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**TURBINE ENGINE RESEARCH CENTER (TERC) DATA
SYSTEM ENHANCEMENT AND TEST ARTICLE
EVALUATION**

Delivery Order 0001

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Battelle Memorial Institute

AUGUST 2008

Final Report

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1.0 SUMMARY

Under the baseline Delivery Order (DO), Battelle provided continued, unbroken support to acquire, process, analyze, and report TERC test data and to ensure the operational readiness of the TERC data acquisition, analysis, control, and computer systems. Tasks were performed to sustain, improve, and manage defined data acquisition, measurement, analysis, control, and computer systems for the TERC, to ensure online and offline functionality of application hardware, and to customize software essential for test article evaluation.

The second Delivery Order defined and authorized aeromechanical characterization research in conjunction with testing performed in the Turbine Engine Research Center (TERC). This research involved data analysis to identify new behavior, verify codes and model simulating aeromechanical behavior, and perform aeromechanical test and evaluation of hardware undergoing testing in the TERC. This work was in direct support of the national High-Cycle Fatigue (HCF) program under Integrated High-Performance Turbine Engine Technology (IHPTET).

2.0 Introduction

This document describes Battelle's work under this contract. This discussion is organized by Performance Work Statement (PWS) tasks, including TERC infrastructure support and improvements. Also included is a description of Battelle's general support for CRF Testing, and summaries of major Tests.

3.0 Methods, Assumptions, and Procedures

Battelle's role in the TERC¹ transcends the execution of assigned tasks or Work Requests (WR). The CRF, and to a slightly lesser extent, the TRF, rely on Battelle to understand all the various systems which comprise it, and to assume leadership in initiating, designing, overseeing, and integrating all systems related to process control and data acquisition. Battelle often defines major tasks to meet the overall goals of the TERC, presenting the need, criteria, specifications, and solutions to TERC management for approval. Battelle defined, designed, implemented, and documented most of the processes used to perform and maintain the process control and data acquisition operations of the CRF.

¹ At contract origination Turbine Engine Research Center (TERC) was considered only the Compressor Research Facility (CRF) and Turbine Research Facility (TRF); however, as of May 2003 the TERC represents all 13 of Turbine Engine Division facilities. The usage of TERC in this report refers only to the CRF and TRF.

4.0 Results and Discussion

The highlights of Battelle's accomplishments are categorized into task areas, as defined in the Statement of Work (SOW), and briefly summarized in the following paragraphs.

4.1 Data Acquisition, Measurement, Analysis, Control, and Computer Systems Research

In Accordance With (IAW) DO#1 SOW Paragraph 3.2, Battelle sustained, improved, and managed defined data acquisition, measurement, analysis, control, and computer systems for the TERC, ensuring online and offline functionality of application hardware and customizing software essential for test article evaluation. This task included modifications in system configurations, procedures, computer hardware, data systems, and networks. Custom software was produced as needed and documentation was updated for special test equipment operation and maintenance manuals, design notes, and system descriptions.

4.2 Data Acquisition, Measurement, Analysis, Control and Computer Systems Management

IAW DO#1 SOW Paragraph 3.3, Battelle sustained control and computer systems through appropriate use of preventive and corrective updates, provided problem diagnoses, and resolved work requests while coordinating all activities to minimize any adverse impact. Systems were reviewed, evaluated, and enhanced to meet increased requirements. All efforts were scheduled and documented.

4.3 Computer System Management

IAW DO#1 SOW Paragraph 3.4, Battelle administered all CRF and TRF internal computer systems and assisted with the computer systems that were primarily administered by the Air Force. Operating systems include VMS, Linux, Sun, and various Windows versions. All TERC information systems, networks, and peripherals (Xterminals, network printer interfaces, printers, etc.) were monitored and managed to ensure continuous, secure, and efficient operation. Hardware and software problems were resolved promptly and efficiently, coordinating with vendors and maintenance personnel as necessary, to enable facility operations to continue on schedule. User accounts were controlled, system security was monitored and enhanced, and problems were resolved as they occurred. System and data backups were performed and validated on all computers for which Battelle is responsible to prevent software and data loss. Computers and network devices were powered down as required for protection from cooling and power outages and restored to service afterwards. Hardware upgrades were researched,

proposed, and installed to meet functionality requirements. Operating systems, application software, procedures, and instructions were updated as required while minimizing downtime.

Battelle maintained the online production application software libraries and procedures, reviewing and updating as required. Standards and templates for software routines and procedures were provided, and their use encouraged. All practical means of tracking software changes were pursued.

Battelle diagnosed problems, maintained, and upgraded the CRF internal network (CRF iLAN) throughout this period. Data acquisition and supporting interfaces were developed and maintained as necessary to meet requirements.

Battelle was the primary provider of problem analysis for the systems and networks. Initial diagnosis would be performed, and in most cases, the problems resolved. If Battelle could not solve the problem internally, the proper organization was contacted and provided with all gathered information and assistance. Additionally, many hours were expended assisting the Division maintenance contractor and Wright Patterson Air Force Base (WPAFB) networking personnel.

Users were provided with informal assistance in all matters concerning systems, networks, printers, user's procedures, file transfers, backups, file recovery, etc.

