesis of organic compounds.

Task 127 - Assessment of the Development Potential of Fe, Al, NiAl, and RSR Alloys

This task was a continuation of the effort by Dr. Williams undertaken in Task 9.

Task 128 - Laser Induced Optical Material Effects

The objective of this work was to formulate and develop new optical materials/coatings for protection of optical systems to jamming and damaging levels of laser radiation.

Dr. Joseph Davison, an employee of UDRI, was the principal investigator. From review of technical literature and current assessments, Dr. Davison selected several materials which show promise as candidates for refractive index - change through (a) change of phase, (b) stoichcometry, and (c) chemistry. Selection was followed by materials preparation as thin films and experimental characterization. Switching behavior was studied.

Task 129 - Elastic-Plastic Finite Element Analysis of Short Cracks

This task was a continuation of the effort under Task 69.

Task 132 - Surface and Interface Energy Correlation in Coatings

Dr. Fredrick M. Fowkes, a Contributive Researcher with UES, was the principal investigator for this task. Dr. Fowkes conducted experiments utilizing AFWAL/ML contact angle goniometer, Fourier transform infrared spectroscopy, attenuated total reflectance, and appropriate analytical techniques to provide data on internal changes during cure of coating that effect surface and interface properties. Correlations were investigated between the energy density and acid-base interactions and the final coating structure and properties. Characterization and correlations were conducted on current and developing Air Force coatings.

Dr. Fowkes submitted a summary report at the end of the research.

Task 133 - Constitution Theory Development

The objective of this work was to develop an experimentally verifiable constitutive theory for compacting metal powder and to apply the theory to the modeling of the vacuum hot pressing (VHP) Process for producing metal-working preforms.

The UES scientist initiated studies to develop (1) a large strain elastic-plastic-creep constitutive theory admitting irreversible volume shrinkage, and (2) an experimental program to determine the constitutive theory parameters. Dr. J.F. Thomas, a Contributive Researcher with

UES, was the principal investigator.

Task 134 - <u>Fracture Characteristics of Advanced Polymeric Materials</u>

The principal investigator for this task was Dr. Vernal Kenner, a Contributive Researcher with UES. The objective of this effort was to explore and develop new test methods to define the fracture characteristics of advanced polymeric materials.

Analytical and experimental stress analysis methods were applied to advanced polymeric materials to inquire into the changes that take place during environmental conditioning and fracture testing. New instrumentation and methods were developed and materials characterized.

Task 135 - <u>Statistics of Dynamic Stresses in Blades</u>

Dr. Jerry Griffin, a Contributive Researcher with UES, was the principal investigator. The AFWAL/ML bladed disk response computer program was utilized as part of an investigation of the effect of statistical variations of blade parameters on response behavior of the blades under idealized models of engine order excitation. Upper and lower bounds of blade amplitude and corresponding stresses were determined, using a Monte Carlo simulation procedure. Statistical estimates were made of the confidence levels of predicted maximum stresses based on samples (representing measurements of stress in a limited number of blades as in an engine test), in order to establish feasibility of realistic sampling procedures for real engine tests, to estimate "worst blade" stresses.

Task 136 - <u>Creep Fatigue Interaction in Alloy 718</u>

UES assigned Dr. J. Wayne Jones as principal investigator for this task. Dr. Jones undertook a study of several aspects of creep-fatigue interactions which affect crack propagation in Alloy 718. Experiments were made to measure post-hold-time fatigue crack propagation rates at elevated temperatures as a function of hold duration, Kmax and K (fatigue). A fractographic study was conducted to determine the crack propagation mode changes after hold time.

Task 137 - Liquid Dilatometer Tests

The objective of this effort was to develop and demonstrate test methods for measuring the process of cure shrinkage directly. Dr. Norman Wackenhut, a Contributive Researcher with UES, was the principal investigator. Dr. Wackenhut checked out, calibrated and conducted tests using an AF dilatometer and resin system, and made recommendations on the basis of the findings. The results were summarized in a brief letter report transmitted to appropriate AF personnel.

Task 138 - Fracture Modeling of Advanced Polymeric Materials

The objective of this effort was to provide analytical support and modeling to define the fracture characteristics of advanced polymeric materials. The principal investigator for this task was Dr. Sam Brockway.

A review of available experimental data from mechanical response and fracture tests was made, analyzed, and analytically modeled. Emphasis was placed on the time-dependent and rheological aspects of behavior and recommendations were made for subsequent investigations.

Task 139 - Theoretical Transport Data Analysis

Dr. Joseph E. Lang, a Contributive Researcher with UES, was assigned principal investigator. Dr. Lang designed computer curve fitting techniques for including the intrinsic transition region of the data and worked on the analysis of transport measurements on gated Hall structures.

Task 140 - Optical Properties of Single Crystals

Dr. Judith Bransky, an employee of UES, was assigned as principal investigator. Dr. J. Bransky investigated both theoretically and experimentally the expected change in optical properties of lithium-doped single crystal nickel oxide films under microsecond-range high voltage pulses, and correlated time-resolved optical transmission with time-resolved voltage/current pulses, as a function of wavelength in the 1-micron and 10-micron regions, of peak field strength, and of pulsewidth.

Dr. J. Bransky developed a first-order model to explain the measure effect and proposed other dopants, host crystals and combinations thereof that would be expected to show (1) enhanced levels of the same effect and (2) other effects involving electrically-induced optical switching. Dr. J. Bransky reported findings to the AFWAL/ML engineers, presented experimental results, and proposed other materials and synthesis methods, with supporting references.

Task 141 - Optical Properties of Thin Oxide Layers

Dr. Izar Bransky, an employee of UES, was principal investigator. Dr. I. Bransky investigated the optical and IR properties of thin oxide layers of the 1st order phase transition materials. Materials of interest were compounds of $BaTiO_3$ with various dopants such as Sm and Pt. Measurements included transmittance and reflectance. Stiochiometry was controlled so that transitions can be studied as a function of temperature. Effects of the phase changes on the index of refraction, reflection and electrical conductivity were studied. A technical report of the work was prepared.

Task 142 - Fluid Cooled Mirrors

Silicon is gaining prominence as a potential material for the fabrication of fluid cooled mirrors for high power laser applications. Uncertainties exist in the surface chemistry and physics of silicon related to its ability to accept metallized coatings, dielectric stack reflectivity enhancement coatings and perform in a superior fashion to other candidate substrate materials when subjected to intense laser radiation. This work required the UES investigator to conduct a brief literature survey of the SOTA of silicon with respect to the above application, to contact leading specialists in the field and to establish program guidelines necessary to further evaluate the surface characteristics of silicon in this application. Dr. Edmund J. Rolinski, a Contributive Researcher with UES, was the principal investigator for this work.

Task 143 - Polymer Mechanical Study

Dr. Ning-Cheng Lee, an employee of UES, was assigned as principal investigator for this task. Dr. Lee investigated acetylene terminated resins-mechanical properties during cure and after cure. The temperature and moisture effects on the properties were characterized. This effort is expected to continue under the follow on contract to the present effort.

Task 144 - Stress Analysis of Hydraulic Seals

The objective of this effort was to develop a theoretical stress analysis of an elastomeric hydraulic seal. Using these analyses, the investigator can identify specific material properties that affect sealing and seal life. The effort undertook to develop an analytical model for an elastomeric o-ring seal in a gland with reciprocating motion and perform parametric analysis to determine seal state-of-stress and material parameters that affect seal behavior.

In the initial portion of the effort the investigator selected, from available analytical models, that program which is most representative of a conventional o-ring seal acting in a groove under reciprocating motion. Following the selection of the best available programs, the investigator undertook to optimize the program to fit the requirements of the seal system.

Dr. Thomas Held, a consultant to UES, was assigned as principal investigator for this work. It is anticipated that his work will continue under the follow-on the contract to this effort.

