

Quarterly Report

Project Title:

Development of a Self-Sustained Wireless Integrated Structural
Health Monitoring System for Highway Bridges

Cooperative Agreement # RITARS11HUMD

First Quarterly Progress Report

Period:

July 15 through October 14, 2011

Submitted by:

The Research Team – University of Maryland with North
Carolina State University and URS

Submitted to:

Mr. Caesar Singh, Program Manager, US DOT

Date: October 21, 2011

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EXECUTIVE SUMMARY

I – TECHNICAL STATUS

Accomplishments by Milestone

- Technical Advisory Committee was formed and kick-off meeting was held on Friday, August 5, 2011, 10:00AM – 3:30PM at CEE Main Conference Room, 1179 Glenn Martin Hall, University of Maryland (Task 1 and Deliverable 1)
- Baseline (preliminary) test bridge in Maryland was selected, which is US 1 bridge over Paint Branch located adjacent to the University. Approval letter, bridge plans and inspection reports were obtained from the MD State Highway Administration on August 30, 2011 (Task 1 and Deliverable 1)
- Project web site (<http://www.ncrst.umd.edu/>) was established and opened to public in August 2011 (Task 1 and Deliverable 2)
- Preparing for the baseline field test - FEM model is established on the preliminary bridge. Purchased data acquisition equipment and LabView software development kits from National Instrument (NI) for lab and field use. (Task 1 and Deliverable 3)
- Designing and testing AE sensor in the lab - Major work conducted in the first quarter includes (1) the development of third-generation of flexible piezoelectric paint based acoustic emission (AE) sensor (including sensor

design and fabrication, and lab characterization of sensor prototypes), (2) designing and asking for price bidding for the lab fatigue test-setup (including test specimen and load frames) for conducting lab characterization test of low-profile piezoelectric paint based AE sensor, (3) noise removal algorithms, and (4) further developing a Labview-based virtual instrument software for data acquisition of AE data. The piezoelectric paint based AE sensor can be used in large amount for near field AE monitoring of fatigue cracks on steel bridges. Broadband stress wave-measurement-based AE sensors made of piezoelectric paint can be employed to capture the entire waveform and thus enable signal-based acoustic emission signal interpretation. In addition, a near-field AE monitoring strategy is being developed for use of piezoelectric paint based broadband AE sensor, which employs a stress-wave-based AE sensing principle and thus has the advantage of improved representation of crack source information. This near-field AE monitoring strategy is currently being verified through both experiments and numerical simulation. (Task 2 and Deliverable 4)

- Developing and evaluating T-R method - Laboratory tests for verifying the time-reversal (T-R method) have been performed. A new two-step signal processing algorithm for tracing the AE location was proposed. Since the calibration needs to be performed before the AE event, the spacing for calibration is a key determining factor for locating AE. An aluminum plate has been tested using impact hammer as a simulated AE source. The experimental results demonstrated robustness of the method for locating AE events. (Task 3 and Deliverable 5)
- Developing and evaluating wireless smart sensor - A prototype wireless intelligent sensor platform, called WISP developed at NC State, with three PCB layers is being redesigned for a single PCB layer. The footprint of the new wireless sensor will be compact with much smaller lateral dimension. (Task 4 and Deliverable 6)
- Developing and evaluating hybrid-mode energy harvester - Based on the baseline field test, we are evaluating the sizing of the solar panel for providing sufficient power for a group of wireless sensors and a relay. (Task 4 and Deliverable 6)
- Preparing and submitting this quarterly status and progress report (Task 6 and Deliverable 11)
- Invited and accepted invitation for presentation at 2012 TRB meeting (Task 6 and Deliverable 12)

The proposed work plan is shown below as Milestones/Deliverables. Dark Shading indicates Deliverable items and Tasks in which the Research Team has been engaged over the past quarter. Lighter shading indicates anticipated duration for Deliverables by quarter.