Battelle designed, implemented, and provided periodic maintenance and updates to all internal computer systems, input/ output (I/O) systems, and all associated devices and interfaces to match functionality with operational requirements. Configuration documentation was maintained, including the tracking of device failures and replacements. All related downtime was coordinated with management and users to prevent conflict with and impact upon operational schedules. In all cases of emergency downtime, Battelle responded with unscheduled manpower and extra hours until operations were restored, always keeping management apprised of 'best estimates' to return to operations.

As part of their system management, Battelle developed and followed procedures to maintain complete backups of all system and application software. Procedures also addressed the archiving of all system configurations, software, acquired data, and analysis for each operational test period.

4.4 Data Management, Reduction and Visualization

IAW DO#1 SOW Paragraph 3.5, Battelle performed data reduction and visualization to support TERC operations, in support of problem diagnosis, and as requested. Battelle provided additional data analysis figures, tables, charts, and graphs for technical reports, publications, and presentations as requested.

Battelle worked toward the goal of unified archiving of all data, software, analysis, and all supporting documentation.

4.5 Problem Resolution

IAW DO#1 SOW Paragraph 3.6, Battelle developed and implemented procedures that provide the most effective and expedient resolutions to recurring problems, with the highest priority given to efficient resolution guidelines for problems occurring during test operations.

Since most problems outside of the range of Battelle responsibilities are first noted when illustrated by the computer displays, they are most often assumed to be computer related and assigned to Battelle. Battelle thoroughly researches these problems and, based on the supporting evidence, forwards the issue to the appropriate personnel.

4.6 Data System Commonality

IAW DO#1 SOW Paragraph 3.7, Battelle designed and implemented computer and data systems that maintained a commonality both within the facility and between the CRF and TRF whenever the functionality allowed.

4.7 Test Article Evaluation

IAW DO#1 SOW Paragraph 3.8, Battelle was instrumental in meeting the requirements of more than 15 test programs during this contract. Computers and systems were modified and configured for each test, system checkouts, and tuning was performed and the problems were resolved. Of major consequence were the massive person-hours spent modifying the application programs to provide for unique test article configurations and increased customer expectations.

Battelle provided manning and analysis of aeromechanic data for a minimum of two test programs. Battelle also participated in the evaluation of the Experimental Design and Analysis System (EDAS) aeromechanical data acquisition system.

4.8 Hours

IAW DO#1 SOW Paragraph 3.10, Battelle personnel worked irregular hours and shifts, and remained on call to support the activities of the TERC. Many voluntary hours were invested to meet the goals and deadlines of the facilities.

4.9 Classified / Proprietary Data

IAW DO#1 SOW Paragraph 3.11 and 3.2.4, Battelle personnel met all requirements for the handling of classified and/or proprietary data up to and including the Secret level. This included maintaining security clearances, complying with all computer and network access requirements, and satisfying non-disclosure agreements. In addition, Battelle provided all setup and operation of the Type 1 Motorola Network Encryption System (NES) units for the facilities.

4.10 Computer and Network Access Requirements

IAW DO#1 SOW Paragraph 3.12, Battelle personnel complied with all certification, training, and documentation requirements to meet all government data system and security regulations and guidelines.

4.11 Government Control and Access

IAW DO#1 SOW Paragraph 3.13, Battelle supported government troubleshooting, modification, and repair of TERC hardware and software. Efforts were adapted to the addition, removal, or modification of areas of Battelle responsibilities by the government. Battelle ensured that the government had full access to all TERC systems, and provided administration level accounts on all Battelle-managed systems as requested.

4.12 TERC Infrastructure & General Support

4.12.1 Aeromechanical Data Acquisition.

Battelle participated in a series of aeromechanical upgrades during this contract. The Aeromechanical Light Probe System (ALPS) was fully implemented, the signal amplifiers and recording media were upgraded, work continued on the development of a Digital Oscilloscope System, and a number of data acquisition systems evaluated.

Aeromechanical Data Acquisition System (AeroDAS). The ever more intensive requirements for aeromechanical data within the CRF made it inevitable that the aeromechanical data acquisition undergo a total restructuring. The primary goals of this station are safety and the 'health' of the test article. The expanding number of channels and data rates made it impossible

to rely on manual observation of oscilloscopes to catch dangerous situations before damage was done, or to fully interpret the data. This overall replacement/upgrade became known as the AeroDAS System.

Battelle participated in this project from the beginning, assisting government personnel in the creation of specifications for the system, and in the evaluation and selection of a vendor. As it was realized that available money would not cover the cost of the desired overall system, Battelle proposed that with careful paring of the initial channel count, and in-house integration by Battelle, the system could be built. New data acquisition systems are complex, requiring a great deal of supporting infrastructure. With the selected vendor concentrating on the actual data acquisition and analysis portions, and Battelle building the infrastructure in-house, the system was better tailored to the CRF and still managed at least a 5 percent savings. Battelle built a Fibre Channel network, constructed a Storage Area Network (SAN) disk system, expanded the Ethernet network, supplied and implemented computers, and found ways to reuse as much existing equipment as possible. The data acquisition vendor, DSPCon, then delivered the signal conditioners, data acquisition processors, and installed their software with Battelle assistance. The reduction of costs, and providing for future expansion were foremost considerations throughout this project.