Task 145 - Wave Shape Effects in Crack Growth in Super Alloys

Creep and fatigue interactions are an important part of the crack growth behavior in engine disks. Both fatigue and creep crack growth are important in the analysis of engine components under spectrum loading. Because of the small number of fatigue cycles in an engine spectrum, the interactions between creep and fatigue must be evaluated. This research project undertakes to evaluate the effects of wave shape and amplitude on the crack growth characteristics of typical turbine disk material. Models will be developed to account for the interactions of creep and fatigue and will be applied to engine spectrum loading in general.

Dr. Noel Ashbaugh, an employee of UES, was assigned as principal investigator. The work under this task is expected to continue under the follow-on contract to this effort.

Task 146 - NDE of Composites

Dr. Ori Ishai, an employee of UES, was principal investigator for this task. The problem of identifying and tracking damage in composites in order to assess the condition of the structure is one which is of great interest to the Air Force. Unfortunately, the complicated nature of the structure and the damage processes has made progress very difficult.

Current in-house research efforts at the AFWAL/Materials Laboratory NDE Branch are directed toward the development of NDE methods to track and quantify damage in composites using ultrasonic backscattering techniques. In order to pursue this research, specimens containing known amounts of damage must be prepared, the NDE results related to those obtained from destructive measurements as well as conventional NDE methods and the overall usefulness of any new NDE methods must be evaluated.

Under this task Dr. Ishai supplied fundamental background information relating NDE results to composite damage, which is necessary to maximize the effectiveness of the AFWAL/ML effort in this area. Specifically, Dr. Ishai provided detailed information on the results of his own research as well as participating in the effort in AFWAL/MLLP to develop new NDE methods for composites.

Task 149 - Application of Finite Element Methods to Bonded Joint Problems

Dr. Shlomit Gali, an employee of UES, was principal investigator for this task. The objective of this effort was to evaluate the sensitivity of various bonded joint configurations to irregularities typical of production. Dr. Gali planned and conducted finite element stress analysis of bonded joint configurations. This work is expected to continue on the follow-on contract to this effort.

SECTION II

Section 2.0 Avionics Laboratory

The description of the tasks performed by UES for the AFWAL/AL is presented in this section.

Task 4 - GaAs MESFET Burnout Investigation Phase I

The objective of this effort was to investigate the microwave pulse and cw burnout properties of gallium-arsendie field effect transistors (MESFETs) used in microwave preamplifiers, to help determine the technology required to fabricate improved devices.

This effort consisted of the fabrication and testing of microwave preamplifier stages employing commercially available GaAs MESFETs. The MESFET devices were then exposed to I-band pulsed microwave signals in the 10 nsec to 1msec range and to continuous-wave signals. Tests were performed to determine the threshold signal levels required for device degradation. The mechanisms responsive for degradation and burnout were investigated by electrical test, optical, and electrical microscopy.

Dr. James J. Whalen, a Contributive Researcher with UES, was assigned as principal investigator on this effort. Dr. Whalen submitted a technical report to the AFWAL/AL engineers at the completion of this effort.

Task 5 - Preparation of Insulator Films on GaAs

The principal investigator for this effort was Dr. Burhan Bayraktaroglu, an employee of UES. This work effort required the UES investigator to develop practical passivation techniques for GaAs integrated circuits. The specific approach included the sputter deposition of insulator films on GaAs and plasma anodization of GaAs. Measurements were made to determine interface surface density, charge trapping, and the nature of any accumulation, inversion, or depletion layers in the metal insulator semiconductor structures. These measurements included capacitance-voltage, conductance-voltage, current-voltage, voltage, voltage breakdown, dielectric constant, photoconductivity, and charge centroid. Results of these measurements were used to evaluate metal insulator semiconductor structures prepared by various techniques for potential use in GaAs devices. In particular the plasma-enhanced deposition of Si_3N_4 was investigated, and properties of films deposited by these means were investigated.

Task 6 - Optical Materials Characterization of GaAs

Dr. Quiesup Kim and Dr. Cheng-Yeuh Chen, UES employees, were the principal investigators on this effort. Scanning and quantitative photo-luminescence experiments were performed for the study of impurities and the homogeneity of their distribution in semiconductor material. This technique was employed to study GaAs, Si and InP substrates material epilayers and GaAs under passivation layer deposited by various means.

Task 7 - Chemical Properties of GaAs

The principal investigator for this effort was Dr. Richard Yalman, a Contributive Researcher with UES. Dr. Yalman developed a model of the chemical reactions involved in growing pure and doped GaAs epitaxial layers with particular concern for 1) residual impurities, 2) growth from metal organic compounds and 3) the chemical equilibrium reactions involved for forming insulating layers on the GaAs.

Task 8 - Preparation of Insulator Films on GaAs

A chemical vapor deposition was set up which allowed the deposition of Si_3N_4 on etched, or freshly grown GaAs. The possibility of using metal organic vapor phase epitaxy for GaAs and GaAlAs was included in the fabrication of the system. The suitability of the approach was evaluated after some test runs were made.

Dr. Robert Turoff, a Contributive Researcher with UES, was the principal investigator. Dr. Turoff presented a summary report of his work to the AFWAL/AL engineers.

Task 11 - Characterization of Ion Implanted Semiconductors

Dr. Richard Kwor, a Contributive Researcher with UES, was the principal investigator. Dr. Kwor characterized implanted III-V compound semiconductors with electrical techniques such as Hall and C-V measurements and correlated these measurements with studies of the concentration profiles as revealed by Secondary Ion Mass Spectroscopy (SIMS). Dr. Kwor presented a summary report of his work to the AFWAL/AL engineers.

Task 13 - High Temperature Superconductivity

Dr. Yun Chung, an employee of UES, was the principal investigator on this excitonic-superconductor program. The program was aimed at high-temperature superconductivity (77 K and above). The initial investigation were focused on CuCl where the potential for high-temperature superconductivity has been observed. Experiments were designed to confirm or negate the diamagnetic anomaly associated with dramatic changes in conductivity that have been observed in CuCl. These experiments required that crystals be grown in the laboratory. Conductivity and magnetic susceptibility measurements were made at pressures as high as 100 K bars. These measurements were also made as a function of temperature. Optical measurements were necessary for characterization purposes.

Analyses of the phenomena was necessary to predict whether other materials may also have potential for high-temperature superconductivity.

Task 14 - High Temperature Hyperconductivity

Dr. John Woollam, a Contributive Researcher with UES, presented a seminar on critical experiments to be performed on the high-temperature hyperconductivity program. Equipment necessary to perform the experiments was outlined. The techniques for growing CuCl crystals was reviewed in this seminar.

Task 15 - Characterization of Microwave Devices

For this task, Dr. F.L. Pedrotti, a Contributive Researcher with UES conducted an investigation of the material problems that affect the performance of solid-state microwave and opto-electronic devices from compound semiconductors by conducting a thorough characterization study of materials processes, and devices and assess the utility of ion-implantation techniques for devices fabrication. Dr. Pedrotti presented a summary report of his work.

Task 16 - Seminar on Defect Structures in Ion Implanted GaAs

Dr. Ray Benson a Consultant to UES, presented a seminar on "Defect Structures in Ion Implanted GaAs," and provided information on the use of the TEM to ion-implanted GaAs.

Task 19 - Impurities and Defects Seminar

For this task, Dr. R.T. Chen, a Contributive Researcher with UES, visited the AFWAL/AL facilities to present a seminar on the Local Mode Spectral Characterization of Impurities and Defects in GaAs, including characterization of microstructure and lattice defects by means of TEM. Dr. Chen discussed and provided insight on problems of mutual interest in the impurity and defect structure of GaAs and related materials and discussed growth and characterization of CuCl crystals for possible high-temperature superconductivity applications.

Task 20 - High-Temperature Superconductivity Seminar

Dr. John Woollam, a Consultant with UES, presented a seminar at the AFWAL/AL facilities on the construction of a pressure cell to make magnetic susceptibility measurements as a function of pressure and temperature on CuCl crystals.

Task 22 - Growth and Properties of GaAs

Dr. G.E. Stillman presented a seminar concerning the growth and properties of gallium arsenide, a material of great importance in solid-state microwave and electro-optic devices. The seminar, open to all interested laboratory scientists, reviewed current research on characterization of gallium arsenide and other III-V semiconductors. Further discussions with Dr. Stillman centered around possible future directions for research at the Avionics Laboratory.