| Deliverables | Action | Quarter No. | | | | | | | | | |
|--------------|---|-------------|---|---|---|---|---|---|---|---|----|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | Form TAC and conduct kick-off meeting. Determine baseline field test procedure (Task 1) | | | | | | | | | | |
| 2 | Establish and update project web site (Tasks 1 & 6) | | | | | | | | | | |
| 3 | Conduct baseline field test and finite element analysis on pre-selected bridges (Task 1) | | | | | | | | | | |
| 4 | Design, fabricate and characterize AE sensor and measure the performance (Task 2) | | | | | | | | | | |
| 5 | Develop and evaluate T-R method for passive damage interrogation (Task 3) | | | | | | | | | | |
| 6 | Develop and experimentally evaluate wireless smart sensor and hybrid-mode energy harvester (Task 4) | | | | | | | | | | |
| 7 | Implement passive damage interrogation T-R algorithm in the wireless smart sensor on bridges (Task 4) | | | | | | | | | | |
| 8 | Integrate and validate AE sensors with wireless smart sensor and hybrid-mode energy harvester (Task 5) | | | | | | | | | | |
| 9 | Develop and conduct field implementation/validation of commercial-ready ISHM system with remote sensing capability (Task 5) | | | | | | | | | | |
| 10 | Recommend strategy to incorporate remote sensing and prognosis into BMS (Task 5) | | | | | | | | | | |
| 11 | Prepare and submit quarterly status and progress reports and final project report (Task 6) | | | | | | | | | | |
| 12 | Submit paper to conference presentations and publication to TRB meeting or other conferences (Task 6) | | | | | | | | | | |

Problems Encountered:

- Subcontract agreement with URS is still under reviewed by the URS Headquarters. It will be established pretty soon. (Update: Subaward agreement is established today, 10/21/2011.)

Future Plans

- Conduct baseline (preliminary) test bridges in Maryland and NC
- Continue designing and testing AE sensor in the lab - Currently the design of third-generation piezoelectric paint-based AE sensor is being finalized along with an external flexible circuit manufacturer. The next quarter will involve fabrication of 400 AE sensors by this manufacturer and these AE sensors will be installed and tested on the fatigue test specimens along with development and verification of remote sensing functionality of a LabView based system. Preliminary tests of piezoelectric paint based AE sensors on the Route-1 bridge is also planned.

- Continue developing and evaluating T-R method - Different spacing for calibration are being conducted experimentally to determine the probability of AE detection. Duration of the sensor data for providing the higher resolution will be optimized.
- Continue developing and evaluating wireless smart sensor – Based on finding, a piezo-based wireless sensor that accommodates four sensors will be designed and tested. The on-board memory will be enlarged to store AS sensing data.
- Continue developing and evaluating hybrid-mode energy harvester - Once the fatigue-critical bridge near NC State is selected by working with NCDOT, a proper location for installing the solar panel and miniature wind turbine energy harvester will be finalized. The battery capacity for this hybrid-mode will be selected for long-term power supply.

II — BUSINESS STATUS

- Hours/Effort Expended – PIs, Drs. Fu spent two summer months, and Zhang and Yuan, spent one summer month each (equivalent to 670 man-hours) on various tasks. Additionally, Dr. Fu worked half month paid by his cost sharing account for 83 man-hours. Three (3) UM and two (2) NCSU graduate assistants worked one and half summer months full-time (40 hours) and one month half-time (20 hours) to the end of September 2011, the quarterly accounting deadline, for a total of 1,670 man-hours (one NCSU assistant is partially cost-shared by their University.)
- Funds Expended and Cost Share –
 - Listed and invoiced in this Quarterly Federal Financial Report (period ending on September 30, 2011): Federal share of expenditure \$42,550.85; Recipient share of expenditure (cost share) \$12,500.
 - Spent but not listed in this Quarterly Federal Financial Report: NCSU invoice to 9/30/2011 \$34,101.67 & cost share \$2,844.67; Dr. Fu’s cost sharing account \$14,711.1; NI equipment software purchase \$897.39; NI DAQ system purchase \$16,666.70. (Total federal share of expenditure \$51,665.76; Recipient cost share \$17,555.77 plus in-kind cost share.)