Since the implementation of AeroDAS, Battelle has been active in its administration, maintenance, and expansion. Battelle has implemented additional monitoring stations, added a tape library, and greatly increased disk storage capacity.

4.12.2 Facility Management Databases

The TERC depends on a number of Microsoft Access databases for its day-to-day operations. They are used to track work requested and performed, data tapes, and cataloging of vendor documentation, historical test information, and related reports. This information is vital for maintaining facility schedules, tracking classified and unclassified system and test data, and troubleshooting hardware problems. Battelle maintained, improved, and expanded these databases, as well as provided user support. For some of the databases, especially the Work Request Database, Battelle provided nearly all of the data entry.

Battelle implemented a purchasing database in Access, constantly improving it to meet increasing demands. Battelle also created and maintained Access databases that consolidated and automated channel configuration for CRF testing.

4.12.3 Networks

The networks maintained by Battelle underwent considerable changes throughout this contract period. Initially the networks that had been implemented by Battelle in earlier contracts

encompassed all areas of the CRF and TRF. Under the AF CITS program most of the networks were to be taken over by base-level organizations. However, little or no information was provided to the local groups regarding how or when this would be implemented or how the local networks connectivity would be maintained. At one point personnel arrived to switch over the CRF/TRF network, but still could not explain how our network would be connected. The switch-over was called off only an hour before the scheduled time when the contractor was finally convinced there was no plan to keep the local networks connected. Battelle worked with the base network, contractor, and division personnel to devise a workable plan, and was active in the implementation at all times to ensure connectivity was not lost. All network segments serving the office portions of the CRF and TRF became the responsibility of the 88th Communications Group (CG), but Battelle remained active in their support, frequently assisting the 88th CG personnel.

All portions of the network that supported CRF testing, now known as the CRF iLAN, were isolated and remained under local control. Throughout this contract Battelle provided administration, maintenance, as well as problem diagnosis, and resolution for the CRF iLAN. The iLAN was progressively upgraded from Thinnet and Thicknet buses to a fiberoptic based starburst configuration, with bandwidth increased up to twenty fold.

Battelle invested considerable time and effort working with TRF, AF RZ Division, and 88th CG personnel to design and implement network segments that would support the expanding TRF requirements and still meet USAF policies and regulations.

As part of the AeroDAS project, Battelle designed and established the first Fibre Channel network in the CRF. This switched network supports the intensive high-speed flow of data required from data acquisition processors to disk storage, and computer access to it.

4.12.4 Certification and Accreditation

The security of the TERC, and maintaining its accreditation to operate its computer systems and networks, was a prime concern for Battelle throughout this contract period. Battelle began preparing for the required 2004 reaccreditation of the TERC LAN months in advance. Due to shifting requirements, changing formats, contradictory guidance, and the forced total restructuring of CRF/TRF networks, Battelle worked for over three and one half years to receive reaccreditation of what is now the CRF iLAN. As soon as that was accomplished, work began on the on-going conversion of all Certification and Accreditation (C&A) documentation from the DITSCAP to DIACAP program as is now required.

To ensure that the CRF maintained its operational accreditation, Battelle invested thousands of hours, created hundreds of pages of documentation, and worked with government personnel at the branch, division, 88th CG, Air Force Research Laboratory (AFRL), and Air Force Material

Command (AFMC). Inspection tours were conducted, security methods explained, meetings attended, and network scans scheduled and supported.

4.12.5 Unit Command Inspection (UCI)

During 2006 the AFRL was involved in a Unit Command Inspection (UCI). Battelle heavily participated in the complete rearrangement of all equipment storage, labeling of all cabinets and shelves, and ensuring that no critical spares or components were lost. Internal configuration databases were updated to reflect new storage locations.

Battelle, as administrators of almost all of the CRF/TRF systems, was critical to the division mandated turn-in of all software media to RZ Division offices. The difficulty of this task was increased since the laboratory nature of the facilities does not easily mesh with the required process that was modeled for an office environment. Battelle examined all systems and software, attended meetings, worked with Division to find workable solutions, and created a database to track software, proofs-of-purchase, and produce reports.

4.12.6 Process Control and Data Acquisition (PCaDA) Futures

The current technological design for the primary Process Control and Data Acquisition (PCaDA) of the CRF was conceived in the late 1980s and very early 1990s, with the basic implementation achieved by 2001. While a number of piecemeal upgrades have been implemented since then, no major PCaDA upgrade has occurred other than the AeroDAS System upgrade of the Aeromechanical Station.

The CRF PCaDA is in the very late phases of its life-cycle. Much of our current, critical, commercial off the shelf (COTS) software is no longer supported or available in the marketplace. The opportunities for piecemeal upgrades of the systems are well past. The CRF infrastructure must move to today's new computing technologies to ensure a reliable, supportable facility. On a time available basis, Battelle has begun to draft fundamental design goals and approaches, focusing on overall concepts and project organization. The overall functions of the CRF PCaDA were analyzed and distilled into a concept that will fit into available and emerging technologies. Several presentations were created to introduce the next-generation PCaDA need, goals, and initial plan. Battelle has done preliminary research into technologies that could be useful, including available PCaDA systems and software. Some vendor discussions were held to increase our understanding of their abilities and shortcomings.