Task 23 - Magneto-Transport Seminar

Dr. J.C. Portal, a Contributive Researcher with UES, presented a seminar on the Magneto-Transport in Semiconductors in High Magnetic Fields to discuss and provide information on problems of mutual interest in the impurity and defect structure of GaAs and of related materials.

Task 25 - Seminar on Superconducting Materials

Dr. John Woollam presented a seminar on the measurements of magnetic susceptability of superconducting materials at elevated pressures and at temperature ranging from liquid helium temperature to room temperature.

Task 28 - Chemcial Properties of GaAs

This was a continuation of Task 7.

Task 29 - GeN Passivation of GaAs

A seminar of GeN Passivation of GaAs was presented by Dr. Krishna Pande of Rutgers University. The focus of this seminar concerned the equipment used for GeN passivation of GaAs currently used at Rutgers University. Dr. Pande also provided samples, prepared at Rutgers, for measurement at the AFWAL/AL for comparative purposes.

Task 30 - System Avionics Design Engineering

Dr. Isaac Porche, a Contributive Researcher with UES, prepared a state-of-the-art review of functional components for multi-processor network with estimation of overall network size and performance capabilities, and predictions of reliable synchronizations for avionics multiproccessor networks.

Task 31 - Seminar on Avionics Research

Task 31, 32, 33, and 34 involved the presentation of seminars by several professors from North Carolina A&T University, concerning research being conducted there of interest to the AFWAL/ML personnel. Dr. Windsor Alexander presented a seminar of digital signal processing and image processing.

Task 32 - Seminar of Avionics Research (See Task 31)

Dr. Ward Collis gave a seminar on the feasibility of conducting research in controlled crystals growth and characterization at North Carolina A&T University.

Task 33 - Seminar on Avionics Research (See Task 31)

Dr. Chung Yu presented a seminar on digital signal processing and image processing.

Task 34 - Seminar on Avionics Research (See Task 31)

Dr. Harold Martin gave a seminar on fault tolerant, microprocessor based systems for applications in avionics environment.

Task 35 - Ion Beam Analysis

Dr. Peter Pronko, an employee of UES, presented a seminar on "Ion Beam Analysis of Ion-Implanted and Laser-Annealed Semiconductors".

Task 36 - Epitaxially Grown Polycrystalline GaAs

Mr. Amitabh Srivastava, an employee of UES, gave a seminar at AFWAL/AL on his recent experimental work on "Crystallographic and Electrical Properties of Epitaxially Grown Polycrystalline GaAs," and discussed with members of the division his work on organometallic growth of GaAs.

Task 37 - Dielectric Properties of Thin Films

Dr. Vijendrh K. Agarwal, a Consultant to UES, gave a seminar on "Dielectric Properties of Thin Films" based on his own experimental and theoretical work during the past years. Discussions of problems of dielectric films on GaAs and interface properties of dielectric films with substrates in general were held with members of the division.

Task 40 - Optical Properties of Solids

Dr. Cheng Yueh Chen, an employee of UES, presented a seminar on "Optical Properties of Solids," and provided information on the use of optical technqiues for materials characterization.

Task 42 - Oxides on III-V Compound Semiconductors

Dr. Gerald Lucowsky of North Carolina State University, presented a lecture on recent work related to the "Oxides of III-V Compound Semiconductors," and discussed the physical chemistry of passivation of GaAs with scientists working at AFWAL/ML in this field.

Task 43 - GaAs and GaAlAs Epitaxial Layers on GaAs

Mr. Amitabh Srivastava, an employee of UES, was principal investigator for this effort. The focus of this task was to investigate the growth of GaAs and GaAlAs epitaxial layers on GaAs with an existing metal-organic chemical vapor deposition system. This system was used to deposit Si_3N_4 and Ge_3N_4 on freshly grown or freshly etched GaAs crystals, via vapor reaction using Silane or Germane and ammonia and to deposit electrical contacts on the thus prepared structures and to measure C-V and G-V response as a function of frequency. The data was interpreted in terms of dielectric properties of the insulator and band bending at the insulator-semiconductor interface.

Task 44 - Rational Data Base System

Dr. M. Casandra Smith of Howard University presented a seminar on research applications in natural language interface of a Rational Data System.

Task 45 - Excitonic Superconductor (See Task 13)

Task 47 - Thin Film Solar Cells

Professor K.L. Chopra presented a seminar on Thin Film Solar Cells, to discuss and provide information on problems of mutual interest in the impurity and defect structure of GaAs and related materials.

Task 51 - Glow Discharge Optical Spectroscopy

Dr. S.S. Yun, a Contributive Researcher with UES, was the principal investigator for this task. Dr. Yun undertook experimental procedures of Glow Discharge Optical Spectroscopy (GDOS) and the interpretation of the GDOS data on ion-implanted III-V compound semiconductors.

Task 57 - Seminar on GaAs Electrical Data

Dr. J.L. Tandon, a consultant to UES, presented a seminar to the AFWAL/AL engineers on the interpretation of electrical data on ion-implanted GaAs.

Task 59 - Shallow Donor and Acceptor Impurities in GaAs

Dr. Anthony Stradling, a consultant to UES, presented a seminar to the AFWAL/AL engineers concerning his work on the identification of shallow donor and acceptor impurities and defects in GaAs and related materials. Dr. Stradling discussed research problems on the characterization of semiconductor device materials.

Task 61 - Crystals Growth Seminar

Dr. Peter Colter, an employee of UES, presented a seminar concerning his work on the crystal growth and electrical characteristics of thin metallic film materials and discussed research problems on the growth and characterization of semiconductor device materials.

Task 64 - Epitaxial GaAs Crystals Growth System

Dr. Robert Turoff and Mr. Ronald Clericus, an employee of UES, addressed this task. An existing gallium arsenide epitaxial growth system was upgraded and automated. A key portion of the flow system was rebuilt to improve its integrity against leaks and to allow for convenient removal and replacement of flow controllers.

A suitable system was designed and implemented for controlling and monitoring an eptiaxial gallium arsenide crystal growth system. This system includes capabilities for: a) entering and storing data; b) monitoring temperatures as measured by thermocouples, c) controlling, monitoring and displaying gas flow rates, d) controlling and displaying the status of gas flow paths via the switching of solenoid valves and panel lights, e) performing time sequenced operations involving all combinations of control and monitoring functions, and f) calling an operator when manual operations must be performed. The system is controlled by an HP 9825A calculator, and outputs consist of data flow back to the calculator, visual displays, an audio alarm, and voltages and contact closures for controlling and monitoring electronic components.

Detailed schematics of all custom-built circuits and components, and a narrative explaining their operation and containing troubleshooting aids were provided.

Task 65 - Advanced Analysis Capabilities for Deep Level Transient Spectroscopy

Mr. Ronald Clericus, an employee of UES, was assigned as principal investigator for this task. A suitable system was designed and acquired for fast signal digitization (3 μsec resolution in 200 to 1000 consecutive intervals), on-line data reduction (within 1 sec maximum) and data storage. The system was interfaced with available equipment: 1) capacitance bridge, 2) programmable pulse generator, and 3) temperature controller/thermocouple via multiprogrammer. All necessary interconnection and software was provided.

Task 71 - Natural Language Interface

Dr. Cassandra Smith of Howard University presented a seminar on a proposed effort entitled "Natural Language Interface."

Discussions and outline of research activities related to the execution of the first stage of this research effort were involved.