ADVISORY/STEERING COMMITTEE MEETING

KICK-OFF MEETING MINUTES – August 5, 2011

Date & Time: Friday, August 5, 2011, 10:00AM – 3:30PM

Place: CEE Main Conference Room, 1179 Glenn Martin Hall, University of Maryland

Subject: Project Kick-off and Technical Advisory Committee (TAC) Meeting

Attendee: TAC: Jeff Robert (MSHA), Abey Tamrat (MdTA), Mrinmay Bismas (NCDOT), Paul Sprouse (NCDOT), Xiaohua “Hannah” Cheng (NJDOT), Caesar Singh (USDOT/RITA)
University of Maryland (UMD): PI - C.C. Fu (PI), Dr. Y. Zhang (co-PI), Linjia Bai, Zhen Li, Tim Saad, Gengwen Zhao, Changjiang Zhou
North Carolina State University (NCSU): Dr. F. G. Yuan (co-PI), Lei Liu
URS: Dr. Y.E. Zhou (co-PI)

Project overview presentation (RITA_ProjectSummary.pdf)

Morning Discussion Session

CRS&SI program

- Mr. Singh mentioned it is part of SAFETEA-LU program. The purpose is a development of an applied program, not a basic research.

Commercial and Remote Sensing Technologies

- Very broad program, but the real emphasis should be on **applied programs** and should be involved with **applied research.**

Background on Sensors

- Sensors are sensitive and give responses to all types of stimulations; including stimulations that come from the environment
- Dr. Zhang is implementing a 3rd generation acoustic emission sensor
 - Piezo Paint AE sensor with reconfigurable sensing dots (RPPS-dots)
- When field experiment in China, every time a train passes on a bridge, the acoustic emission sensor (on the crack) gives a response

Self-sustainable power source

- Dr. Yuan adopted Miniature Wind Turbine System for this project
- In some areas of bridge, wind may be more prevalent than solar energy
- However, wind energy is more complementary to solar because it doesn't store energy as well

Wireless Sensor System @ NCSU

- WISP – wireless sensor platform with hybrid architecture
- Top Layer – Communications layer (interfacing bond to accommodate different sensors)
- Middle – Processing layers

Financials of the Project

- Funding stops @ the prototype stages
 - It is provided on a case by case basis

- It is possible more funding is available at the end of the project
- The rights of product are to the University but the government/DOT does have access to information
- University has the rights to patent the project
- Because the project is a funded by a public funding source, it should be available to the public

Challenges of Outreach process

- Selling the whole package to the user community may be difficult
 - Community will have to learn how to use the monitoring system
- If it brings benefit to bridge owner it will sell itself

AE Sensor for Bridge Monitoring

- Dr. Zhang mentioned Caltrans contracted PAC for a \$3.4M value project to deploy 640 AE on San Francisco Bay Bridge to remotely monitor 384 critical eyebars for early detection of fatigue defects.

Project Execution

- From beginning we will start assessing the bridges
 - Dr. Fu proposed that one prospective bridge is on route 1 with a creek and pathway underneath
 - Will coordinate with Mr. Robert of MDSHA
- URS is involved w/ all bridges in MD that have fatigue cracks. Ed Zhou will help us pick one bridge from his knowledge of bridges
- A bridge should also be picked with appropriate access

Crack Monitoring/Sensor Placement

- We can detect internal defects if they propagate
- We use FEM to find “hotspot”
- Read inspection reports to learn more about the selected bridges
- Mr. Tamrat mentioned the Tidings Bridge may be a bridge of choice due to availability of access
 - Be careful to choose a bridge and not choose one just because of its convenience

