

WL-TR-95-2125

SHORT-TERM PROPULSION AND POWER  
DEVELOPMENT ANALYSIS/ASSESSMENT AND  
INFORMATION DISSEMINATION-(UES)



UES, INC.  
4401 DAYTON-XENIA ROAD  
DAYTON OH 45432-1894

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JULY 1995

FINAL REPORT FOR 06/08/90-08/05/95

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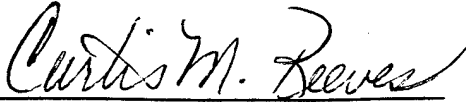
AEROPROPULSION AND POWER DIRECTORATE  
WRIGHT LABORATORY  
AIR FORCE MATERIEL COMMAND  
WRIGHT PATTERSON AFB OH 45433-7251

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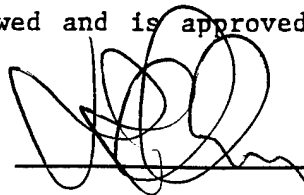
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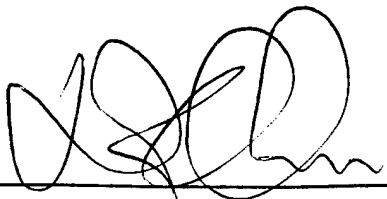
This technical report has been reviewed and is approved for publication.



CURTIS M. REEVES  
PO Contract Monitor  
Aero Propulsion and Power Directorate



FRED W. OLIVER, Chief  
Technology Management Division  
Aero Propulsion and Power Directorate



FRED W. OLIVER  
Technology Management Division  
Aero Propulsion and Power Directorate

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# REPORT DOCUMENTATION PAGE

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<b>13. ABSTRACT (Maximum 200 words)</b>  This final report documents a summary of all technical work accomplished and information obtained in performance of the contract "Short-Term Propulsion and Power Development Analysis/Assessment and Information Dissemination" (Contract No. F33615-90-C-2086) in support of the Aero Propulsion and Power Directorate, Wright Laboratory, Air Force Materiel Command, Wright Patterson AFB, OH.  Work accomplished under this contract was documented by UES, Inc. as Project 246. Individual tasks were identified as Project 246-001 through Project 246-047. The various tasks accomplished under this contract covered a wide variety of technical fields and areas of study. Examples of these areas include design and testing of heat transfer devices and combustors; design, fabrication and installation of an Ethylene Fuel System; design and engineering analysis of sonic and supersonic nozzles; historical research on the History of the Gas Turbine Engine and the 75th Anniversary History of the Aero Propulsion and Power Directorate; and improve the design and efficiency of airbreathing propulsion systems.				
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This "Short-Term Propulsion and Power Development Analysis/Assessment and Information Dissemination" contract was very ably managed and administered by Mr. Curtis M. Reeves, Project Engineer, WL/POMX. His efforts greatly facilitated the work of the Principal Investigators on the various task orders and the UES contract program management.

Within UES, Inc. this contract was managed by Mr. John M. Howard, Director, Applied Sciences and Engineering Division. Mr. Jerry McCluer, Ms. Donna Cullen and Ms. Glessna LeBaron provided day-to-day administrative oversight, and editing of the final report.

## Summary

### 1.0 Summary

During the five year period of performance for this contract the Aero Propulsion and Power Laboratory (APPL) became the Aero Propulsion and Power Directorate (APPD). Throughout this final report, the two names are meant to be interchangeable.

The overall period of performance for this contract was from 6 Aug 1990 to 5 Aug 1995. A total of 50 tasks were originally assigned. Task numbers 31, 34, 37, 38, and 43 were canceled. Task number 24 had a stop work order issued by the government. All remaining tasks have been successfully completed. Final reports for tasks 001, 003, 006, 007, 008, 009, 010, 012, 013, 014, 014A, 016, 017, 020, 021, 029, 030, 032, 035, 039, 040, 041, 042, 044, 045, and 047 were provided to the government. Final reports for tasks 002, 004, 04A, 005, 010A, 011, 015, 018, 019, 022, 023, 025, 026, 027, 028, 033, 036, and 046 were not required by the government.

The various tasks accomplished under this contract cover a wide variety of technical fields and areas of study. Examples of some of these areas include design and testing of heat transfer devices and combustors; design, fabrication and installation of an Ethylene Fuel System; design and engineering analysis of sonic and supersonic nozzles; historical research on the History of the Gas Turbine Engine and the 75th Anniversary History of the Aero Propulsion and Power Directorate; Balance and Testing of High Speed Rotors; conducting seminars on Fluid Film Lubrication; and improve the design and efficiency of airbreathing propulsion systems.

A complete listing of all tasks included in this contract can be found in Table 1. Detailed descriptions of each task can be found in the main section of this report. Table 2 provides a list of conference presentations made in conjunction with certain tasks.

## Introduction

### 2.0 Introduction

The Aero Propulsion and Power Laboratory (APPL) from time to time encounters problems in the areas of short term external analyses and assessments of programs, along with techniques for the timely dissemination of information from such programs in the areas of research, exploratory, and advanced development programs. In those cases where the laboratory does not have the internal resources necessary to resolve these problems, a contractual means was needed to supplement the laboratory's capabilities. The Laboratory frequently utilizes the academic community to either solve or develop an approach to the solution of the research problems encountered.

This effort provides short-term external analyses and assessments of programs, along with techniques for the timely dissemination of information from such programs, in support of Aero Propulsion and Power Laboratory (APPL) research, exploratory, and advanced development programs. The purpose is to provide maximum visibility of overall APPL program directions, requirements, and advancements to all levels of Air Force program management. In addition, the program will keep DoD, industry and government agencies abreast of each others' program directions, thus providing a more focused and complementary research environment to the advantage of both. This is a key element for the research and development to be transitioned or transferred when appropriate. Strategic studies are being performed to evaluate current state of the applicable propulsion technology and the recommended course of action for the Directorate. Typical efforts sponsored under this program include:

- a. Solution of urgent problems which require immediate attention and also have time constraints which preclude other methods of obtaining a solution.
- b. Provide a rapid response vehicle for technology reviews or an assessment of the current or proposed program's technical procedures, approach, or risk.
- c. Definition of long term basic or applied research necessary for the solution of complex technical problems.

Separate and specific tasks were established under this contract to perform research within the individual research areas. A total of 50 tasks were assigned under this contract. Five were canceled, one had a stop work order issued, and the remaining 44 tasks were completed. A listing of the tasks assigned under this contract is presented in Table 1.

When the necessary talents were not available within the internal resources of UES, Inc., the services of researchers from outside the company were obtained. Services obtained from outside the company were limited to much less than 50 percent of the total contract effort.

All computer programs developed were demonstrated as being fully compatible with the Wright-Patterson Air Force Base (WPAFB) computer system, and the installed software operating system. The demonstrations were performed at WPAFB with the software installed on a WPAFB computer chosen by agreement between the contract researcher and the WPAFB Effort Focal Point.