Task 72 - Avionics Research Efforts at Historically Black Colleges

Task 72, 73, 74, 75, 76, 77, 78, 79, 87, and 88 were for the attendees of a seminar concerning Avionics Research problems addressed at Historically Black Colleges. Attendees were:

Ms. Janel Scott, Tuskegee Institute, ALA
Ms. Laly Washington, Tuskegee Institute, ALA
Mr. Wilbert Jones, Howard University, Washington D.C.
Dr. Winser Alexander, North Carolina A&T University, N.C.
Dr. Kenneth Perry, Atlanta Univ., CRT/GA Tech. Ess., GA.
Mr. Kinzie Kelly, Atlanta University, Center, GA.
Mr. James Rucker, Atlanta University, Center, GA.
Ms. Kathleen A. Battle, Morris Brown College, GA.
Dr. Frank Weaver, Morris Brown College, GA.

Task 73 - Avionics Research Efforts at HBC's (See Task 72)

Task 74 - Avionics Research Efforts at HBC's (See Task 72)

Task 75 - Avionics Research Efforts at HBC's (See Task 72)

Task 76 - Avionics Research Efforts at HBC's (See Task 72)

Task 77 - Avionics Research Efforts at HBC's (See Task 72)

Task 78 - Avionics Research Efforts at HBC's (See Task 72)

Task 79 - Avionics Research Efforts at HBC's (See Task 72)

Task 84 - Auger Spectroscopic Analysis

Dr. John T. Grant, a consultant with UES, performed Auger Spectroscopic depth profile analysis of government furnished samples of Si_3N_4/GaAs structures. Reports of the findings were delivered to the AFWAL/ML engineers.

Task 87 - Avionics Research Efforts at HBC's (See Task 72)

Task 88 - Avionics Research Efforts at HBC's (See Task 72)

Task 92 - GaAs Epitaxial Growth by $H_2/AsCl_3/Ga$

The principal investigator for this effort was Dr. Richard Yalman, a Contributive Researcher with UES. Dr. Yalman provided information and performed theoretical calculations on the equilibrium and non-equilibrium chemical reaction kinetics and thermodynamics involved in the vapor phase epitaxial growth of GaAs on bulk crystal substrates by the $H_2/AsCl_3/Ga$ and related vapor phase reaction methods. In particular, Dr. Yalman employed a digital electronic calculator to program and calculate parameters pertinent to the vapor phase epitaxial chemical reactions, such as entropy, enthalpy, free energy, reaction rates of chemical species, optimum growth temperatures, source gas flow rates and dopant gas incorporation, as well as other chemical and thermodynamics parameters which influence growth rate and epitaxial layer quality. Dr. Yalman performed preliminary calculations on the chemical and thermodynamic conditions required for growth of several ternary and quarternary III-V component epitaxies, such as GaInAs, InAlAs, GaAlAs and GaInAsP. A summary report of this work was delivered to the AFWAL/AL engineers.

Task 93 - Seminar on COVINREST Concepts

Dr. Kenneth Perry of Georgia Tech presented a seminar on aspects of research conducted at the Engineering Experiment Station, Georgia Tech University pertinent to radar/ECM simulation and analysis over irregular terrain as might be applicable to the COVINREST concepts.

Briefing on applicable research in VLSI application to digital signal processing activities pertaining to radar and other image analyses was presented.

Task 94 - Theoretical Model of GaAs

Dr. Krishan K. Bajaj, an employee of UES, was assigned as principal investigator for this effort. Dr. Bajaj pursued a research program which had the following main thrusts in the area of theoretical semiconductor physics and communicated the results of this work to personnel of the Electronic Research Branch of the AFWAL/AL.

Dr. Bajaj performed calculations of the energy levels of various impurities and impurity complexes such as D^- and Hydrogen molecular like structures and exciton and exciton complexes (both with impurities and other excitons) in the presence of screening due to free carriers in compound semiconductors. These calculations were done using materials involving perturbation and variational approaches. Theoretical modeling of systems such as hetrojuction multilayers and fabricated devices (FETs, detectors, etc). with a focus to relate the material parameters with the device performance parameters was undertaken, as well as work on a theoretical model to explain the phenomenon of thermal conversion in GaAs.

Dr. Bajaj provided theoretical support to several experimental groups involved in far-infrared spectroscopy photoluminescence, crystal growth, deep level transient spectroscopy and ion implantation of GaAs.

Task 95 - Plasma Enhanced Deposition

The principal investigator for this program was Dr. Vivian Merchant, an employee of UES. Under this task Dr. Merchant designed a Plasma-Enhanced Deposition System. A brief description of the system design parameters is given below. The design was turned in to the AFWAL/AL engineers.

A system was designed which allows the controlled deposition of Si_3N_4 or Ge_3N_4 films on 1" dia. GaAs and the etching of GaAs by HF, HCl and $AsCl_3$. It was designed according to Ultra-High Vacuum (UHV) standards, with well controllable gas flow-rates, pressure and radio frequency discharge. The sample can be introduced via a vacuum lock arrangement and provisions were made to vary its temperature between room temperature and 650°C. The sample chamber reaches vacuum of 10^{-9} torr prior to deposition. A residual gas analyzer can be connected to the system. Pressure, flow, temperature and R-F controls are automatic and programmable. Optical ports are available for in-stiu ellipsometric measurements and/or light induced reactions at the GaAs surface.

Task 96 - Effects of Distortion on CuCl

Dr. Takao Pakeichi of North Carolina Central College, presented a seminar on the "Theoretical Effects of Distortion on Electronic Properties in Copper Chloride."

Task 98 - GaAs Passivation and GaAs IGFET's

Dr. Hausila P. Singh, an employee of UES, was the principal investigator of the effort. This work effort required Dr. Singh to apply practical passivation techniques to GaAs transistors and integrated circuits. This technique was applied to devices with low threshold voltages (~0.7V). The specific approacn included deposition of Si_3N_4 and Al_2O_3. Measurements were performed to evaluate the effectiveness of the passivation layer; measurement techniques included drift studies, DLTS studies, and performance studies at microwave frequencies. The work effort required Dr. Singh to perform research and development work in the area of GaAs IGFETs. GaAs IGFET technology developed at AFWAL/AADE has verified transistors, inverters, flip-flops, ring oscillators, and divide by two circuits. Dr. Singh's was responsible for further development of this technology. More specifically, Dr. Singh explored selfaligned IGFETs, fabricated and tested integrated circuits (e.g., prescalers, multiplexers). The high-speed performance of these circuits was verified by Dr. Singh. A summary report of this work was presented to the AFWAL/AL engineers.

Task 99 - Deposition Equipment Safety Study

Mr. Amitabh Srivastava was the principal investigator for this effort. The vapor-phase deposition equipment at the AFWAL/AL in-house facilities for the growth of insulating films on Gallium Arsenide was inspected and brought into compliance with industrial safety standards. All necessary modifications were made, and a standard operational procedure for the operation of the system was documented.

Task 100 - AADR Program Advisory Group

Dr. Tom Collins and Dr. Cohn, consultants to UES, were the principal members of this Advisory Group. UES established this advisory group to provide a continuing assessment of AADR's technical program and to make recommendations for improvements. This group was accessed on a schedule established by the AFWAL/AL and UES personnel. Typically, a member was asked to do an on-site, in-depth review of a phase of the program, and the entire group met for a comprehensive review. The results of all group activity was consolidated and summarized periodically.

Task 101 - 130 Kilogauss Nb_3Sn Superconductive Magnet System

Dr. Edward Mains and Dr. G. Ciancetta, Contributives Researchers with UES, were the principal investigators for this effort. They presented a seminar to the AFWAL/AADR scientists and engineers on the design, construction and operation of 130 Kilogauss Nb_3Sn Superconductive Magnet System contained in a Janis Cryogenic Dewar, originally purchased from the Intermagnetics General Corp., and outlined critical modifications to this system, which involve changes and alterations in the Liquid Helium Reservior containing the superconductive solenoid, as well as changes to the electrical wiring and power supply. They provided up-dated engineering drawings and operational manuals on this magnet system.

