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6. AUTHORS Dr. Glenn J. Rix			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Georgia Institute of Technology School of Civil and Environmental Engineering Atlanta, GA 30332-0355		8. PERFORMING ORGANIZATION REPORT NUMBER NA	
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11. SUPPLEMENTARY NOTES Approved for public release; distribution unlimited.			
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13. ABSTRACT (Maximum 200 words) A multi-channel data acquisition system including a variety of sources and receivers was purchased to support research at Georgia Tech aimed at the Air Force's need to develop innovative airbase technologies. The equipment purchased comprises a complete multi-channel system for acquiring, processing, analyzing, and displaying dynamic signals. The system provides the capability to more accurately and rapidly perform nondestructive tests, and has thus far been used on two research efforts involving dynamic measurements. On one project involving a USAF Palace Knights student, a comprehensive experimental study was conducted to investigate the suitability of a modal analysis approach for identification of unknown pile embedment lengths. The second project is aimed at developing a non-invasive field technique that uses the dispersion properties of surface waves to determine the shear wave velocity profile at a site. The technique uses passive measurements of surface waves arising from microtremors and/or cultural noise such as traffic. Surface wave dispersion relationships are determined using frequency-wavenumber analyses.			
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May 8, 1999

Captain Michael T. Chipley
AFOSR/NA
110 Duncan Avenue, Room B115
Bolling AFB, DC 20332-8050

Re: Final Technical Report, (DURIP 98/99) Multi-Channel Data Acquisition System for
Nondestructive Testing of Airbase Facilities, Grant No. F49620-98-1-0233

Dear Captain Chipley:

The following report identifies the equipment purchased under the grant referenced above, describes changes made to the original list of the equipment contained in the proposal for this grant, and summarizes two research projects on which the equipment has been used during the past year.

A multi-channel data acquisition system including a variety of sources and receivers was purchased to support research at Georgia Tech aimed at the Air Force's need to develop innovative airbase technologies. U.S. forces must be able to deploy to any area of the world on short notice to conduct operations. For maximum effectiveness, these forces must utilize existing infrastructure whenever possible, but the suitability of the existing infrastructure for military operations may be uncertain. An essential task is to rapidly and nondestructively assess the structural condition of existing airbase infrastructure including pavements and bridges.

Equipment List

The equipment purchased comprises a complete multi-channel system for acquiring, processing, analyzing, and displaying dynamic signals. The system provides the capability to more accurately and rapidly perform nondestructive tests, and it will be used in a variety of other military and civilian applications involving dynamic measurements. The following list summarizes the equipment purchased using this grant:

Description	Vendor/Manufacturer	Cost
Multichannel Data Acquisition System	Hewlett Packard	\$41,345.10

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Monitors for Multichannel Data Acquisition System	Compaq Corporation	\$2,381.00
Software for Multichannel Data Acquisition System	Data Physics Corporation Vibrant Technology The Mathworks SciTech International	\$14,975.25
Shipping Cases	Contact East	\$971.39
Piezoelectric Accelerometers	Wilcoxon Research	\$21,893.48
Piezoelectric Vibration Generator	Wilcoxon Research	\$5,980.00
Signal Conditioner	PCB Piezotronics	\$4,665.00
Data/Video Projector	In Focus Systems	\$3,475.00
Torque Transducer	FUTEK Advanced Sensor Technology	\$653.50
Personal Computers and Peripherals	Micron Electronics AV Networks	\$6,685.56 \$1,491.25
Miscellaneous Materials and Supplies	Miscellaneous Vendors	\$1,026.52
Indirect Costs		\$4,479.55
Total		\$110,022.60

The primary components of the data acquisition system are the multichannel system (Hewlett Packard) and software (Data Physics) that are identical to the items identified in the proposal. Additional personal computer software (Vibrant Technology, The Mathworks, and SciTech International) and hardware (Compaq, Micron Electronics, and AV Networks) were purchased to permit additional post-processing of data beyond the basic capabilities of the HP system. Shipping cases (Contact East) were purchased to protect the system during transit to test sites. A data-video projector (In Focus Systems) was purchased to use in educational environments with large groups.