<b>Task Order #</b>	<b>Task Title</b>	<b>Principal Investigator</b>	<b>Status</b>
001	Aero Propulsion and Power Laboratory (APPL) Technical Display	Mr. Gary Streby, UES, Inc.	Complete
002	Ammonia Heat Transfer Testing and Data Acquisition	Mr. David Ryan, UES, Inc.	Complete
003	Heat Transfer Testing and Equipment Support	Mr. John Tennant, UES, Inc.	Complete
004	Advanced Fuel System Simulation	Mr. James Shardo, UES, Inc.	Complete
004A	Advanced Fuel System Simulation and Additive Evaluation	Mr. James Shardo, UES, Inc.	Complete
005	Swirl Combustor Fabrication, Instrumentation and Testing	Mr. Charles Smith, UES, Inc.	Complete
006	Combustion Phenomena and Combustor Design	Dr. David T. Pratt, University of Washington	Complete
007	Design of Water Cooled Turboramjet Research Combustor Hardware of Test Cell 22	Mr. Gary Streby, UES, Inc.	Complete
008	The Turbojet Revolution Examined: The History of the Gas Turbine Engine in the United States	Mr. James St.Peter, UES, Inc.	Complete
009	Flow Visualization for Transonic Compressor Rotors	Dr. Michael Brendel, University of Dayton	Complete
010	Design, Fabrication and Installation of an Ethylene Fuel System for Test Cell 22	Mr. Gary Streby, UES, Inc.	Complete
010A	Complete Installation of an Ethylene Storage Facility for Test Cell 22	Mr. Gary Streby, UES, Inc.	Complete
011	Detailed Design of APPD Technical Display & Information Dissemination Area	Mr. Gary Streby, UES, Inc.	Complete
012	Design of Hydraulic Positioning System for Research Combustors in Test Cell 22	Mr. Gary Streby, UES, Inc.	Complete
013	Vapor Phase Lubrication for High Temperature Rolling Element Bearings	Dr. E. Earl Graham, Cleveland State University	Complete

**Table 1. Task Listing (page 1 of 4)**

<b>Task Order #</b>	<b>Task Title</b>	<b>Principal Investigator</b>	<b>Status</b>
014	Design and Engineering Analysis of Sonic and Supersonic Combustor Nozzles and Installation of Combustor Hardware	Mr. Gary Streby, UES, Inc.	Complete
014A	Design and Engineering Analysis of Sonic and Supersonic Combustor Nozzles and Installation of Combustor Hardware	Mr. Gary Streby, UES, Inc.	Complete
015	Installation of Hydraulic Power System	Mr. Gary Streby, UES, Inc.	Complete
016	Research -- Combined Cycle Propulsion	Dr. H. Doyle Thompson, PHD Technology, Inc.	Complete
017	Theoretical Modeling of EHD Lubrication in Point Contacts	Dr. Farshid Sadegh, Purdue University	Complete
018	Advanced Turbine Aerothermodynamic Research Rig (ATARR) Technology	Mr. Matthew Streby, UES, Inc.	Complete
019	Detailed Design of APPD Technical Display & Information Dissemination Area (Part 2)	Mr. Gary Streby, UES, Inc.	Complete
020	The Turbojet Revolution Examined: The History of the Gas Turbine Engine in the U.S. including the work of Dr. Hans von Ohain	Mr. James St.Peter, UES, Inc.	Complete
021	The 75th Anniversary History of the Aero Propulsion and Power Directorate	Mr. Albert Misenko & Mr. Gary Streby, UES, Inc.	Complete
022	Optical Considerations for a Flow Visualization Method Applicable to Transonic Compressor Rotors	Dr. Michael Brendel, University of Dayton	Complete
023	Basic Mechanism of Vapor Phase Lubrication	Dr. E. Earl Graham, Cleveland State University	Complete
024	Development of Liquid Metal Lubricated Spiral Groove Bearing (LMSGB)	Dr. Joseph Tevaawerk, Battelle	Decoped by Air Force
025	R&D Information Display for Fuels and Lubes and Power Divisions	Mr. Gary Streby, UES, Inc.	Complete
026	Turboramjet Combustor and Nozzle Performance Analysis	Dr. H. Doyle Thompson, Purdue University	Complete

**Table 1. Task Listing (page 2 of 4)**

<b>Task Order #</b>	<b>Task Title</b>	<b>Principal Investigator</b>	<b>Status</b>
027	High-Speed Generator Rotor Balance and Spin-Pit Test	The Balancing Co.	Complete
028	Advanced Turbine Aerothermal Research Rig (ATARR) Facility Configuration and Documentation Management System	Mr. Matthew Streby, UES, Inc.	Complete
029	Test Cell 22 Safety and Emergency Analysis	Mr. Gary Streby, UES, Inc.	Complete
030	Air to Surface Supersonic Cruise Missile Propulsion Alternatives Study Documentation	Mr. Raymond E. Fredette, Consultant	Complete
031	Canceled by Air Force		Canceled
032	Development/Demonstration of a Flow Visualization Method Applicable to Transonic Compressor Rotors	Dr. Michael Brendel, University of Dayton	Complete
033	Continuation of Balance and Spin Testing of High-Speed Rotors	The Balancing Co.	Complete
034	Not issued		Not Issued
035	Document the Life and Work of Dr. Hans von Ohain and Complete and Edit the History of the Aircraft Gas Turbine Engine in the United States	Mr. James St.Peter, UES, Inc.	Complete
036	Fluid Film Lubrication Seminar	Dr. Bernard J. Hamrock, Ohio State University	Complete
037	Canceled by Air Force		Canceled
038	Canceled by Air Force		Canceled
039	Active Magnetic Bearing Auxiliary Systems	Dr. Alan Palazzolo, Texas A&M University	Complete
040	Carbon-Carbon Composites for Bearing Applications	SAIC & B.F. Goodrich	Complete
041	Microanalysis of Tribological Studies	Dr. André Sommer, Miami University, Oxford, Ohio	Complete

**Table 1. Task Listing (page 3 of 4)**

042	Complete Book on the Life and Work of Dr. Hans von Ohain and edit, as required, the History of the Aircraft Gas Turbine Engine in the United States	Mr. James St.Peter, UES, Inc.	Complete
043	Canceled by Air Force		Canceled
044	Airbreathing Propulsion Exergetics Analysis	Dr. Howard M. Brilliant, Consultant	Complete
045	Comparative Analysis of U.S. and Russian Missile/Advanced Propulsion Systems	Ketco, Inc.	Complete
046	Comparative Analysis of U.S. Aircraft Gas Turbine Engine Technology	Mr. James St.Peter, UES, Inc.	Complete
047	Airbreathing Propulsion Exergetics Analysis, Phase II	Dr. Howard M. Brilliant, Consultant	Complete

**Table 1. Task Listing (page 4 of 4)**

<b>Task Order #</b>	<b>Presentation Title</b>	<b>Presented By</b>	<b>Date</b>
047	AIAA 95-2767, Analysis of Scramjet Engines Using Exergy Methods	Dr. H. M. Brilliant, UES, Inc. Consultant	10-12 Jul 1995
047	AIAA 95-3030, Second Law Analysis of Present and Future Turbine Engines	Dr. H. M. Brilliant, UES, Inc. Consultant	10-12 Jul 1995

**Table 2. Conference Presentations**

## **Task Order Descriptions**

### **3.0 Task Order Descriptions**

This section contains a description of each Task Order. Full-text copies of all final reports provided to the APPD for specific Task Orders are available through either APPD or UES, Inc.