Task 103 - Epitaxial Crystal Growth

Dr. Peter Colter, a UES employee, was the principal investigator for this task. Dr. Colter pursued research program in epitaxial crystal growth and materials characterization which had the following main thrusts and communicated the results of this work to personnel of the Electronic Research Branch (AADR): Dr. Colter performed final modifications and maded final calibration measurements on a new multibubbler $AsCl_3$/Ga/H2 vapor phase crystal growth reactor system designed to synthesize GaAs epitaxy under substoichiometric growth conditions, Dr. Colter used this reactor to investigate growth of GaAs epitaxy under Ga and As-rich growth conditions, to determine conditions necessary to achieve stoichiometric and substoichiometric growth, and to determine the effect of stoichometry and foreign impurities on the electrical and optical properties and the electronic defect structures of GaAs VPE layers.

Dr. Colter performed materials characterization measurements and determined intrinsic and extrinsic properties of as-grown VPE GaAs and related materials by means of photoluminescence, absorption and reflection spectroscopy. An investigation of electrical characteristics of As-grown GaAs epitaxy and related materials by means of Hall measurements, resistivity and C-V profile techniques was performed.

Task 104 - Theoretical Semiconductor Physics Study

This was a continuation of the effort undertaken in Task 94.

Task 105 - Chemical Kinetics of GaAs Growth

This was a continuation of the work started in Task 92. Under this effort Dr. Yalman pursued a research program which had the following main thrusts and communicated the results of this work to personnel of the Electronics Research Branch (AADR). Dr. Yalman performed thermodynamic and chemical kinetic calculations for the Ga/$AsCl_3$ reaction both in Hydrogen and in inert gas flows, and performed thermodynamic and chemical kinetic calculations for the In/$AsCl_3$ reaction both in Hydrogen and in inert gas flows and compared results with available experimental data. Dr. Yalman performed theoretical studies of the thermodynamics and reaction mechanisms of unintentional dopants (residual contaminants) for the Ga/$AsCl_3$ reaction and initiated a theoretical study of reaction rates and growth mechanism of the growth-substrate crystallographic orientation.

Task 106 - Preparation of Insulator Films on GaAs

This was a continuation of the effort undertaken in Task 5.

Task 107 - Magnetic Susceptability of Superconducting Materials

Dr. John Woollam, a consultant with UES, presented a seminar of the measurement of magnetic susceptability of superconducting materials at elevated pressures and at temperatures ranging from liquid helium temperature to room temperature.

Task 108 - High-Temperature Superconductivity

This was a continuation of the work started in Task 13.

Task 109 - Defect Structures of GaAs

Dr. Cheng Yueh Chen, an employee of UES, was the principal investigator for this program. Dr. Chen undertook an effort ot study the problems involved in the impurity and defect structures of GaAs and related materials and to study the growth and characterization of CuCl crystals for possible high-temperature superconductivity applications. Dr. Chen incorporated the use of optical techniques for materials characterization.

Task 110 - Epitaxial Layer Growth on GaAs

This was a continuation of the effort undertaken in Task 43.

Task 112 - GaAs MESFET Investigation Phase II

Dr. James J. Whalen, a Contributive Researcher with UES, was the principal investigator for this task. This effort was a continuation of the Phase I GaAs MESFET Burnout Investigation (See Task 4). The technical work was divided into three areas. The first involved determining burnout data for commerical GaAs MESFETs with aluminum (Al) gates and titanium-platinum-gold (Ti-Pt-Au) gates to CW microwave signals. The second area consisted of performing additional failure diagnostics on GaAs MESFETs overstressed with usec pulses. Scanning Electron Microscope (SEM) diagnostic techniques were used. The third area involved electro-thermal modeling of GaAs MESFETs overstressed with nsec and usec pulses. The goal was to develop electrothermal analysis techniques similar to those used for silicon pn junctions. A technical report of the work was delivered to the AFWAL/AL personnel.

Task 113 - Applications of Ion Beam Analysis

Dr. Rabi S. Bhattacharya, an employee of UES, presented a seminar on the "Application of Ion Beam Analysis."

Task 115 - TEM Investigations of Material Properties

Dr. Vijay Sethi of the Argonne National Laboratory presented a seminar concerning the use of the TEM to determine material properties.

Task 121 - Defect Structures in Ion Implanted GaAs

Dr. K. Seshan of the University of Arizona presented a seminar on defect structures in ion-implanted GaAs and the use of TEM to ion implanted GaAs.

Task 130 - Ion Implantation for Device Fabrication

Dr. F.L. Pedrotti, a Contributive Researcher with UES, was the principal investigator for this effort. Dr. Pedrotti investigated the material problems that affect the performance of solid-state microwave and opto-electronic devices from compound semiconductors by conducting a thorough characterization study of materials, processes, and devices and assessed the utility of ion implantation techniques for device fabrication.

Task 131 - Evaluation of Thermionic Cathodes

Dr. Gustav K. Medicus, a Contributive Researcher with UES, was the principal investigator for this effort. The goal of this program was to improve thermionic cathodes by providing an improved qualitative understanding of their emission. The aim of the program was to match theoretical and experimental current-voltage curves for the full range of cathode operation. Of special interest was the high-current-density Schottky range where conventional theory breaks down.

Active oxide-type cathodes consistently exhibit a "Schottky temperature: (obtained form the ration log $J/V^{1/2}$; J = current, V - cathode to anode voltage) significantly different from the cathode temperature. Theoretically, these two temperatures should be equal. Dr. Medicus proposed a new theory which explains this discrepancy; however, reinterpretation of J-V curves in all three basic current-density ranges (retarding field range, space charge limited range, and Schottky range) was necessary.

Dr. Medicus performed emission tests of thermionic oxide-type cathodes, plotted the J-V curves and analyzed results. The emission test were performed in a movable-anode test tube. An improved version of the test tube was fabricated, the improved tube was used on this program. A second derivative machine was assembled for plasma studies conducted at the Avionics Laboratory. Dr. Medicus used the experimental data to test recent developments in thermionic emission theory which resulted from Avionics Laboratory Project 20020244 and Avionics Laboratory Contract F33615-79-C-1876. Extensions and modifications were made to the theory, based on experimental data. Dr. Medicus submitted progress reports on this work.

SECTION III

Section 3.0 Program Schedule

This final program schedule for the contract is presented. A total of 71,614 man-hours were delivered under this contract.

PROGRAM SCHEDULE	SYSTEM NO. (PROJ) 718	SUBSYSTEM F33615-79-C-5129	TYPE Management Summary	AS OF FINAL

LINE	PROGRAM MILESTONES	PRIOR SCHED MO	PRIOR SCHED YR	FISCAL YEAR 1980	FISCAL YEAR 1981	FY 19	FY 19	FY 19	COMPL DATE QTR	COMPL DATE FY
1	Task UES 1: Molecular Spectroscopy of surfaces				C ▲ (S)	NCELL	ED			
2	Task UES 2: Synthesis of Organic Compounds				▲ (J)					
3	Task UES 3: Silicon Elec. Trasport Theory				▲ (S)	COMPLETE				
4	Task UES 4: GaAs MESFET Burnout Investigation			▲ (S)	COMPLETE					
5	Task UES 5: Preparation of Insul. Films on GaAs			▲ (S)	COMPLETE					
6	Task UES 6: Optical Materials Char. of GaAs			▲ (S)	COMPLETE					
7	Task UES 7: Chemical Properties of GaAs			▲ (J) COMPLETE						
8	Task UES 8: Preparation of Insul. Films on GaAs			▲ (J) COMPLETE						
9	Task UES 9: Development Potent. of Fe_3Al,NiAl,RSR			▲ (S)	COMPLETE					
10	Task UES 10: Surface Treatment to Tit. Alloys			▲ (S)	COMPLETE					
11	Task UES 11: Characterization of III-V Compound Implants			▲ (S)	COMPLETE					
12	Task UES 12: Composites Material Analysis			▲ (S)	COMPLETE					
13	Task UES 13: High Temp. SuperConductivity				▲ (D) COMPLETE					
14	Task UES 14: Consultant High Temp. Superconductivity			▲ (O) COMPLETE						
15	Task UES 15: Characterization of Microwave Devices				▲ (O) COMPLETE					
16	Task UES 16: Defect Structures in Ion Implanted GaAs			▲ (N) COMPLETE						
17	Task UES 17: Pole Figure Analysis of Polymers			▲ (A)	COMPLETE					
18	Task UES 18: Prediction of Dynamic Stress in Baldes			▲ (M) COMPLETE						
19	Task UES 19: Impurities & Defects Seminar			▲ (D) COMPLETE						