A variety of transducers were acquired for the system including low and high frequency piezoelectric accelerometers (Wilcoxon Research) and corresponding signal conditioners (PCB Piezotronics). The low-frequency accelerometers were substituted for the vertical geophones (Mark Products) contained in the original proposal because of their superior performance at

very low frequencies. An additional torque transducer (FUTEK) was acquired to enable measurements of torsional excitation applied to nondestructive test specimens.

The piezoelectric vibration generator (Wilcoxon Research) listed above is identical to the proposed item. The larger dynamic force generators (APS Dynamics) originally shown in the proposal were not purchased because the smaller piezoelectric vibration generator proved sufficient for the needs of the studies summarized below.

Summary of Research Performed with System

Nondestructive Determination of Unknown Pile Tip Elevations Using Modal Analysis

A comprehensive experimental study was conducted to investigate the suitability of a modal analysis approach for identification of unknown pile embedment lengths. Knowledge of the embedment depth is critical in assessing the structural capacity of a bridge and, therefore, its serviceability for military operations. Dr. Mary Leigh Hughes, a participant in the U.S. Air Force Palace Knights program, performed the study under the supervision of the principal investigators. Dr. Hughes was on assignment at Georgia Tech from Wright Laboratories, Flight Dynamics Directorate, Airbase Technology Branch (WL/FIVC).

A small-scale pile facility containing partially embedded piles of different lengths, cross section dimensions, and encasement attributes was constructed so that experimental pile response data could be gathered in a controlled laboratory environment. Impact tests were performed at a number of locations on each model pile, and the modal parameters for each were estimated from the resulting frequency response function data. To supplement the information gathered in the experimental program, three types of numerical analyses were conducted to simulate the frequency response characteristics of the pile-soil systems. Modal parameters corresponding to those computed from the experimental data were produced from each of the three analyses. Comparison of the modal parameters estimated from model piles with similar cross section dimensions and different buried lengths showed essentially no variation in natural frequency values as the buried length increased, in the frequency range that was practical to measure. Modal damping values showed greater variation with pile embedment depth, but no discernable trends were apparent that would allow identification of the embedded length. Results from the numerical studies indicated the same. It was concluded, then, for reasons cited in the text, that identification of pile embedment lengths using modal analysis is not a practically feasible task.

Frequency-Wavenumber Analysis of Passive Surface Waves

The Spectral Analysis of Surface Waves (SASW) test is a non-invasive field technique which uses the dispersion properties of surface waves to determine the shear wave velocity profile at a site. Traditional SASW methods typically use an active source to generate surface (Rayleigh) waves that are measured by a linear array of geophones. The depth of investigation is usually limited by the inability of the source to produce low frequency, long wavelength surface waves. This limitation can be overcome by using passive measurements of surface waves

arising from microtremors and/or cultural noise such as traffic. Surface wave dispersion relationships are determined using frequency-wavenumber analyses. Ground vibrations are recorded by a two-dimensional array of sensors deployed on the ground surface. The frequency-wavenumber spectrum is determined with Capon's Minimum Variance Distortionless Look method, which adapts the array's sensor weights to the observed signal and noise characteristics. The sensor weights produce a spatial filter that passes undistorted any monochromatic plane wave traveling at a velocity corresponding to a selected wavenumber k_0 and suppresses waves traveling at velocities corresponding to wavenumbers other than k_0 . Once the dispersion curve is determined using frequency-wavenumber analysis, a non-linear, smoothed inversion algorithm is employed to determine the shear wave velocity profile.

Please contact me if you have any questions about the equipment purchased under this grant or how the equipment is being used on the two research projects described above. Thank you for the opportunity to participate in the Defense University Research Instrumentation Program.

Very truly yours,

A handwritten signature in black ink, appearing to read 'G. L. Rix', with a stylized flourish at the end.

Glenn L. Rix
Associate Professor of Civil and
Environmental Engineering