#### **Task No.: 001**

#### **Task Title: Aero Propulsion and Power Laboratory (APPL) Technical Display**

Principal Investigator: Mr. Gary Streby, UES, Inc.

Period of Performance: Aug 1990 - 31 Mar 1991

**Task Objective:** To determine the type, quantity, cost, and display format of a series of portable scale models portraying the major applications of APPL technology including engines for aircraft, cruise missiles, tactical missiles, and high mach vehicles, along with aircraft power systems, and satellite baseload and weapon power systems.

**Task Description:** UES provided an assessment which described the type, quantity, costs, and display format of displays and scale models. The displays and models portrayed major applications of new technologies developed by the Aero Propulsion and Power Directorate. The Technical Display Area assessment described the physical characteristics of the Technical Display Area and gave a short review of the goals and objectives of each division of the Aero Propulsion and Power Directorate. The assessment process was described and recommendations for displays and models provided. Also presented were options for the design and fabrication of two scale models for possible display.

The assessment provided information on what are considered major technology applications within the Directorate. Discussed were some major technology achievements describing their relations to the past and prospects for the future. The assessment described how some major technologies or breakthroughs have or will be transitioned into civilian products or services. The assessment determined, in some cases, how the technologies developed by one division enhances the efforts of other divisions. The results obtained aided in making recommendations for possible scale models or series of models which would best depict the development of major technology applications.

For the technical assessment, UES determined the display format for models and displays within the Technical Display Area. UES, working with Wanamaker Advertising Arts, Inc. of Dayton, Ohio, prepared sketches and artists' renderings of the proposed Technical Display Area. Sketches and artists' renderings visually depicted how displays and models may be arranged and what style may be used for the display cases/modules.

Final Report: Two copies of the final report entitled "Technical Display Area Assessment for Aero Propulsion and Power Directorate" were provided to the Air Force WL/POMX, 1 April 1991.

## **Task No.: 002**

### **Task Title: Ammonia Heat Transfer Testing and Data Acquisition**

Principal Investigator: Mr. David M. Ryan, UES, Inc.

Period of Performance: 1 Oct 1990 - 30 Sep 1991

Task Objective: To perform experimental testing on advanced heat transfer devices along with upgrading the data acquisition system on a High Power Spacecraft Thermal Management System (HPSTM).

Task Description: UES, Inc. designed, fabricated, and tested heat transfer devices and data acquisition systems critical to the Thermal Laboratory of the Aero Propulsion and Power Directorate. UES' personnel focused on the data acquisition system, designed for a High Power Spacecraft Thermal Management System (HPSTM), and capillary loop modeling to predict HPSTM behavior.

Final Report: A final report was not required.

## **Task No.: 003**

### **Task Title: Heat Transfer Testing and Equipment**

Principal Investigator: Mr. John Tennant, UES, Inc.

Period of Performance: 1 Oct 1990 - 30 Sep 1991

Task Objective: To support and perform experimental testing on specified heat transfer devices including the oxygen heat pipe and the rotating thermosyphon.

Task Description: UES, Inc. designed, fabricated, and tested heat transfer devices critical to the Thermal Laboratory of the Aero Propulsion and Power Directorate. The primary emphasis of this task focused on the support required for the experimental set-up and testing of the oxygen heat pipe and for the investigation of magnetically augmenting the heat transfer capability of this pipe.

Final Report: Two copies of the final report entitled "Heat Transfer Testing and Equipment Support" were provided to the Air Force WL/POMX on 12 June 1991.

**Task No.: 004**

**Task Title: Advanced Fuel System Simulation**

Principal Investigator: Mr. James Shardo, UES, Inc.

Period of Performance: 3 Jan 1991 - 31 Mar 1992

Task Objective: To evaluate the thermal stability performance of several baseline aviation turbine fuels in a Reduced Scale Fuel System Simulator. This will include modification, operation and maintenance of the existing Reduced Scale Aircraft Fuel System Simulator (RSFSS) located in Building 490, Rooms 143 and 144, Area B, Wright-Patterson AFB.

Task Description: UES, Inc. provided the technical support to conduct thermal stability performance studies of several baseline aviation turbine fuels in the RSFSS. UES modified the RSFSS in accordance with designs provided by the Government project engineer; documented the electrical and mechanical portions of the RSFSS for future reference; and prepared an Operation and Maintenance Guide for the RSFSS.

Final Report: A final report was not required.

**Task No.: 004A**

**Task Title: Advanced Fuel System Simulation and Additive Evaluation**

Principal Investigator: Mr. James Shardo, UES, Inc.

Period of Performance: 1 Apr 1992 - 30 Jun 1992

Task Objective: This task was a follow-on effort to previous Task Order Number 004. Its objectives were to perform additional baseline and additive testing on a selected pipeline drag reducing additive using a Reduced Scale Fuel System Simulator (RSFSS) and to document the results of this testing; to enhance data collection techniques on the (RSFSS); and to convert existing mechanical and instrumentation drawings into CAD compatible form and to provide the capability of maintaining these drawings in this form for the useful life of the RSFSS.

Task Description: UES, Inc. performed testing on the Reduced Scale Fuel System Simulator to evaluate Conoco CDR-102M Flow Improver Additive and provided simulator data to the Government Project Engineer for reduction.

UES converted existing pencil electrical and mechanical drawings to AutoCAD Release 11 Change 2 format and provided the necessary software and hardware to keep the converted drawings updated as Reduced Scale Fuel System Simulator configurations change.

Final Report: A final report was not required.

### **Task No.: 005**

#### **Task Title: Swirl Combustor Fabrication, Instrumentation, and Testing**

Principal Investigator: Mr. Charles Smith, UES, Inc.

Period of Performance: 1 Jan 1990 - 15 Jan 1992

Task Objective: To assist and perform experimental testing on state-of-the-art advanced combustors with inlet swirl, to upgrade and maintain the integrity of the combustor set-up to accept a myriad of different instrumentation for laser based diagnostics and high frequency fast response temperature and pressure measurements.

Task Description: UES, Inc. provided engineering and technical support to conduct experimental testing on state-of-the-art advanced combustors with inlet swirl, to upgrade and maintain the integrity of the combustor set-up to accept a myriad of different instrumentation for laser based diagnostics and high frequency fast response temperature and pressure measurements. Data collected was included in the database used by the Air Force's scientists and engineers to upgrade and validate current computational fluid dynamics (CFD) codes.

Final Report: A final report was not required.

### **Task No.: 006**

#### **Task Title: Combustion Phenomena and Combustor Design**

Principal Investigator: Dr. David T. Pratt, University of Washington

Period of Performance: 1 Mar 1992 - 31 May 1992

Task Objective: To produce the chemical reaction computer codes necessary to facilitate the learning process in combustion phenomena and combustor design.

Task Description: UES, Inc. subcontractor wrote portions of the textbook that directly addressed combustion phenomena and combustor design. The subcontractor focused on producing the chemical reaction computer codes necessary to facilitate the learning process. The subcontractor was responsible for the combustion-related material to collaborate with Dr. William H. Heiser of the USAF Academy in the writing of the forthcoming AIAA Series textbook entitled "Hypersonic Airbreathing Propulsion".