This is a project that becomes more critical each day. The CRF computer/network infrastructure has served the facility well, and will continue for some time, but the design and implementation of a next-generation PCaDA system will take years, and cannot wait until the current systems are in failure mode.

4.13 CRF Test Support

The preparation for and support of each individual CRF test program is a major achievement of which Battelle is a very significant part. During this contract period Battelle supported at least 13 such CRF test periods. Battelle's participation in a CRF test is briefly summarized in the following paragraphs.

4.13.1 Information Gathering

A CRF test requires a great deal of information to be acquired and circulated to those doing the preparation. The count and types of data channels, the test article speed ranges, and valve control information are just a portion of the information required. If direct file transfer and remote displays are required, then information must be gathered concerning the sponsor's network and IP addressing. The need for cooperation and coordination between the number and wide diversity of groups required for this phase can make it difficult to accomplish. Battelle not only works to collect, organize, and implement this information, but has played a significant role in defining what information is needed.

4.13.2 System Preparation

Before any setup work can be done, data from the previous test must be totally archived, and the proper classification of disks selected for each computer system. Then the multiple disk sets are stripped of all unnecessary files and accounts, and 'initialized' for the installation of the new test setup. A modified CRF iLAN version of DD Form 2875 System Authorization Access Request (SAAR) is prepared, completed, and approved for each individual requiring access to the systems during the new test campaign. Operator procedures are reviewed to assure they are up to date and appropriate for the classification level.

The latest version of the online application software is installed, and work begins to mold it to the current test's requirements. All temporary software modifications incorporated for a specific test are removed. Configuration databases and information are transferred onto the main computer systems. These databases include system and data acquisition configurations for both the facility and the test article, limit-checking information, system (gearbox, pedestal, motor, and auxiliary drive system) configuration, and microsequence process control configurations.

4.13.3 Communications Preparation

Preparation for direct data transfer begins months in advance. Direct data transfer requires the use of an approved Type 1 Encryption unit. Once the necessary network information is exchanged between the sponsor and the CRF, a Memorandum of Understanding (MoU) must be

written, reviewed, and approved by security officials of both organizations. Firewall exceptions for the network encryption device must be approved and implemented by base and USAF networking groups, as well as the sponsor. The CRF iLAN systems are then programmed with the addressing and gateway information. Once it is believed that the infrastructure is in place in both organizations the link is tested. It can often take more than a month to work through initial setup problems due to the number and diversity of groups that must be coordinated and actively involved in the problem diagnosis.

4.13.4 Software Preparation

The software preparation is normally the greatest portion of test preparation. It is not uncommon for a test to require more than 200 routines/modules to be modified multiple times. Quite frequently software must be modified and expanded to meet new input, analysis, and display requirements.

The sponsor normally requires the standard CRF data formats to be modified to match their latest protocols for their own data systems. This requires processes to be modified and/or created to convert the data, modify labeling, and store the data file until it is transmitted to the sponsor. This must also be tested and approved prior to the start of actual operations.

4.13.5 Pre-Test Checkout

Battelle provides support for all aspects and phases of the CRF check-out, including drive system, end-to-end signal checks, tuning of valves, and calibration. Computer Operator and software support is provided for all levels of micro/macrosequence operations. Battelle provides active support to resolve all issues that might affect operations.

4.13.5 Test Staffing

During the earlier part of the contract, Battelle often provided more than 18 hours a day of staffing during test operations, and provided an Aeromechanical Engineer to monitor the test article health. Though this has been cut back at USAF request, the better part of two Battelle person days are expended in support of each day of test operations. Each test day, Battelle personnel review the previous evening's operation notes and analyze all concerns. The Online software is activated in the proper mode for data review, to research problems, and test out various aspects of facility operation. The encrypted communications link is activated, tested, and data remaining from the previous run is converted and transferred to the sponsor.

All requests for database and display changes are processed, and software promoted for that evening's operations. Support is provided as needed for tuning, calibration, and data system check-outs. Battelle also maintains an open-shop environment to assist CRF and sponsor personnel with system, data, and basic day-to-day operational questions and training. Battelle

personnel attend the daily pre-test meeting (as needed), providing updated system and data status. Extra hours are frequently expended in order to ensure a smooth start to the evening's operations.

4.13.6 Problem Diagnosis and Resolution

Most problems, even those outside of the range of Battelle responsibilities, are usually first noted when illustrated by the computer displays. Therefore they are most often assumed to be computer or communications related and assigned to Battelle. Battelle then thoroughly researches each problem and, based on the supporting evidence, forwards the issue to the appropriate personnel. Even when Battelle is not the principal in the diagnosis and resolution, all possible support is provided to ensure minimal downtime.

Battelle commonly implemented temporary work-arounds to prevent even non-computer issues from creating operational stoppages.

4.13.7 On-Going Changes

The start of actual test operations does not mean the end to changes. Battelle continues to provide both database and software changes throughout a test period to meet government requests. Some additional changes may be done to increase the efficiency of the process control software. All changes are done on a noninterference basis, and tested as much as possible prior to being promoted to the online operational libraries.