Afternoon Discussion Session

Prospective Bridges for Monitoring

- Bascule Bridge (Route 27 in city 2.5 hours from Raleigh, NC) proposed by Mr. Sprouse of NCDOT
 - Type of draw bridge w/ fatigue at the end toward counterweights

- Rest Area Truss Bridge proposed by Dr. Biswas of NCDOT
 - Currently unused, but can put maintenance trucks on it

Implementation of Sensors on other Material Bridges

- AE sensors can be used for termite detection on timber structures
- Surface differences between concrete and steel
 - Smoother surface on steel structures

Identifying Existing Crack Location

- Try to find out propagation
- Paint based system
- Acoustic based system

Post Processing

- Analyze the signal from sensor(s) to determine Remaining Useful Life
 - To what point do small cracks become important
- First test for signs of potential damage, and use these signs to show the cause

Sensor Placement Strategy

- More sensors used are better
- Come up with heuristic guideline for critical placement

Goals of Project

- Configure a way extrapolate data from one sensor location and apply to other locations on the bridge
- Before we see the crack, we can detect the crack
 - Our goal is to detect *crack initiation*

Sensors Behavior

- Sensor can only tell if energy is released, means active
 - It's not the size of crack that sensor detects

Developing sensor vs. sensors already on the Market

- This prospective system will be autonomous and real time
- Project gives boost to further development to make cost effective

Commercialization

- When various companies package a product, who owns the package
 - Not coming up with a *ground up* development of remote based system
 - Intellectual property concerns
- The purpose of commercialization is not for financial profit, but to make more available to public

- Although the system will be commercially available the creative application of the system is eventually Intellectual Property

Conclusions/Emphasis of Project

- Monitor propagation of existing crack(s)
- Detect crack(s) for crack initiation
 - This will happen in the lab, because if we could do this in the field then the project wouldn't be necessary
 - After crack detection we have to qualify what type of crack it is
 - Sensors will detect existence of active crack, but will not detect inactive crack (such as cracks created during product manufacturing)
- Both crack initiation detection and existing crack propagation monitoring are important

Appendix A – Copies of Subcontracts

Appendix B – Copies of Equipment Purchase Receipts

UNIVERSITY OF MARYLAND
COLLEGE PARK, MARYLAND 20742
SUBAWARD No. Z981001

This Subaward, by and between the University of Maryland, College Park. ("UM") a public corporation and instrumentality of the State of Maryland, located at College Park, Maryland 20742, (hereinafter referred to as the "UM") and North Carolina State University (hereinafter referred to as "SUBAWARDEE").

WITNESSETH

WHEREAS, UM in furtherance of its education and research mission is the recipient of funds from the U.S. Department of Transportation (hereinafter referred to as Prime Sponsor); and UM is desirous of engaging SUBAWARDEE to provide work associated with the Project titled "Development of a Self-Sustained Wireless Integrated Structural Health Monitoring System for Highway Bridges" under Prime Award No. RITARS11HUMD; CFDA No. 20.701.; and

WHEREAS, SUBAWARDEE is prepared and willing to provide the aforementioned work,

NOW THEREFORE, in consideration of the above premises and of the mutual promises and other good and valuable considerations set forth below, UM and SUBAWARDEE agree as follows:

1. STATEMENT OF WORK

SUBAWARDEE agrees to furnish work to be done under this Subaward in accordance with its proposal and budget incorporated herein as Attachment A.

2. PERIOD OF PERFORMANCE

The period of performance of this Subaward shall be July 15, 2011 through July 14, 2013.

3. KEY PERSONNEL

The following SUBAWARDEE individual(s) are considered key personnel essential to the work under the Subaward. SUBAWARDEE will notify UM in writing of any changes in key personnel. Any change in the individual(s) or their level of effort requires written modification to this Subaward.

F.G. Yuan

4. POINTS OF CONTACT & SUBAWARD INFORMATION

The following serve as the representatives of UM and SUBAWARDEE in the areas indicated:

(a) For UM:

(i) TECHNICAL REPRESENTATIVE

SUBAWARD NO. Z981001

University of Maryland.