Final Report: A copy of the Final Report entitled, "Chapter 6: Design and Analysis of the Combustion System" was provided to the Air Force WL/POMX, 15 October 1992.

### **Task No.: 007**

**Task Title: Design of Water Cooled Turboramjet Research Combustor Hardware for Test Cell 22**

Principal Investigator: Mr. Gary Streby, UES, Inc.

Period of Performance: 30 Aug 1991 - 30 Nov 1991

Task Objective: To complete the design of water-cooled combustor sections, nozzles, measurement probes, and related hardware for installation on the thrust stand in Test Cell 22.

Task Description: UES, Inc. provided the engineering and design support to complete detailed design of the Turboramjet Design. A list of components which required completion of design or details were: Window Section, Nozzle Section, IFF, Probe Section, Space Sections, Instrumentation Requirements, and Assembly.

In addition, UES, Inc. completed engineering calculations and analysis for the remaining components and provided input to the design effort. An Engineering Design Book was completed detailing all engineering calculations.

Final Report: An engineering design notebook and design drawings were provided to the Air Force WL/POMX on 9 December 1991.

**Task No.: 008**

**Task Title:** The Turbojet Revolution Examined: The History of the Gas Turbine Engine in the United States.

Principal Investigator: Mr. James St. Peter, UES, Inc.

Period of Performance: 18 Sep 1991 - 18 Jun 1992

Task Objective: To complete the portion of the history of the aircraft gas turbine engine dealing with the history of Pratt & Whitney aircraft gas turbine engine developments and insert the specific engine history into the existing chapter structure.

Task Description: UES, Inc. conducted historical research on the following Pratt & Whitney aircraft gas turbine engine development programs: J42; J48; J52; J57; TF33, J58, TF30, F100; JT9D.

Final Report: A final report entitled "History of the Aircraft Gas Turbine Engine in the United States" was provided to the Air Force WL/POMX, 8 April 1993.

**Task No.: 009**

**Task Title:** Flow Visualization for Transonic Compressor Rotors

Principal Investigator: Dr. Michael Brendel, University of Dayton

Period of Performance: 4 Oct 1991 - 3 Jul 1992

Task Objective: To determine and demonstrate a flow visualization technique which is suitable to determine shock location in an operating transonic compressor rotor.

Task Description: UES, Inc. subcontractor conducted a study to determine a class of flow visualization methods which were most likely to meet the requirement of indicating shock location in the operating transonic compressor rotor. The subcontractor then procured the required measurement equipment for use in his facility and in the Compressor Aerodynamics Research Laboratory operated by the Compressor Research Group. The subcontractor conducted experiments intended to finalize the specific flow visualization technique.

Final Report: A final report entitled "Transonic Flow Visualization Using Condensed Water Vapor" was provided to the Air Force WL/POMX, 22 October 1992.

**Task No.: 010**

**Task Title: Design, Fabrication and Installation of an Ethylene Fuel System for Test Cell 22**

Principal Investigator: Mr. Gary Streby, UES, Inc.

Period of Performance: 3 Apr 1991 - 30 Mar 1992

Task Objective: To design, purchase and install an ethylene storage and fuel supply system for Test Cell 22 including instrumentation and flow control.

Task Description: UES, Inc. provided to the Experimental Research Branch of the Advanced Propulsion Division the engineering, design and technical services to design, fabricate and install an ethylene fuel system for Test Cell 22. The ethylene fuel system consisted of a storage facility, distribution piping and necessary instrumentation and control devices.

Final Report: An engineering report for the design and installation of an ethylene and hydrogen storage facility to support Test Cell 22, Building 22E was provided to the Air Force WL/POKA, 6 December 1991.

**Task No.: 010A**

**Task Title: Ethylene Storage Facility Installation**

Principal Investigator: Mr. Gary Streby, UES, Inc.

Period of Performance: 27 Jul 1992 - 3 Jun 1993

Task Objective: To complete installation of an ethylene storage facility for Test Cell 22.

Task Description: UES, Inc. continued from Task 10 the installation of an ethylene storage and supply system capable of supplying 1 lb/sec of ethylene at 600 psig and maintaining a temperature of 70 degrees F. The gas bottle storage capacity was increased from the original request of 16 bottles to 40 bottles. Additionally, the building is compatible with surrounding buildings, and windows and openings to the basements adjacent to the storage facility were designed to be blocked and sealed. The installation of piping, controls, instrumentation, heat exchangers and other necessary components identified and purchased under Task 10 were completed.

Final Report: A final report was not required.

**Task No.: 011**

**Task Title: Detailed Design of APPD Technical Display & Information Dissemination Area**

Principal Investigator: Mr. Gary Streby, UES, Inc.

Period of Performance: 31 Oct 1991 - 30 Sep 1992

Task Objective: To provide a functional design, layout details, and recommendations for a furnished technical display area which will promote the activities of the APPD and the Main Conference Room facilities.

Task Description: UES, Inc. performed all necessary work to accomplish layout, style, color, and design of furnishings applicable to a commercial/business reception area which complimented the display area of the Main Conference Room of the APPD.

Final Report: A final report was not required.

**Task No.: 012**

**Task Title: Design of Hydraulic Positioning System for Research Combustors in Test Cell 22**

Principal Investigator: Mr. Gary Streby, UES, Inc.

Period of Performance: 27 Sep 1991 - 31 Mar 1993

Task Objective: To complete the design of hydraulic positioning system to compensate for thermal expansion of combustor hardware mounted on the thrust stand in Test Cell 22.

Task Description: UES, Inc. provided to the Experimental Research Branch of the Advanced Propulsion Division engineering and design support to complete the design of a hydraulic positioning system. The hydraulic positioning system was designed to compensate for the thermal expansion of combustor hardware mounted on the thrust stand in Test Cell 22. The design of the hydraulic positioning system included positioning devices to maintain the ramjet exit plane in a constant position relative to the facility exhaust entrance.

Final Report: A final report entitled "Burner II Modification Operating Instructions" was provided to the Air Force WL/POKA on 4 May 1993.

### **Task No.: 013**

**Task Title: Vapor Phase Lubrication for High Temperature Rolling Element Bearings**

Principal Investigator: Dr. E. Earl Graham, Cleveland State University

Period of Performance: 13 Jan 1992 - 31 Aug 1992

Task Objective: To identify alternate lubricants to tricresyl phosphate (TCP) that are as good or better for high temperature vapor phase lubrication.

Task Description: UES, Inc. subcontractor studied three chemical classes of lubricants to assess their suitability as vapor phase lubricants. The three classes of lubricants were hydrotreated mineral oil; alternate organo-phosphates; and oxygenated organic compounds. The study included initial static tests to determine the type and rate of deposition over a range of environmental conditions. Dynamic tests were performed on the most promising candidates, using a reciprocating sliding contact tester and a rolling contact tester typical of highly loaded ball bearings.

Final Report: A final report entitled "Vapor Phase Lubrication of Metals and Ceramics For A Rolling Contact Fatigue Tester Using Alternative Lubricants" was provided to the Air Force WL/POMX, 15 October 1992.

### **Task No.: 014**

**Task Title: Design and Engineering Analysis of Sonic and Supersonic Combustor Nozzles and Installation of Research Combustor Hardware**

Principal Investigator: Mr. Gary Streby, UES, Inc.