4.13.7 Archiving

To assure that sufficient disk space is available for each evening's run, Battelle archived acquired test article and facility data throughout the test. When necessary, previously archived data is returned from tape to disk for examination.

At the end of test operations all data, software, configurations, and the system image as a whole are archived to tape and stored for future reference.

4.13.8 Prominent CRF Tests

The following provides highlights of the work provided by Battelle for prominent TERC test programs in support of Air Force clients during this contract. Not included in this description is the extensive reconfiguration, set-up, troubleshooting, and problem solving characteristic of every study, as highlighted in the previous sections.

4.13.8.1 CRF Pratt & Whitney (P&W) — XTE-67 Support

Battelle provided multi- and swing-shift test support for the Test Operator and Aeromechanics manning positions throughout this test program. TERC information systems were maintained to support testing objectives. Dynamic configuration of the Aeromechanics Monitoring Stations was maintained, and log sheets documenting online recording of dynamic data and test events and data tape usage were compiled and stored. Additional personnel were provided on an as-needed basis to resolve test critical facility and data problems. Battelle successfully maintained all areas for which it was responsible and assisted other facility personnel in their efforts whenever requested.

4.13.8.2 CRF General Electric (GE) - XTE-77 Test Support

Battelle provided multi- and swing-shift test support for the Information Systems Operator and Aeromechanics manning positions throughout the test program, maintained data backups, resolved hardware problems, and supported data processing, transfer, and archival efforts. TERC information systems and networks were actively configured and monitored in excess of eighteen hours each day to support all facets of testing. Dynamic configuration of the Aeromechanics Monitoring Stations was maintained, and online recording of dynamic data and test events, as well as, data tape usage were compiled and stored. In addition to the two manning positions additional personnel were made available as-needed across all shifts to resolve test critical facility and data problems. Battelle made database / display changes, and efficiently managed and supported all areas defined in the SOW. In addition, they provided many hours of assistance to other facility personnel to ensure overall test objectives and schedules were met.

4.13.8.3 CRF General Electric (GE) - F110 Test Support

Battelle staff provided test support for the F110 test program. To comply with the Air Force's request to reduce expenditures, test manning hours were streamlined and extended on call support was provided. Individual staff maintained flexible work schedules to accommodate the specific needs of each test objective assigned to the evening shift. Test data was transferred daily to GE the morning following each run. Test Article and Facility End of Day Data and system backups were maintained and high speed and facility data playback support was provided as requested.

A large percentage of the work requests assigned to Battelle dealt with problems deemed computer issues because errors were highlighted on test monitoring displays. All such issues were researched, tracked, documented, and then forwarded to the appropriate personnel. Exhaustive I/O testing was performed to diagnose instrumentation configuration concerns, after which the problem was assigned to appropriate personnel.

4.13.8.4 CRF Rolls Royce (RR) - RC104B Test Support

Battelle staff continued to provide information systems support for the RR test program. Onsite and on call test manning was provided for first and second shift operation. Open shop support was maintained with Rolls Royce personnel to answer day-to-day, as well as, data and system operation questions. Open shop support was also provided to in-house Air Force personnel to assist them in resolving problems with their respective systems. Staff frequently worked extended days at Air Force personnel's request to support testing. Daily support was also provided for valve calibration and tuning, as well as, data system checkout. All staff maintained flexible work schedules to accommodate the specific needs of AF individuals and each test plan phase. Battelle put in a substantial amount of effort to create a new data format file (in Système International or SI units). This work created one file format for the customer to use at their home office and another that could be used for a quick analysis using Microsoft Excel. Battelle staff empirically found documentation errors in the format description. Battelle corrected these errors and released the changes to the customer.

Due to the proprietary nature of this program a new set of RAID disks was created from spare disks and carriers. A stand-alone backup of the baseline OPS and RIC systems was made and then copied to the new disk set. The new disk set was stripped of all unnecessary files and accounts. Just prior to the start of the test campaign, the latest version of the online software was copied from the standard system, and the software promoted. RC104B accounts were activated based on submitted forms.

TERC website links were established and maintained for the RR program. Test notes, photographs and other available information was migrated there to facilitate stronger communications and compile information in a central location for easy access.

Battelle staff maintained the Work Request Database to track all RR work performed in the facility. Daily work requests were entered into the database, tracking numbers assigned, and task progress was tracked to completion. Coordination was maintained between requestors and implementers to ensure sufficient and accurate information was entered into the database. Various reports were generated for management personnel and meetings.

Computer system operational duties were performed to ensure successful execution of each test phase. Systems were brought up and down in support of offline, No-Load, data review, macrosequence execution and other support efforts, as well as for standard online testing. Data and system backups were maintained, data was stored, reformatted, and transferred to compact disk (CD) for RR, and data playback was supported.

During this test campaign, Battelle donated overtime to address a recurring problem with critical Channel updates. This problem was more a nuisance than a dangerous condition, and resulted in

some wasted test time. Battelle staff members collected data on the problem, added logging to pinpoint the problem source, and optimized software on the main computer system. When that had little effect, Battelle focused on problems in the DDNTC computer that collected and shuttled data to the main computer system. Battelle again optimized code, collected data, and began to note empirically when conditions improved or worsened. Battelle determined that the DDNTC box was near its limits of capacity and required frequent disk defragmentation and re-boots (ostensibly to clear “memory leaks”). Battelle took extra effort to nurse the computer through the test without additional problems and replaced the computer after the test. The problem has not recurred.