- (i) SUBAWARDEE agrees to notify UM promptly if there is any change of status in any of the above certifications.

21. DISPUTES

The parties agree to use their best efforts to resolve any disagreement that arises out of this Agreement and to forward disagreements to others in their organization for resolution when necessary prior to seeking remedy by law.

22. GOVERNING LAW

Any dispute arising from performance under this agreement will be submitted to a court of competent jurisdiction.. Pending resolution of any dispute, SUBAWARDEE shall proceed diligently with the performance of its obligations under this Agreement.

23. ADMINISTRATIVE NOTICES

All notices or requests issued by the parties under this Agreement shall be directed to the Administrative Contacts named in Article IV. The parties agree that either or both may elect to conduct their transactions, execute, transmit, and store this agreement by electronic means including, but not limited to, facsimile, transmission to or by computer link, modem, or other electronic communication device. The parties agree that an electronic record or copy of this document shall be given the same accord as an executed original. Either party may also elect to conduct some or all transactions by non-electronic means.

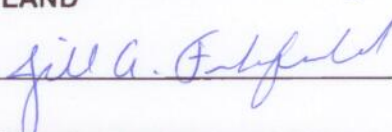
24. ENTIRE SUBAWARD

This Subaward represents the entire understandings of UM and SUBAWARDEE, and can only be modified in writing and duly executed by both parties.

FOR: NORTH CAROLINA STATE UNIVERSITY

By: 
 Name: **JOHN CHAFFEE**
 Title: **ASSOCIATE DIRECTOR
SPONSORED PROGRAMS**
 Date: 8-4-11

FOR: UNIVERSITY OF MARYLAND

By: 
 Name: **Jill Frankenfield, Contract Manager**
 Title: **Research Administration & Advancement**
 Date: 8/4/11



National Instruments Corp.
11500 N. MoPac Expwy
Austin, TX 78759-3504

Tel: (800) 531-5066
Fax: 512-683-8411

SALES ORDER ACKNOWLEDGEMENT

Company : University of Maryland
 Contact : Charity McGee
 Fax Number :
 Sales Order No : 2327048
 Date : 13-SEP-11
 Customer Order No : McGee
 Terms : Credit card
 Currency : USD
 Quote Number : 1573839:1

BILL TO ADDRESS

University of Maryland
 1173 Glenn Martin Hall
 Charity McGee
 College Park MD 20742
 UNITED STATES

SHIP TO ADDRESS

University of Maryland
 1173 Glenn Martin Hall
 Yunfeng Zhang
 College Park MD 20742
 UNITED STATES
 Civil & Environmental Engineering

| Part No. | Request Date | Schedule Ship Date | Order | List Price | Discount | Extended Price | |
|---|--------------|--------------------|-----------|------------|----------|----------------|--------|
| 1.1 | 850108-93H | 13-SEP-11 | 15-SEP-11 | 1 | 0.00 | 0.00 | |
| LABVIEW 2011 DEVELOPMENT SYSTEM FOR WINDOWS, ENGLISH, MEDIA End User: Yunfeng Zhang Country of Origin : IRELAND | | | | | | | |
| 2.1 | 940006-01 | 13-SEP-11 | 13-SEP-11 | 1 | 2,149.50 | 65.00% | 752.32 |
| LABVIEW STANDARD SERVICE PROGRAM Inactive > 60 Days, 1 Yr Renewal of LABVIEW PROFESSIONAL DEVELOPMENT SYSTEM, WINDOWS S/N M71X59564 End User: Yunfeng Zhang From 16-AUG-11 - 15-AUG-12 See Single Seat License Info Page for Details | | | | | | | |
| 3.1 | 781106-35 | 13-SEP-11 | 15-SEP-11 | 1 | 499.00 | 75.00% | 124.75 |
| LABVIEW MATHSCRIPT RT MODULE, WINDOWS New Single Seat License(s) With 1 Yr LABVIEW STANDARD SERVICE PROGRAM End User: Yunfeng Zhang See Single Seat License Info Page for Details Country of Origin : IRELAND | | | | | | | |