Period of Performance: 21 Jan 1992 - 21 Apr 1992

Task Objective: To provide Detailed Design Drawings and Engineering Analysis of Sonic and Supersonic Combustor Nozzles and Install Research Combustor on Test Cell 22 Thrust Stand.

Task Description: UES, Inc. provided the engineering, design and technical support to complete the design and analysis of both Sonic and Supersonic Nozzles for the Research Combustor installed in Test Cell 22. These nozzles were required for the facility to function properly so combustion data could be obtained.

Final Report: A final report entitled "Design and Engineering Analysis of Sonic and

Supersonic Combustor Nozzles Installation of Research and Combustor Hardware" was provided to the Air Force WL/POMX, 8 May 1992.

**Task No.: 014A**

**Task Title: Design and Engineering Analysis of Sonic and Supersonic Combustor Nozzles and Installation of Research Combustor Hardware**

Principal Investigator: Mr. Gary Streby, UES, Inc.

Period of Performance: 20 Apr 1992 - 19 Jun 1992

Task Objective: To provide Detailed Design Drawings and Engineering Analysis of Sonic and Supersonic Combustor Nozzles and Install Research Combustor on Test Cell 22 Thrust Stand.

Task Description: UES, Inc. continued from Task 14 to provide designs and engineering analyses for sonic and supersonic exit nozzles for a research combustor to be installed in Test Cell 22 of the Aero Propulsion and Power Directorate. These nozzles were required for the facility to function properly so combustion data could be obtained.

Final Report: A final report entitled "Design and Engineering Analysis of Sonic and Supersonic Combustor Nozzle" was provided to the Air Force WL/POMX, 22 July 1992.

**Task No.: 015**

**Task Title: Installation of Hydraulic Power System**

Principal Investigator: Mr. Gary Streby, UES, Inc.

Period of Performance: 28 Jan 1992 - 30 May 1992

Task Objective: To provide Hydraulic Power for Operation of Thrust Stand/Exhauster Interface System

Task Description: UES, Inc. provided the engineering and technical support to the Advanced Propulsion Division to install a hydraulic power system for Test Cell 22 in building 18E. A source of hydraulic power was required to actuate the thrust stand positioning system for the ramjet exit nozzle. This hydraulic system is capable of providing 3000 psi pressure at approximately 5 gpm.

Final Report: A final report was not required.

**Task No.: 016****Task Title: Research - Combined Cycle Propulsion**

Principal Investigator: Dr. H. Doyle Thompson, PHD Technology, Inc.

Period of Performance: 15 Feb 1992 - 30 Nov 1992

Task Objective: To perform the following tasks: 1) Turboramjet Test Article/Facility Design and Analysis; 2) Development of CFD and Advanced Propulsion Analysis; and 3) Lectures in Computational Methods and Propulsion Processes.

Task Description: UES, Inc. subcontractor accomplished all of the tasks stated above.

Final Report: Final reports entitled "Combustion Efficiency Calculations from Thrust Measurements" dated 13 May 1992; "Suggested Placement of Pressure and Temperature Taps for the 40% Nozzle" dated 13 May 1992; "Nozzle Heat Transfer Calculations" dated 16 July 1992; "Thermocouple Order"; "Load Cell Noise Reduction for the Thrust Stand in Room 22" dated 9 September 1992 were provided to the Air Force WL/POMX, 9 September 1992.

**Task No.: 017****Task Title: Theoretical Modelling of EHD Lubrication in Point Contacts**

Principal Investigator: Dr. Farshid Sadegh, Purdue University

Period of Performance: 12 Mar 1992 - 11 Mar 1993

Task Objective: To theoretically model the pressure, temperature, traction, and film thickness of elasto-hydrodynamic (EHD) lubrication in point (circular or elliptic) contacts.

Task Description: UES, Inc. subcontractor developed a numerical mathematical model for the response of EHD lubricated point contacts to variation in load, speed, and lube system material parameters. The model estimated pressure, temperature, traction, and film thickness distributions within the point contact zone. The model was incorporated into a computer program with suitable high quality color graphics subprograms to clearly illustrate results using a Unix® operation system.

Final Report: A final report entitled "Modelling/Investigation of EHD Point Contacts" was provided to the Air Force WL/POMX, August 1993.

## **Task No.: 018**

**Task Title: ATARR Technology**

Principal Investigator: Mr. Matt Streby, UES, Inc.

Period of Performance: 5 Jun 1992 - 30 Dec 1992

**Task Objective:** To provide technical expertise to insure the advanced eddy brake design, manufacturing, installation and check-out technology does not cause facility operational/scheduling difficulties.

**Task Description:** UES, Inc. provided to the Components Branch of the Turbine Engine Division the necessary engineering support to conduct a Critical Path Analysis of activities associated with the Advanced Turbine Aerothermodynamic Research Facility (ATARR). UES developed a critical path analysis using project management software on a PC computer. The critical path analysis will incorporate all aspects of design, manufacturing, installation and check-out associated with the ATARR facility. The results from the critical path analysis were utilized to make recommendations to resolve technical difficulties and problems which may impact facility operational/scheduling difficulties.

**Final Report:** A final report was not required.

## **Task No.: 019**

**Task Title: Detailed Design/Fabrication of APPD Technical Display/Information Dissemination Area (Part 2)**

Principal Investigator: Mr. Gary Streby, UES, Inc.

Period of Performance: 26 May 1992 - 30 Sep 1992

**Task Objective:** The Aero Propulsion and Power Directorate has prepared an area adjacent to the main conference room in building 18G to promote the dissemination of technical information at -- and interaction among participants in -- Directorate R&D functions. This task will complete the design and furnishing of the display area and main conference room and provide a display on the fuels and lubricants developed by the Directorate.

**Task Description:** UES, Inc. provided to the APPD, engineering, management, and technical services to improve and enhance the Technical Display and Information Dissemination of the Technical Display Area and Main Conference Room. The specific goals of this task were to complete the interior artwork of the IHPTET engine model display which was started on a previous task. This artwork highlighted various IHPTET

engine components and enhanced visual perception of the design; recommended and purchased display panels/models for use in the Technical Display Area; and UES, with the assistance of Wanamaker Advertising Arts, Inc. made recommendations for purchasing and creating display materials for the walls of the Technical Display Area and the Main Conference Room.

Final Report: A final report was not required.

### **Task No.: 020**

**Task Title: The Turbojet Revolution Examined: The History of the Gas Turbine Engine in the United States Including the Work of Dr. Hans von Ohain.**

Principal Investigator: Mr. James St. Peter, UES, Inc.

Period of Performance: 15 Aug 1992 - 30 Sep 1993

Task Objective: To continue the historical research of those engines necessary to complete the history of the aircraft gas turbine engine in the United States and to corroborate historical research into the work of Dr. Hans von Ohain.

Task Description: UES, Inc. provided historical research on the J30, J46, T54, T55, T76, F107, J402, T56 and Pegasus engines. UES additionally conducted corroborative research into the chapter of the book dealing with the scientific and engineering work of Dr. Hans von Ohain, both in Germany in early 1940 and in the United States from 1946 to the present. A Technical Supplement entitled "History of the Aircraft Gas Turbine Engine In The United States" was provided to the Air Force Aero Propulsion and Power Directorate on 1 October 1993.