Software modifications were made continuously to support the ever changing instrumentation configuration, and test changes. Work assignments were received via work requests or personal request. Many hours were invested supporting others in resolving their problems.

4.13.8.5 GE XTE-77-2

Throughout XTE77-II, Battelle performed day and evening computer operator support, test data and event logging (EVL), Facility Historical Data (FHD), and High Speed Data (HSD) backups, tracking of all work requests resulting from the previous evenings run, generation and transmission of static and monitor data points to GE per their request, and coordination with test day coordinator on a daily basis.

In addition database changes were made based on GE and government requests, additional error checking solutions were added to GE Core Drive Fan (CDF) file transmission software, a report was generated on speed excursion, limit-checking was modified as requested, logic for standby pump and its status displays was updated, facility personnel were assisted with their tasks and questions, useless logging was reduced and the meaningfulness of information logged was increased, a new form of an alphabetized HSD file was created, Drive System vibration signals acquired from scopes were reviewed, a mechanism to clear “special” faults (Speed Control, etc.) was reviewed, use of the Access database Limit-Check entry form was streamlined, the PLC ladder diagram routine was coded, termination panel labeling was improved, and operator notes and instructions were expanded and improved.

In addition to Work Requests(WRs), Battelle was responsible for, or assisted in, diagnosis and resolving problems that included the following: problems with EDAS caused by Aeromechanics personnel inputting the wrong settings, bugs in global common assignments that could potentially wipe out some valve data, File Transfer Protocol (FTP) problems actually caused by GE attempting to transmit extremely large sized data files during testing, Exciter E2 problems, errors in Test Article Data Reduction Counts Storage (TADRCS), test article backups, Facility Data Screen 26 updates, a number of initially unexplained Etrips, TIME2 & TIME3 headers going negative, spurious’ panel arming, Build_Info_Window problems (where users gather information with a middle-mouse click), speed command problems at Minimum Speed, and

problems in the Drive Lubrication Oil (DLO) System (controlled by a USAF-controlled Programmable Logic Controller (PLC)).

During this test campaign, Battelle personnel contributed weeks of 16 to 18 hour days (without an overtime premium) researching a problem in the Direct Current (DC) Loop of the electrical motors/generators in the facility. Battelle personnel came in early to perform their standard daily test preparation tasks and stayed late into the evening to monitor testing and attempt to solve a problem with spurious currents applied to the electrical fields of the DC Loop equipment. Battelle staff worked 16-hour days and repeatedly (daily) concluded that the problems emanated from the USAF-maintained and controlled PLCs. The problem ultimately damaged the DC Loop equipment in the facility, terminating the test campaign and requiring an expensive repair effort. USAF personnel found that the problem resided in the PLC. CRF personnel met to develop approaches to avoid this problem in the future. Battelle brought forward five distinct approaches to address and neutralize problems in the PLC. Battelle personnel refined these solutions, working with USAF personnel and onsite contractors. Battelle implemented changes to address the problem. Those changes have long-lasting benefits for the facility; this new logic has prevented a recurrence of this problem numerous times.

As the XTE-77/SE2 Test ended, Battelle supported post-processing and evaluation, performed the final Test Article End-of-Day (TA EOD) tasks, and cleaned up specialized code. Also, Stand Alone Backups were executed, and archived in the CRF databases. NES audit files from the GE side of the encryptor link were secured from GE, combined with the CRF audit files, and archived.

4.13.8.6 VAIIPR Testing

Manning support was provided for the computer engineer position for first and second shift operation. Software was cycled multiple times a night for database upgrades and problem solving. The 1600 Run Meeting was attended each evening to review the test plan for the night.

On the morning following each evenings run Static Data Files were created, copied from OPS through DDNTC and FTP'd to the VAT storage area. Aeromechanics light probe data was gathered, zipped and transferred to the VAT. The data format design was another distinct format that required a number of new software routines. The VAT proved to be a somewhat troublesome link that often timed out or lost connection. These problems added to the time required to achieve the test objectives and analysis.

All data files (EVL, FHD, HSD, and Test Article (TA)) were backed up after each evenings run.

Throughout the test program assistance was provided to track and resolve problems which arose as a result of changes made by engineers throughout the day. Hardware failures were remedied promptly to minimize downtime. Flexibility was maintained to allow last minute requests to be implemented quickly. Software enhancements were made when feasible to improve or streamline test operation.

Consultation was provided to Honeywell representatives on the data file format. Assistance was also provided to reprocess the data.

4.13.8.7 G603001-14_GE 3-Stage Test Support

Battelle provided Computer Operator duties for this test, both during the day and consulting on problems during the evening shift. This included the starting of the software, establishing the NES encryption link, initializing the FTP account, and tape backups of the data. Facility Historical Data was restored from tape as necessary for review by government personnel. Battelle also provided information on several data acquisition questions, and reminded users of proper procedures for maintenance of printers, etc.