Shipping and Handling: 20.32
Subtotal: 897.39
Total Tax: 0.00
Final Tax will Reflect on your Billing Invoice
Order Total: 897.39

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Single Seat License Information Page

Company : University of Maryland
 Contact : Charity McGee
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 Sales Order No : 2327048
 Date : 13-SEP-11
 Customer Order No : McGee
 Terms : Credit card
 Currency : USD
 Quote Number : 1573839:1

| Line | P/N | Description | Qty | Unit | Extended |
|------|-----------|---|-----|----------|----------|
| 2.1 | 940006-01 | LABVIEW STANDARD SERVICE PROGRAM Inactive > 60 Days, 1 Yr Renewal of LABVIEW PROFESSIONAL DEVELOPMENT SYSTEM, WINDOWS S/N M71X59564 End User: Yunfeng Zhang From 16-AUG-11 - 15-AUG-12 Current List Price: 4,299.00 Inactive > 60 Days - 50% | 1 | 2,149.50 | 2,149.50 |
| | | Calculated List Price | | | 2,149.50 |
| | | Discount Applied | | | 65.00% |
| | | Calculated Net Price | | | 752.32 |
| 3.1 | 781106-35 | LABVIEW MATHSCRIPT RT MODULE, WINDOWS New Single Seat License(s) With 1 Yr LABVIEW STANDARD SERVICE PROGRAM End User: Yunfeng Zhang | 1 | 499.00 | 499.00 |
| | | Calculated List Price | | | 499.00 |
| | | Discount Applied | | | 75.00% |
| | | Calculated Net Price | | | 124.75 |

If you have questions regarding your scheduled ship date or the date does not meet your needs, please contact us at 512-683-0100 or toll-free within the US/Canada at (800) 531-5066 and reference the Sales Order Number shown on page one of this acknowledgement.

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301-405-5813

Date 09/15/11 Purchase Order T156053

Effective Dates
START / 0/ END / 0/

Terms N 30 F.O.B. - Destination-Prpd/A

Solicitation No. Delivery Date
09/30/11

Purchasing Contact Phone
Tracy Schlegel 301-405-5828

Requisition No. Department Reference No. Vendor ID No.
R155675 ***** B7418713270

Vendor
NATIONAL INSTRUMENTS CORP
11500 NORTH MOPAC EXPRESSWAY
AUSTIN TX 78759-3504

Ship To
UNIVERSITY OF MARYLAND
CIVIL & ENVIR ENGINEERING
1133 ENGINEERING BUILDING
ATTN: CHUNG C. FU
COLLEGE PARK MD 20742

| Account Number | Percent | Amount | Account Number | Percent | Amount |
|----------------|---------|--------|----------------|---------|--------|
| | | | | | |

| Item No. | Quantity | Unit | Description | Unit Price | Extension |
|----------|----------|------|--|------------|-----------|
| 001 | 1.00 | EA | THE OMB CIRCULAR A110 PROVISION IS HEREBY INCORPORATED BY REFERENCE, SEE ATTACHMENT C1. PXIE-1082, 8-SLOT 3U PXI EXPRESS CHASSIS PART # 780321-01 01-5-29908-4090 | 2,969.10 | 2,969.10 |
| 002 | 1.00 | EA | POWER CORD, AC U.S., 120 VAC 2.3 METERS PART # 763000-01 01-5-29908-4090 | 8.10 | 8.10 |
| 003 | 1.00 | EA | NI STANDARD SYSTEM ASSURANCE PROGRAM FOR PXI PART # 960903-02 01-5-29908-4090 | 1,040.00 | 1,040.00 |
| 004 | 1.00 | EA | NI PXIE-8108 CORE 2 DUO 2.53 GHZ | 4,049.10 | 4,049.10 |