Final Report: A final report entitled "History of the Aircraft Gas Turbine Engine In The United States" was provided to the Air Force WL/POMX on 1 October 1993.

### **Task No.: 021**

**Task Title: The 75th Anniversary History of the Aero Propulsion and Power Directorate**

Principal Investigator: Mr. Al Misenko and Mr. Gary Streby, UES, Inc.

Period of Performance: 8 Mar 1993 - 31 Aug 1994

Task Objective: The creation of a comprehensive history of the Aero Propulsion and

Power Directorate and its predecessors, recognizing its first 75 years of existence.

Task Description: UES, Inc. provided research and documentation to create a definitive history of the APPD and its predecessors.

Final Report: A draft final report entitled "Draft Chapters for History of the Aero Propulsion Laboratory" was provided to the Air Force WL/POMX, 1 October 1993.

## **Task No.: 022**

### **Task Title: Optical Considerations for a Flow Visualization Method Applicable to Transonic Compressor Rotors**

Principal Investigator: Dr. Michael Brendel, University of Dayton

Period of Performance: 28 Oct 1992 - 28 Sep 1993

Task Objective: To investigate appropriate seeding material for a Mie-scattering flow visualization approach applicable to closed loop compressor rig operation and determine and demonstrate the best method (in terms of minimizing the effect on the flow field and practicality) of introducing laser illumination into the rotor flow field.

Task Description: UES, Inc. subcontractor conducted a study to determine the best seeding material useable in the Mie-scattering flow visualization technique identified during an earlier task. The objectives were to minimize particle size, ensure thorough mixing of the seed with air to promote density correlation, and minimize risk to personnel and hardware. The subcontractor procured the required dispersal hardware and demonstrated the feasibility of the seeding material and method at the subcontractor's facility. Flow characteristics which are representative of the compressor rotor flow field were investigated. The demonstration included high subsonic free stream velocities over an object, such as an airfoil, where local supersonic/shocked flow exists.

The subcontractor also investigated methods of introducing the laser illumination into the rotor flow field. Examples of approaches included a fixed position, gimble source at the wall or traversed source near the rotor exit. The subcontractor fabricated a prototype of the chosen approach and demonstrated its use at the subcontractor's facility.

Final Report: A final report was not required.

**Task No.: 023****Task Title: Basic Mechanisms of Vapor Phase Lubrication**

Principal Investigator: Dr. E. Earl Graham, Cleveland State University

Period of Performance: 4 Feb 1993 - 3 Nov 1993

Task Objective: To investigate the controlling mechanisms of vapor deposition and establish methods to activate surfaces and form lubricous deposits.

Task Description: UES, Inc. subcontractor investigated the optimal conditions for vapor phase lubrication using X-1P and other phosphazenes. X1-P, a phosphazene supplied by Dow Chemical, was identified as a safe and potentially superior alternative to tricresyl phosphate for vapor phase lubrication under both rolling and sliding contact. The subcontractor used a range of different materials (M50 steel, alloys of Fe, Ni, Co, Cr, and Mo and  $\text{Si}_3\text{N}_4$ ). The subcontractor studied deposition rates at different temperatures from 300° C and up to the upper limits of the material being used (up to 800° C) and reported on the basic mechanisms of vapor deposition which included the activation energy for the process and the controlling mechanism of deposition from the subcontractor's investigation.

Final Report: A final report was not required.

**Task No.: 024****Task Title: Development of Liquid Metal Lubricated Spiral Groove Bearing (LMSGB)**

Principal Investigator: Dr. Joseph Tevaarwerk, Battelle

Period of Performance: 23 Feb 1993 - 29 Aug 1993

Task Objective: To perform preliminary design effort preparatory to development testing of a LMSGB for the Nr 1 bearing position of the T63 engine.

Task Description: UES, Inc. subcontractor designed a LMSGB as a replacement for the Nr 1 ball bearing employed in the T63. This plan selected a minimum cost path to engine demonstration of the LMSGB. The specific design concept permitted continuous operation of a T63 engine at normal operating conditions, with no oil flow to the Nr 1 bearing position which included provisions for sealing the liquid metal within the bearing, so no refurbishment was required between shut-down/start-up operations.

Final Report: A final report was not required.

**Task No.: 025**

**Task Title: R&D Information Display for Fuels & Lubes and Power Divisions**

Principal Investigator: Mr. Gary Streby, UES, Inc.

Period of Performance: 31 Dec 1992 - 9 Apr 1993

Task Objective: To design and fabricate R&D informational displays to provide for the dissemination of technical information to express the history, capabilities, and achievements of WL/POS and WL/POP.

Task Description: UES, Inc. fabricated and installed a technical dissemination informational display depicting the contributions of the Fuels and Lubrication Division over the past fifty years. The display was coordinated with the APPD Technical Display Area in color and style and was interesting as well as informative. The display was fabricated for disassembling and moving the display to other base locations where it could be reassembled. Historical and technical information was presented detailing specific goals and achievements that were obtained from the developments and advancements of aviation fuels and lubricants. The display showed how the public and commercial aviation enterprises have benefitted from the investments in fuels and lubrication research and development.

In addition, UES provided the engineering and design expertise to research and produce a set of design and fabrication drawings for a one-half scale model of an aircraft power system drive unit.

Final Report: A final report was not required.

**Task No.: 026**

**Task Title: Turboramjet Combustor and Nozzle Performance Analysis**

Principal Investigator: Dr. H. Doyle Thompson, Purdue University

Period of Performance: 8 Mar 1993 - 23 Dec 1993

Task Objective: To perform on-site experimental investigations to determine the performance of a representative turboramjet combustor and thrust nozzle; and develop computational methods for determining turboramjet combustor and nozzle performance

from experimentally derived data, such as thrust, pressure, and temperature measurements.

Task Description: UES, Inc. subcontractor performed on-site experimental investigations to determine the performance of a representative turboramjet combustor and thrust nozzle. In addition, computational methods were developed for determining turboramjet combustor and nozzle performance from experimentally derived data, such as thrust, pressure, and temperature measurements.

Final Report: A final report was not required.

### **Task No.: 027**

**Task Title: High-Speed Generator Rotor Balance and Spin-Pit Test**

Principal Investigator: The Balancing Co.

Period of Performance: 25 Mar 1993 - 25 May 1993

Task Objective: To balance and spin-test a simulated rotor for the MEA IPU generator, and quantify friction/windage power losses.

Task Description: UES, Inc. subcontractor provided the engineering and technical support necessary to spin-pit test two high speed rotors that were approximately 4.3 inches in diameter and 7 inches long to simulate the rotor for the More Electric Aircraft (MEA) IPU generator.

Final Report: A final report was not required.

### **Task No.: 028**

**Task Title: ATARR Facility Configuration and Documentation Management System**

Principal Investigator: Mr. Matt Streby, UES, Inc.

Period of Performance: 8 Mar 1993 - 8 Oct 1993

Task Objective: To develop and implement a facility configuration and documentation management system (CDMS) for ATARR.