PROGRAM SCHEDULE	SYSTEM NO. (PROJ) 718	SUBSYSTEM F33615-79-C-5129	TYPE Management Summary	AS OF

LINE	PROGRAM MILESTONES	PRIOR SCHED MO	PRIOR SCHED YR	FISCAL YEAR 1980 (O N D J F M A M J J A S)	FISCAL YEAR 1981 (O N D J F M A M J J A S)	FY 19 (1 2 3 4)	FY 19 (1 2 3 4)	FY 19 (1 2 3 4)	COMPL DATE QTR	COMPL DATE FY
1	Task UES 20: High Temperture Superconductivity			N: ▲ COMPLETE						
2	Task UES 21: Synthesis of Organic Compounds			J: ▲ SEE TASK UES 2						
3	Task UES 22: Growth & Properties of GaAs			O: ▲ COMPLETE						
4	Task UES 23: Magneto-Transport Seminar			N: ▲ COMPLETE						
5	Task UES 24: Review of Welding Processes			J: ▲ COMPLETE						
6	Task UES 25: Consultation on Superconding Materials			D: ▲ COMPLETE						
7	Task UES 26: Optical Properties of Thin Oxide Layers				D: ▲ COMPLETE					
8	Task UES 27: NDE Techniques			S: ▲ COMPLETE						
9	Task UES 28: Chemical Properties of GaAs			J: ▲ COMPLETE						
10	Task UES 29: Set up for GEN Passivation of GaAs			J: ▲ COMPLETE						
11	Task UES 30: System Avionics Design Eng.			J: ▲ COMPLETE						
12	Task UES 31: Consultation in Digital Sig. Process.			J: ▲ COMPLETE						
13	Task UES 32: Consultation in controlled crystal growth			J: ▲ COMPLETE						
14	Task UES 33: Consultation in digital Si. Process.			J: ▲ COMPLETE						
15	Task UES 34: Consultation on Fault Tolerent Microprocessers			J: ▲ COMPLETE						
16	Task UES 35: Seminar on Ion Beam Analysis of Ion Implants			F: ▲ COMPLETE						
17	Task UES 36: Epitaxially Grown Polycrystalline GaAs			J: ▲ COMPLETE						
18	Task UES 37: Dieletric Prop. of Thin Films			F: ▲ COMPLETE						
19	Task UES 38: NDE for Multi-Layered Structures				S: △ CANCELLED	CANCELLED				

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PROGRAM SCHEDULE	SYSTEM NO. (PROJ)			SUBSYSTEM															TYPE							AS OF						
LINE	PROGRAM MILESTONES	PRIOR SCHED		FISCAL YEAR 1980												FISCAL YEAR 1981												FY 19	FY 19	FY 19	COMPL DATE	
		MO	YR	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	1 2 3 4	1 2 3 4	1 2 3 4	QTR	FY
1	Task UES 39: Weathering of Coatings for Aircraft																				▲ COMPLETE											
2	Task UES 40: Seminar on Optical Properties of Solids							▲ COMPLETE																								
3	Task UES 41: Seminar on Rutherford Backscattering													▲ COMPLETE																		
4	Task UES 42: Oxides on III-V Compounds							▲ COMPLETE																								
5	Task UES 43: GaAs and GaAlAs Epitaxial Layers on GaAs														▲ COMPLETE																	
6	Task UES 44: Rational Data Base System							▲ COMPLETE																								
7	Task UES 45: Excitonic-Superconductor														▲ COMPLETE																	
8	Task UES 46: Liquid-Solid Erosion in Transparent Mat'ls														▲ COMPLETE																	
9	Task UES 47: Thin Film Solar Cells							▲ COMPLETE																								
10	Task UES 48: Statistical Analysis of Failure of Composites														▲ COMPLETE																	
11	Task UES 49: Effect of Cooling Rate on Ti-Alloy Weldment														▲ COMPLETE																	
12	Task UES 50: Raman Scattering from NbO_2									▲ COMPLETE																						
13	Task UES 51: Glow Discharges Optical Spectroscopy														▲ COMPLETE																	
14	Task UES 52: Slow Strain Rate Embrittlement of Tantalum									▲ COMPLETE																						
15	Task UES 53: AT Resin Toughening Mechanisms													▲ COMPLETE																		
16	Task UES 54: Crack Growth Rate Determination-Displacement Meas.														▲ COMPLETE																	
17	Task UES 55: Mechanisms in Elevated Temperature Crack Growth Modeling													▲ COMPLETE																		
18	Task UES 56: Spectrum Loading Models for Crack Growth at Elev. Temp.														▲ COMPLETE																	
19	Task UES 57: Consultation on GaAs Electrical Data									▲ COMPLETE																						

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PROGRAM SCHEDULE	SYSTEM NO. (PROJ) 718	SUBSYSTEM F33615-79-C-5129	TYPE Management Summary	AS OF

LINE	PROGRAM MILESTONES	PRIOR SCHED		FISCAL YEAR 1980												FISCAL YEAR 1981												FY 19				FY 19				FY 19				COMPL DATE	
		MO	YR	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	1	2	3	4	1	2	3	4	1	2	3	4	QTR	FY
1	Task UES 58: Organic Polymer Synthesis													▲ COMPLETE																											
2	Task UES 59: Consultation on shallow Doner & Acceptors in GaAs										▲ COMPLETE																														
3	Task UES 60: TEM of Hydrovac Specimens														▲ COMPLETE																										
4	Task UES 61: Crystal Growth Seminar										▲ COMPLETE																														
5	Task UES 62: Electron Microscopy of Ordered Compounds														▲ COMPLETE																										
6	Task UES 63: Relating Chemical Quality Assurance to Compounds																					▲ COMPLETE																			
7	Task UES 64: Upgrading of Eptaxial GaAs Crystal Growth System																							▲ COMPLETE																	
8	Task UES 65: Advanced Analysis Capability for DLTS																							▲ COMPLETE																	
9	Task UES 66: Magnetically Changed Optical Properties														▲ COMPLETE																										
10	Task UES 67: Dynamic Stresses in Blades																▲ COMPLETE																								
11	Task UES 68: Theoretical Transport Data Analysis													▲ COMPLETE																											
12	Task UES 68(a): Analysis of Laminated Composition																								▲ COMPLETE																
13	Task UES 69: Stress Analysis of Short Cracks																							▲ COMPLETE																	
14	Task UES 70: Two Photon Absorption											▲ COMPLETE																													
15	Task UES 71: Natural Language Interface											▲ COMPLETE																													
16	Task UES 72: R&D with HBC's											▲ COMPLETE																													
17	Task UES 73: R&D with HBC's											▲ COMPLETE																													
18	Task UES 74: R&D with HBC's											▲ COMPLETE																													
19	Task UES 75: R&D with HBC's											▲ COMPLETE																													

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PROGRAM SCHEDULE	SYSTEM NO. (PROJ) 718	SUBSYSTEM 33615-79-C-5129	TYPE Management Summary	AS OF