Subject to the purchase terms and conditions on both sides of this form, and its attachments, furnish goods and/or services described herein. See terms and conditions on reverse. Questions concerning this order should be directed to the Buyer:

Total CONTINUED

By: Authorized Signature *See page 2*

Date Page No. 1

Send invoice in triplicate to:
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Chesapeake Building, Room 3101
University of Maryland
College Park, MD 20742 301-405-2640

Include your FEI number or Social Security number on each invoice
Include the purchase order number on each invoice
University Tax Exempt Number: 30002563
Manufacturer's Federal Excise Tax Registration Number 52 730123K



Department of Procurement and Supply
2113-R Chesapeake Building
College Park, MD 20742-3111
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Date 09/15/11 Purchase Order T156053

Effective Dates
START / 0/ END / 0/

| | | | | | |
|--------------------|--------------|------------------|--------------------------|---------------|--|
| Terms | FO.B. | Solicitation No. | Delivery Date | | |
| Purchasing Contact | Phone | Requisition No. | Department Reference No. | Vendor ID No. | |
| Tracy Schlegel | 301-405-5828 | R155675 | ***** | B7418713270 | |

| | |
|---|--|
| Vendor | Ship To |
| NATIONAL INSTRUMENTS CORP *** PO CONTINUATION *** *** PAGE NUMBER BELOW *** | UNIVERSITY OF MARYLAND CIVIL & ENVIR ENGINEERING 1133 ENGINEERING BUILDING ATTN: CHUNG C. FU COLLEGE PARK MD 20742 |

| | | | | | |
|----------------|---------|--------|----------------|---------|--------|
| Account Number | Percent | Amount | Account Number | Percent | Amount |
| | | | | | |

| Item No. | Quantity | Unit | Description | Unit Price | Extension |
|----------|----------|------|--|------------|-----------|
| | | | CONTROLLER, WIN 7 PART # 781033-04 01-5-29908-4090 | | |
| 005 | 1.00 | EA | NI PXI-5105, 8-CH, 60 MS/S DIGITIZER W/ 128 MB PART # 779685-02 01-5-29908-4090 | 5,759.10 | 5,759.10 |
| 006 | 1.00 | EA | NI PXIE-4330 8-CHANNEL, 24-BIT, BRIDGE INPUT MODULE, NI-DAQMX DRIVER SOFTWARE AND LAB VIEW PART # 781346-01 01-5-29908-4090 | 2,519.10 | 2,519.10 |
| 007 | 1.00 | EA | NI TB-4330 TERMINAL BLOCK FOR PXIE-4330 PART # 781347-01 01-5-29908-4090 | 269.10 | 269.10 |
| 008 | 1.00 | EA | SMB-100, SMB TO BNC FEMALE PART # 763389-01 01-5-29908-4090 | 53.10 | 53.10 |

Subject to the purchase terms and conditions on both sides of this form, and its attachments, furnish goods and/or services described herein. See terms and conditions on reverse. Questions concerning this order should be directed to the Buyer:

Total \$ 16,666.70

By: Authorized Signature

[Signature]
ADW

Date 9/16/11

Page No. 2

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Include the **purchase order number** on each invoice
University Tax Exempt Number: 30002563
Manufacturer's Federal Excise Tax Registration Number 52 730123K

ATTACHMENT C1

Required Grant/Cooperative Agreement Flowdown Provisions

For all orders from \$2,500 to \$100,000 funded by a federal grant/cooperative Agreement, incorporate the following OMB Circular A110 provision:

Contract Work Hours and Safety Standard Act (40 U.S.C. 327-333) – Where applicable, if order involves the employment of mechanics or laborers, the contractor shall comply with Sections 102 and 107 of the Contract Work Hours and Safety Standards Act (40 U.S.C. 327-333), as supplemented by Department of Labor regulations (29 CFR part 5).