When post processing on the GE3-Stage Test was completed, Battelle checked out the VMS CD from the AFRL/PR centralized library, and made two tape archives of the VMS GE 3-Stage Test data. The NES was 'zeroized' (cleared), and the now-invalid key returned through COMSEC channels. The NES cabinet is now fully locked, until an encryptor is required. Battelle requested the logs from the GE NES, and archived all GE 3-Stage NES configuration and logs.

The GE 3-Stage Test returned to the CRF later in the year. Battelle completed all of the normal tasks performed to setup and execute a test in the CRF. These include:

- Mailing out system configuration, valve worksheets, limit-checking reports, high speed data reports, and microsequence set-ups.
- Modifying system configuration, worksheets, etc. based on information obtained.
- Setting the appropriate namelist files/database generation files.
- Updating the I/O configurations and run parameters (in a facility control database known as FC2LDB).
- Configuring the appropriate DataForth modules in the CAMAC to handle the different valve set-ups.
- Eliminate old (temporary) changes from the previous test and applying updates to the current Test code.
- Establish and program the Test data format for delivery to the customer.
- Testing the data transfer.
- Backups and archives of Test Article Data, Event Logger, Facility Historical, and High Speed Data files from each run.
- Ensure online systems are started and functional for each Test session, as well as other 'operator' duties.

Battelle support for the GE 3stage Test also included:

- Assisting technicians with diagnosis and repair of vibration sensor ZRE-36.
- Assisting to remove an electronic control set for an unused solenoid.
- Improving the readability of output from the *Channel_Info* routine.
- Changing of flow parameters, and database values.
- Modifying the Trim Panel Display to display complete valve names.
- Added logic to start a copy of the EVL on XT02.
- Modified several views to adjust for the replacement of Xterminals.
- Clarified a number of log messages.
- Assisted in solving a tuning problem under RIC control.
- Changed the build phase values.
- Extracted HSD to Excel for analysis by government personnel.
- A number of general improvements in the readability or functionality of the online software.

At the end of the GE 3stage Test, all data, VMS system information, and logs were archived. The encryptor was cleared and the used key turned in.

4.14 G603001-16 P&W LPC

In preparation for this Test, limit-checking, high-speed file definition, and facility database changes were made. A new Sequence.NML file was created to include the Diesel Generator microsequence. All set-up work was guided by test preparation checklists, which were updated and expanded as appropriate.

Battelle provided constant daily computer operator support, starting the online software in many configurations to meet the needs for tuning, valve calibrations, database changes, etc. In all cases Battelle was mindful of the diverse needs of the users and their scattered locations. Training was provided in the use of the software to new personnel. Problem diagnosis for all the usual problems, such as loose connections, was provided for terminal users. Battelle assured that encrypted communications were active and the account passwords for data transfer were entered on a daily basis. Systems and I/O crates were cycled as necessary to accommodate configuration changes and keep the facility fully functional. Battelle recovered files from system backups as required.

Battelle assisted with the daytime AeroDAS operation throughout the test, and stepped in for most of a week when government personnel were unavailable. Battelle assisted in data upload and backup, daily channel checks, starting the monitoring station software, and in shipping the customer data tapes. Battelle also noted the fragmentation of the uploaded data disk, and initiated periodic defragmentation. Battelle also assisted P&W personnel with the playback of AeroDAS data as requested.

Battelle put in a multitude of donated overtime hours in achieving the objectives for this test campaign. The customer had a unique, rigid, and poorly documented file format that differed significantly for Static and Monitor Data Point Files. This new format required an extensive number of hours to create. In addition to the typical problems, they had another format used so that the CRF could send a file of merged AeroDAS and HPDAS Data in a file that was very complicated to create and, again, very poorly documented. The customer also wanted an accelerated sampling rate for the HPDAS. This meant that the files were larger than in other test campaigns. Since CRF testing frequently continues for eight hours or more, the size of these files ultimately caused storage and transmission problems. Battelle staff worked 7 days per week (with no overtime premium) to shuttle data to the customer and to resolve a multitude of other legitimate and false problems. Battelle issued file format documentation corrections to the customer.

Battelle assisted with facility calibration, tuning, and problem diagnosis on multiple occasions. In particular Battelle assisted with valve, Exciter, motor bearing, and speed control variables, often extracting data, then producing analysis and graphs to guide the solutions. Battelle also assisted in the extraction and transfer of Facility Historical Data for power analysis.

Other tasks done for P&W include:

- multiple work requests to fix a -999 value for S2/S3 setpoints. Work was done to prove that this was a processing error in their systems.
- creating and Emailing a Health Checklist screen print.
- coordinating a patch on the P&W server.
- communicating file transfer status.

Battelle provided software and configuration changes throughout this test, including:

- enabling and disabling the Customer Bleed Valve in TA_Peculiar.
- modifying limits for RTDs.
- added the Diesel Generator microsequence to No-Load and Facility Auxiliary macrosequences.
- modified the check of residual voltages.
- modified configurations to change between the Low Speed and High Speed Motors.
- modified software to use mechanical speed variables instead of corrected speed during Minimum or Idle Speed actions.
- added and modified multiple screen graphics and variables.
- updated Discharge Safe and Surge schedules on multiple occasions.
- disabled selected Critical Channels.
- Created a procedure to help track software changes.
- modified software to reduce unneeded printouts and to remove temporary files.
- modified Critical Channel alarm actions to be based on time versus 'passes'.
- coded a delta-RPM rate test termination action.