Task Description: UES, Inc. provided the engineering expertise to develop and implement a facility configuration and documentation management system (CDMS) for the ATARR

facility. UES provided on-site support to prepare and implement a permanent facility management system. UES documented current and on-going changes to ATARR hardware and software; tracked facility usage for maintenance and troubleshooting purposes; and formalized the method of facility record keeping and the procedure for making, approving and documenting changes.

Final Report: A final report was not required.

**Task No.: 029**

**Task Title: Test Cell 22 Safety and Engineering Analysis System**

Principal Investigator: Mr. Gary Streby, UES, Inc.

Period of Performance: 14 Apr 1993 - 31 Dec 1993

Task Objective: To conduct a Safety and Engineering Analysis of the Advanced Propulsion Division's combined cycle combustion research facility in Test Cell 22, Building 18E.

Task Description: UES, Inc. provided the engineering and technical support services to conduct a Hazard, Safety and Engineering Analysis. The analysis covered facilities and equipment associated with the high pressure gas and fuel systems in Test Cell 22 located in Building 18E. Studies included a hazards analysis, a failure modes and effects analysis and a fault tree analysis. Primary focus of the study was the fuel and high pressure gas systems hazards associated with experimental testing. In addition, UES assisted the Air Force to compile Operational Procedures for Test Cell 22.

Final Report: A final report entitled " Test Cell 22 Hazard and Safety Analysis" was provided to the Air Force WL/POKA on 9 Dec 1993.

**Task No.: 030**

**Task Title: Air-To-Surface Supersonic Cruise Missile Propulsion Alternatives Study Documentation**

Principal Investigator: Mr. Raymond E. Fredette, Consultant

Period of Performance: 18 May 1993 - 1 Dec 1993

Task Objective: To provide text, technical data and drawings concerning vehicle conceptual designs of turbojet powered air-to-surface supersonic cruise missiles derived in the Air-To-Surface Supersonic Cruise Missile Propulsion Alternatives Study. The

information assembled will be suitable for inclusion in a forthcoming Wright Laboratory Aero Propulsion and Power Directorate technical report.

Task Description: UES, Inc. consultant applied information gathered from the Air-To-Surface Supersonic Cruise Missile Propulsion Alternative Study to provide an assessment of the vehicle trades accomplished in this study. Expendable turbojet powered designs were described in this task and included lifting body and winged configurations. Aerodynamics, mass properties, flight performance data, methodology citation and justification were included.

Final Report: A final report entitled "Conceptual Air-To-Surface Missiles For Internal Carriage In Large Weapons Bays: An Application For Advanced Expendable Supersonic Turbojet Engines" was provided to the Air Force WL/POMX on 22 Dec 1993.

### **Task No.: 031**

**Task Title: Development and Performance Evaluation for Re-designing Compressor Hardware (PERCH) Computer Program**

Principal Investigator: N/A

Period of Performance: N/A

Task Objective: N/A

Task Description: Task was canceled by the Air Force.

Final Report: N/A

### **Task No.: 032**

**Task Title: Development/Demonstration of a Flow Visualization Method Applicable to Transonic Compressor Rotors**

Principal Investigator: Dr. Michael Brendel, University of Dayton

Period of Performance: 1 Oct 1993 - 1 Sep 1994

Task Objective: To demonstrate the flow visualization system on actual compressor hardware and validate an appropriate data acquisition scheme.

Task Description: UES, Inc. subcontractor worked directly with the Air Force

Compressor Aero Research Lab Facility. The subject program conducted by the Compressor Research Group involved the experimental determination of shock position and structure as it exists in a transonic compressor fan rotor. A series of rotors which include upswept, back swept, and forward swept leading edges were investigated. The subcontractor investigated a means of providing optical access to the compressor to be used for recording flow visualization image. In addition, the subcontractor integrated the flow visualization system into the Parametric Blade Study research rig owned by the Air Force. The rig and other appropriate hardware were provided to the subcontractor for this purpose.

The subcontractor investigated methods of data acquisition in developing the method to maximize image clarity and minimize acquisition speed. The quality of image had to ultimately be such that any shock present in the viewing region was visible. Also requested, were other flow features, such as shock-boundary layer interaction to be visible as well. The image (or data) acquisition speed was minimized in order to minimize any change in compressor operating point which might occur during the acquisition process.

Final Report: A Final Report entitled "Development/Demonstration Of A Flow Visualization Method Applicable to Transonic Compressor Rotors" was provided to the Air Force WL/POTF, 30 September 1994.

### **Task No.: 033**

**Task Title: Continuation of Balance and Spin Test of High-Speed Rotors**

Principal Investigator: The Balancing Co., Inc.

Period of Performance: 28 Jul 1993 - 27 Sep 1993

Task Objective: To balance and spin-test a simulated rotor for the MEA IPU generator, and quantify friction/windage power losses.

Task Description: UES' subcontractor provided the engineering and technical support necessary to balance two government provided rotors and spin-test a simulated rotor for the MEA IPU generator and quantify friction/windage power losses.

Final Report: A final report was not required.

### **Task No.: 034**

**Task Title: N/A - Task was not issued**

Principal Investigator: N/A

Period of Performance: N/A

Task Objective: N/A

Task Description: N/A

Final Report: N/A

### **Task No.: 035**

**Task Title: Document the Life and Work of Dr. Hans von Ohain and complete and edit the History of the Aircraft Gas Turbine Engine in the United States**

Principal Investigator: Mr. James St. Peter, UES, Inc.

Period of Performance: 23 Nov 1993 - 23 Jul 1994

Task Objective: To conduct historical research into primary and secondary sources concerning the life and work of Dr. Hans von Ohain.

Task Description: UES conducted corroborative research into the scientific and engineering work of Dr. Hans von Ohain, both in Germany in the early 1940's and in the United States from 1946 to the present. UES devoted a part of the historical research to the T53, T55, T76, F107, J402, and T56 engines.

Final Report: A final report entitled "Aero Propulsion and Power Directorate - The McCook Field Years (1917 - 1927)" was provided to the Air Force WL/POMX on 7 April 1995.

### **Task No.: 036**

**Task Title: Fluid Film Lubrication Seminar**

Principal Investigator: Dr. Bernard J. Hamrock, Ohio State University

Period of Performance: 9 Mar 1994 - 5 Aug 1994

Task Objective: To present a series of seminars covering fluid film lubrication

Task Description: UES, Inc. subcontractor conducted 11 seminars for the Wright Laboratory, Aero Propulsion and Power Directorate. The seminars occurred biweekly at Wright Patterson Air Force Base and each ran approximately 2 1/2 hours. The subcontractor also furnished 30 copies of "Fundamentals of Fluid Film Lubrication" to the Aero Propulsion and Power Directorate.

Final Report: A final report was not required.

**Task No.: 037**

**Task Title: More Electric Aircraft Program Planning and Roadmapping**

Principal Investigator: N/A

Period of Performance: N/A

Task Objective: N/A

Task Description: Task was canceled by the Air Force.

Final Report: N/A

**Task No.: 038**

**Task Title: Aero Propulsion and Power Directorate's Hazardous Materials Computerized Inventory Data Input**

Principal Investigator: N/A

Period of Performance: N/A

Task Objective: N/A

Task Description: Task was canceled by the Air Force.