LINE	PROGRAM MILESTONES	PRIOR SCHED		FISCAL YEAR 1980												FISCAL YEAR 1981												FY 19				FY 19				FY 19				COMPL DATE	
		MO	YR	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	1	2	3	4	1	2	3	4	1	2	3	4	QTR	FY
1	Task UES 76: R&D with HBC's											▲ COMPLETE																													
2	Task UES 77: R&D with HBC's											▲ COMPLETE																													
3	Task UES 78: R&D with HBC's											▲ COMPLETE																													
4	Task UES 79: R&D with HBC's											▲ COMPLETE																													
5	Task UES 80: Processing Science												▲ COMPLETE																												
6	Task UES 81: Processing Science												▲ COMPLETE																												
7	Task UES 82: NDE for Multi-Layer Structures														▲ COMPLETE																										
8	Task UES 83: Material Behavior Modeling													▲ COMPLETE																											
9	Task UES 84: Auger Spectroscopic Analysis																									▲ COMPLETE															
10	Task UES 85: Organic Polymer Synthesis																									▲ COMPLETE															
11	Task UES 86: Microstructural Stability in Al RSP Alloys																									▲ COMPLETE															
12	Task UES 87: R&D with HBC's											▲ COMPLETE																													
13	Task UES 88: R&D with HBC's											▲ COMPLETE																													
14	Task UES 89: Laser Induced Optical Material Effects																											▲ COMPLETE													
15	Task UES 90: Processing Micro-structure Maps												▲ COMPLETE																												
16	Task UES 91: Theoretical Experimental Formability												▲ COMPLETE																												
17	Task UES 92: GaAs Epitaxial Growth by $H_2/AsCl_3/Ga$													▲ COMPLETE																											
18	Task UES 93: Consultation on COVINREST												▲ COMPLETE																												
19	Task UES 94: Theoretical Model of GaAs														▲ COMPLETE																										

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PROGRAM SCHEDULE	SYSTEM NO. (PROJ) 718	SUBSYSTEM F33615-79-C-5129	TYPE Management Summary	AS OF

LINE	PROGRAM MILESTONES	PRIOR SCHED MO	PRIOR SCHED YR	FISCAL YEAR 1980 (O N D J F M A M J J A S)	FISCAL YEAR 1981 (O N D J F M A M J J A S)	FY 19 (1 2 3 4)	FY 19 (1 2 3 4)	FY 19 (1 2 3 4)	COMPL DATE QTR	COMPL DATE FY
1	Task UES 95: Plasma Enhanced Deposition				▲ (F) COMPLETE					
2	Task UES 96: Effects of Distortion on CvCl			▲ (A) COMPLETE						
3	Task UES 97: ICAM Integrated Decision Support System			▲ (S) COMPLETE						
4	Task UES 98: GaAs Passivation and GaAs IGFETs				▲ (S) COMPLETE					
5	Task UES 99: Deposition Equipment Safety Study				▲ (D) COMPLETE					
6	Task UES 100: AADR Program-Advisory Group				▲ (D) COMPELTE					
7	Task UES 101: 130 Kilograms Nb_2Sn Superconductivity Magnet				▲ (D) COMPLETE					
8	Task UES 102: IMC Concepts Investigation				▲ (M) COMPLETE					
9	Task UES 103: Epitaxial Crystal Growth				▲ (S) COMPLETE					
10	Task UES 104: Theoretical Semiconductor Physics				▲ (S) COMPLETE					
11	Task UES 105: Chemical Kinetics of GaAs Growth				▲ (S) COMPLETE					
12	Task UES 106: Insulator Films on GaAs				▲ (S) COMPLETE					
13	Task UES 107: Magnetic Susceptability of Superconducting Materials				▲ (S) COMPLETE					
14	Task UES 108: Excitonic Superconductor Program				▲ (S) COMPLETE					
15	Task UES 109: Defect Structures of GaAs				▲ (S) COMPLETE					
16	Task UES 110: Epitaxial Layer Growth on GaAs				▲ (S) COMPLETE					
17	Task UES 111: Optical Properties of Magneto-Optical Materials				▲ (D) COMPLETE					
18	Task UES 112: GaAs MESFET Investigation: Phase II				▲ (S) COMPLETE					
19	Task UES 113: Ion Beam Analysis Seminar				▲ (O) COMPLETE					

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PROGRAM SCHEDULE

SYSTEM NO. (PROJ) 718 | SUBSYSTEM F33615-79-C-5129 | TYPE Management Summary | AS OF

LINE	PROGRAM MILESTONES	PRIOR SCHED (MO / YR)	FISCAL YEAR 1981 (O N D J F M A M J J A S)	FISCAL YEAR 1982 (O N D J F M A M J J A S)	FY 19 (1 2 3 4)	FY 19 (1 2 3 4)	FY 19 (1 2 3 4)	COMPL DATE (QTR / FY)
1	Task UES 114: Training Techniques Survey		▲ O — COMPLETE					
2	Task UES 115: TEM Investigation of Material Properties		▲ O — COMPLETE					
3	Task UES 116: Dynamic Stress in Blades		▲ J — COMPLETE					
4	Task UES 117: Laminate Optimization		▲ S	COMPLETE				
5	Task UES 118: ICAM Integrated Decision Support System		▲ A	COMPLETE				
6	Task UES 119: HBC's Involvement in VHSIC/VLSI		▲ D — COMPLETE					
7	Task UES 120: Polymer Mechanical Study		▲ S	COMPLETE				
8	Task UES 121: Seminar on Defect Structures		▲ D — COMPLETE					
9	Task UES 122: Spectroscopy from Polymer Fractures		▲ S	COMPLETE				
10	Task UES 123: AT Resin Toughening Mechanisms		▲ S	COMPLETE				
11	Task UES 124: Characterization of Electronic Materials		▲ S	COMPLETE				
12	Task UES 125: Synthesis of Organic Compounds II		▲ A	COMPLETE				
13	Task UES 126: Synthesis of Organic Compounds III			△ CANCELLED				
14	Task UES 127: Development Potential of Selected Alloys		▲ S	COMPLETE				
15	Task UES 128: Laser Induced Optical Material Effects		▲ A	COMPLETE				
16	Task UES 129: Elastic-Plastic Analysis of short cracks		▲ S	COMPLETE				
17	Task UES130: Ion Implantation for Device Fabrication		▲ S	COMPLETE				
18	Task UES 131: Evaluation of Thermionic Cathodes		▲ S	COMPLETE				
19	Task UES 132: Surface and Interface Energy Correlation in Coatings		▲ S	COMPLETE				

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PROGRAM SCHEDULE | SYSTEM NO. (PROJ) 718 | SUBSYSTEM F33615-79-C-5129 | TYPE Managment Summary | AS OF

LINE	PROGRAM MILESTONES	PRIOR SCHED		FISCAL YEAR 19 81												FISCAL YEAR 19 82												FY 19				FY 19				FY 19				COMPL DATE	
		MO	YR	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	1	2	3	4	1	2	3	4	1	2	3	4	QTR	FY
1	Task UES 133: Constitution Theory Development														▲	COMPLETE																									
2	Task UES 134: Fracture Characteristics of Advanced Polymeric MAterial														▲	COMPLETE																									
3	Task 135: Statistics of Dynamic Stresses in Blades														▲	COMPLETE																									
4	Task 136: Creep-Fatigue Interaction in Alloy 718														▲	COMPLETE																									
5	Task 137: Liquid Dilatometer Tests														▲	COMPLETE																									
6	Task 138: Fracture Modeling of Advanced Polymeric Materials														▲	COMPLETE																									
7	Task 139: Theoretical Transport Data Analysis														▲	COMPLETE																									
8	Task 140: Optical Properties of Single Materials														▲	COMPLETE																									
9	Task 141: Optical Properties of Thin Oxide Layers														▲	COMPLETE																									
10	Task 142: Surface Characteristics of Silicon														▲	COMPLETE																									
11	Task 143: Polymer Mechanical Study														▲	COMPLETE																									
12	Task 144: Stress Analysis of Hydraulic Seals														▲	COMPLETE																									
13	Task 145: Wave Shape Effects in Crack Growth in Super Alloys														▲	COMPLETE																									
14	Task 146: NDE of Composites														▲	COMPLETE																									
15	Task 147: Analysis of Energy Levels in Silicon														▲	COMPLETE																									
16	Tasl 148: Elevated Temperature Fatigue														▲	COMPLETE																									
17	Task 149: Finite Element Methods for Bonded Joints														▲	COMPLETE																									
18																																									
19																																									