Battelle also assisted P&W with the packing and removal of their cables and equipment.

4.15 TRF Test Programs

During this contract period, Battelle supported three TRF test programs; the Combustor Simulator, the Cooled F119 Rotor, and DUST. Battelle integrated VXI I/O systems into the existing data acquisition, and eventually retired a portion of the CAMAC I/O systems. Nearly all of the TRF applications were upgraded at least once. Systems and hardware were upgraded and replaced to meet the goals of the TRF.

The TRF used a post-test data transfer procedure that took hours and had a very high failure rate, resulting in total data loss. Battelle redesigned the process and implemented an approach that resulted in transfers that took minutes instead of hours, and had the ability to recover data should the transfer fail. Battelle also designed and implemented procedures and macros to help analyze and archive the data.

4.16 Delivery Order Two

Under Delivery Order Two, six aeromechanical characterization research tasks were performed. Each area focused on research objectives of test programs scheduled for the TERC.

Task I Onsite Aeromechanical Research: Interface support was provided to the University of Kentucky, the Massachusetts Institute of Technology and Virginia Polytechnic Institute to transfer TERC test program data and information required to perform each research effort.

Task II Flutter Precursor Identification in Transonic Compressors: The University of Kentucky (UK) finalized their investigation into flutter precursor identification in transonic compressors. Based upon data obtained from the Honeywell Engine System (HES) test in the Compressor Research Facility (CRF), the existence of flutter precursor waves was confirmed in a previous effort. This effort concluded this investigation in the flutter precursor region.

Task III Forced Response Evaluation: Forced response evaluation was conducted in conjunction with the Massachusetts Institute of Technology (MIT) to provide a detailed evaluation of the development of inlet flow distortion and the influence of specific flow parameters on the response of compressor blades. This work was used to define the appropriate means to evaluate compressors and fans for high-cycle fatigue (HCF) resistance and drew on research performed at the CRF and at General Electric. The work concentrated on comparing flight test results to ground test data to determine appropriate ground test requirements for HCF evaluations.

Task IV Distortion Transfer Prediction for Multistage Axial Compressors: Distortion transfer prediction for multistage axial compressors was investigated in conjunction with Virginia Polytechnic Institute and State University (VPI) to determine how a multistage transonic compressor rotor effects inlet flow distortion. Existing CRF test data was used to perform detailed analyses on how a multistage transonic compressor rotor transfers inlet flow distortion to downstream blade rows. The research considered compressor loading, different distortion patterns, and rotor speeds. A third-order model of the distortion transfer that occurs in transonic compressors was developed. Limits and capabilities of this nonlinear model were defined to help develop a better testing procedure for axial compressors.

Task V Characterization and Management of Transonic Compressor Tip Clearance and Casing Treatment Flows: Characterization and management of transonic compressor tip clearance and casing treatment flows were performed in conjunction with MIT. This task concentrated on addressing technical issues that lead to quantification of flow processes defining effective casing treatment operation and design guidelines for casing treatment in high speed (transonic) compressors with performance representative of current/future designs. There are two aspects: (1) aerodynamic performance as measured in terms of changes in peak efficiency and stall margin, and (2) aeromechanical response associated with resulting flow unsteadiness in the tip region. Two goals were researched. One was to identify, in a quantitative manner, the end wall flow features which are critical in the mechanism of operation of casing treatment in high speed compressors. A second goal was to define the fluid dynamic effects leading to improved casing treatments without the attendant aeromechanical difficulties. A third goal was to use the results to develop design guidelines/criteria for casing treatments that result in compressor pressure rise capability and performance enhancement. Experiments, computations, and analysis/modeling were performed to address the issues necessary for the accomplishment of the stated objectives.

Task VI Prediction of Blade Response from Finite Element Analysis Using Forces Determined from Computational Fluid Dynamics Analysis: Prediction of blade response from finite element analysis using forces determined from computational fluid dynamics (CFD) analyses was performed in conjunction with VPI. This task investigated the potential for using finite element analysis along with CFD simulation to predict the blade loading on a transonic compressor blade resulting from inlet flow distortion. The predicted non-uniform blade loading was compared to existing experimental data. An analytical method model that provides a means to predict resonant forcing functions that would be detrimental to the compressor blading was also provided.

5.0 CONCLUSION

Throughout the life of this contract, Battelle's on-site support of the Turbine Engine Research Center met or exceeded all contractual requirements, was performed within time and cost constraints, and conformed to government regulations and requirements.

Efforts included multi shift test support, problem diagnosis, and hardware/software modifications throughout the facilities. All TERC computer systems, peripherals, and networks were continuously monitored, managed, and enhanced to ensure reliable operation and to provide additional functionality. Major process control and data acquisition enhancements were implemented in the CRF and TRF to increase capability. All efforts were documented and coordinated with government, maintenance, and vendor personnel.

Throughout this contract, as in previous contracts, Battelle was an integral part of the TERC. More than system administrators, programmers, and integrators, Battelle provided an enduring pool of critical knowledge and uniquely experienced manpower to support the past, present, and future operations of the TERC.