Final Report: N/A

**Task No.: 039**

**Task Title: Active Magnetic Bearing Auxiliary Systems**

Principal Investigator: Dr. Alan Palazzolo, Texas A&M University

Period of Performance: 1 Aug 1994 - 6 Jul 1995

Task Objective: To develop capability at WPAFB for experimental evaluation of diverse auxiliary systems for active magnetic bearings used for gas turbine engine main shaft support.

Task Description: UES, Inc. subcontractor designed details of one or more test rigs for use in experimental evaluation of auxiliary bearings. Capabilities for evaluation of a wide range of auxiliary systems, including rolling element bearings with low volume lubrication and gas bearings were included. The subcontractor developed simulation codes for prediction of backup bearing response to various external conditions.

Final Report: A Final Report entitled "30K Test Rig Auxiliary Bearing Drop Simulation" was provided to the Air Force WL/POSL, 10 July 1995.

### **Task No.: 040**

**Task Title: Carbon-Carbon Composites for Bearing Applications**

Principal Investigator: SAIC and B.F. Goodrich

Period of Performance: 14 Jul 1994 - 17 Feb 1995

Task Objective: To develop carbon-carbon (C-C) composite ball bearing cage materials suitable for high speed (>1.5 MDN), high temperature (900-1200°F) oxidation resistance.

Task Description: UES, Inc. subcontractors developed three types of C-C composite materials suitable for high speed, high temperature ball bearing cages. They also developed a C-C material which has good circumferential (hoop) and axial strength as well as good high temperature ((900-1200°F) oxidation resistance.

Final Report: A final report and the carbon-carbon compost samples were provided to the Air Force WL/POSL on 17 October 1994.

### **Task No.: 041**

**Task Title: Microanalysis of Tribological Surfaces**

Principal Investigator: Dr. Andre Somm er, Miami University, Oxford, Ohio

Period of Performance: 14 Jul 1994 - 6 Jul 1995

Task Objective: To characterize bearing surfaces using infrared and Raman microanalysis.

Task Description: UES, Inc. subcontractor analyzed approximately twenty-five bearing samples using infrared microspectroscopy and Raman microprobe analysis. The samples were delivered periodically during the course of the effort by WL/POSL.

Final Report: A copy of the findings and samples were submitted to the Air Force WL/POSL, 5 July 1995.

### **Task No.: 042**

**Task Title: Complete book on the life and work of Dr. Hans von Ohain and edit, as required, the History of the Aircraft Gas Turbine Engine in the United States**

Principal Investigator: Mr. James St. Peter, UES, Inc.

Period of Performance: 10 Aug 1994 - 28 Apr 1995

Task Objective: To write a biography of Dr. Hans von Ohain; edit the History of the Aircraft Gas Turbine Engine in the United States; and complete the 75-year illustrative history of the Aero Propulsion and Power Directorate and the McCook Field Power Plan Lab document.

Task Description: UES created a biography of Dr. Hans von Ohain with emphasis on his work in Germany before and during WWII and in the United States from 1946 to the present. UES edited the History of the Aircraft Gas Turbine Engine in the United States and completed the 75-year illustrative history of the Aero Propulsion and Power Directorate and the McCook Field Power Plan Lab document.

Final Report: A draft Final Report entitled "Seventy-Five Year History of the Air Force Aero Propulsion and Power Directorate" was provided to the Air Force WL/POTF in November 1994.

### **Task No.: 043**

**Task Title: N/A**

Principal Investigator: N/A

Period of Performance: N/A

Task Objective: N/A

Task Description: Task was canceled by the Air Force.

Final Report: N/A

**Task No.: 044**

**Task Title: Airbreathing Propulsion Exergetics Analysis**

Principal Investigator: Dr. Howard M. Brilliant, Consultant

Period of Performance: 15 Nov 1995 - 12 May 1995

Task Objective: To improve the design and efficiency of high-performance airbreathing propulsion systems using an important new analytic technique called "exergetics" and to provide technical support in the planning and management of research and development in the fields of aircraft/missile propulsion and power.

Task Description: UES, Inc. consultant improved the design and efficiency of high-performance airbreathing propulsion systems using an important new analytical technique called "exergetics" and provided technical support in the planning and management of research and development in the fields of aircraft/missile propulsion and power at Wright-Patterson Air Force Base.

Final Report: A Final Report entitled " Exergy Studies of Airbreathing Propulsion Systems" was combined with the follow-on task 047 and submitted to the Air Force WL/POMX, 6 July 1995.

**Task No.: 045**

**Task Title: Comparative Analysis of U.S. and Russian Missile/Advanced Propulsion Systems**

Principal Investigator: Ketco, Inc.

Period of Performance: 13 Mar 1995 - 6 Apr 1995

Task Objective: To increase U.S. awareness and understanding of developmental Russian air-to-air missile ramjet propulsion technology and its challenges to the U.S. military and U.S. technology base.

Task Description: UES, Inc. subcontractor researched and established Russian AAM-AE missile design parameters for its ramjet propulsion missile system. The subcontractor analyzed the existing US VFDR AMRAAM airbreathing air-to-air missile configuration to ensure that external differences and similarities are accurately noted and accounted for. The subcontractor conducted a design effort to establish the AAM-AE Russian missile external configuration and fabricated, assembled, and delivered an engineering archetype, complete with support structure and detachable aerodynamic control surfaces, for Government research to determine form, fit and function for possible technology exploitation into U.S. systems. The archetype was analyzed in conjunction with existing in-house test research on variable flow ducted rocket propulsion systems.

Final Report: was submitted to the Air Force WL/POPR, 17 March 1995.

**Task No.: 046**

**Task Title: Comparative Analysis of U.S. Aircraft Gas Turbine Engine Technology**

Principal Investigator: Mr. James St. Peter

Period of Performance: 28 Apr 1995 - 6 Jul 1995

Task Objective: To complete analysis of select aircraft gas turbine engines.

Task Description: UES, Inc. completed historical analysis of select aircraft gas turbine engines for the narrative history of the aircraft gas turbine engine entitled: "A Tradition of Excellence: The History and Evolution of the Aircraft Gas Turbine Engine In the United States." UES incorporated into the completed history a new engine, the General Electric 185 engine. The J85 turbojet engine was added to Chapter 18, "Special Aircraft Gas Turbine Engine Applications."

Final Report: A final report was not required.

**Task No.: 047**

**Task Title: Airbreathing Propulsion Exergetics Analysis, Phase II**

Principal Investigator: Dr. Howard M. Brilliant, Consultant

Period of Performance: 15 May 1995 - 6 Jul 1995

Task Objective: To improve the design and efficiency of high-performance airbreathing propulsion systems using an important new analytical technique called "exergetics" and to provide technical R&D support in the fields of aircraft/missile propulsion and power.

Task Description: UES, Inc. consultant continued with a Phase II of an effort started on task 044. UES conducted on-site studies and investigations of turbojet, turbofan, and turboprop engine airbreathing propulsion systems. The Phase I effort concentrated on the scramjet engine cycle. Phase II extended this detailed research to other engine cycles with turbo machinery.

Final Report: A final report entitled "Exergy Studies of Airbreathing Propulsion Systems" was combined with task 044 and submitted to the Air Force WL/POMX, 6 July 1995.