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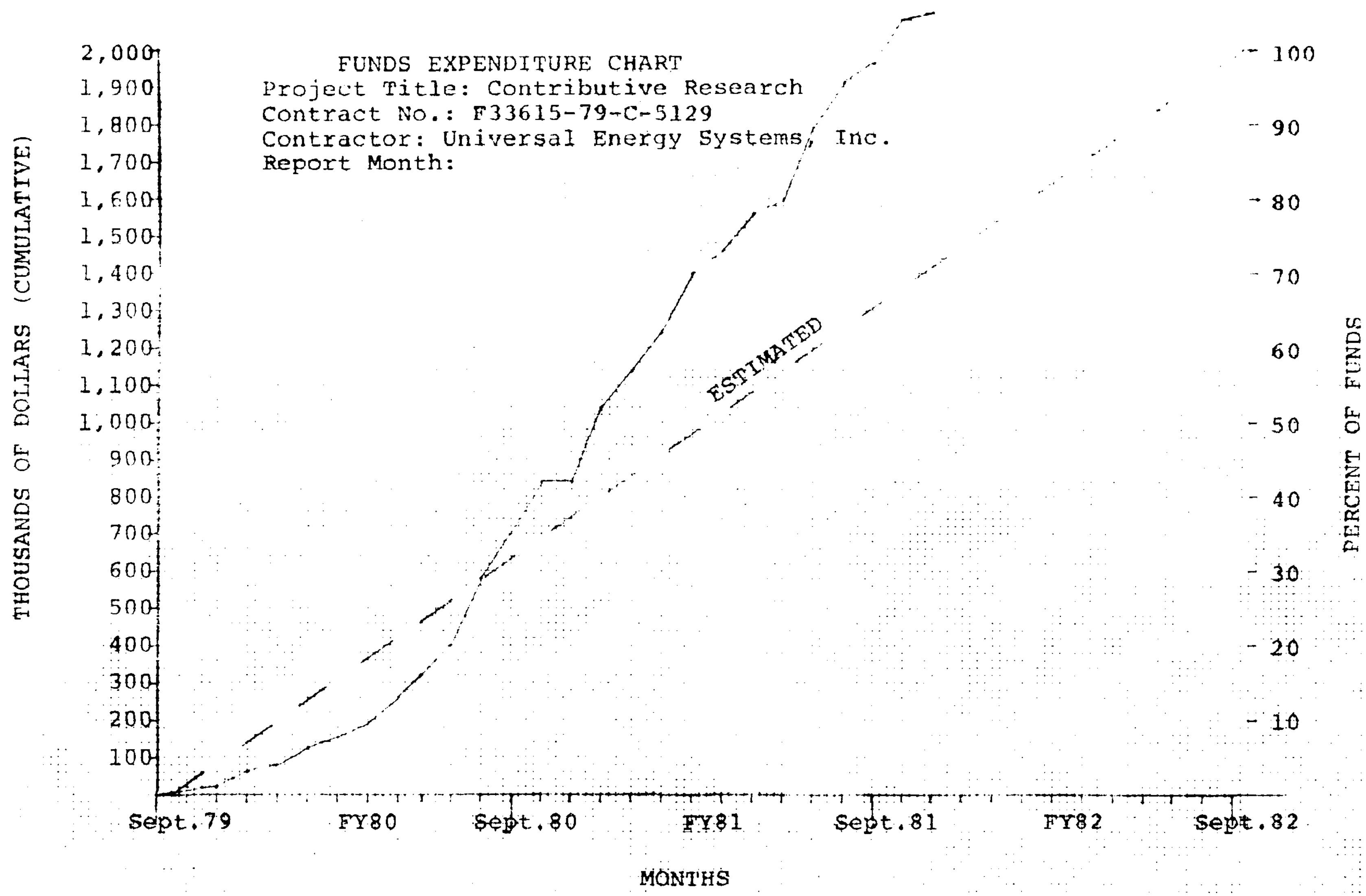
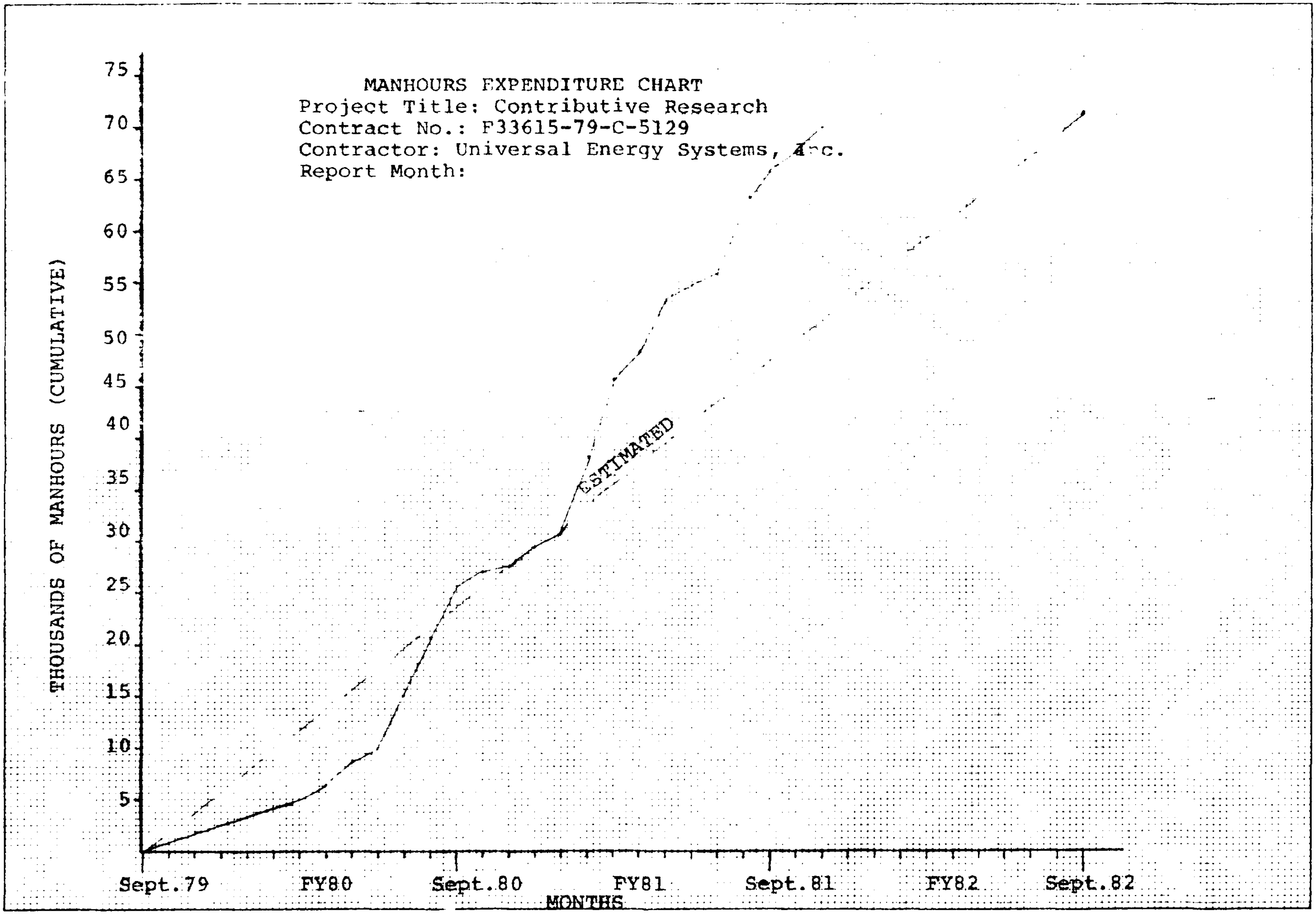


FUNDS EXPENDITURE CHART
Project Title: Contributive Research
Contract No.: F33615-79-C-5129
Contractor: Universal Energy Systems, Inc.
Report Month:
THOUSANDS OF DOLLARS (CUMULATIVE)
2,000
1,900
1,800
1,700
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
PERCENT OF FUNDS
100
90
80
70
60
50
40
30
20
10
ESTIMATED
Sept.79
FY80
Sept.80
FY81
Sept.81
FY82
Sept.82
MONTHS

FINAL MANHOURS EXPENDITURE CHART 4/1/82



END

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